ALTERNATIVES ANALYSIS MEMORANDUM (AAM)

FOR

TRONOX NAVAJO AREA URANIUM MINES CENTRAL GEOGRAPHIC SUB-AREA OF THE AMBROSIA LAKE SUB-DISTRICT, GRANTS MINING DISTRICT MCKINLEY COUNTY, NEW MEXICO

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TABLE OF CONTENTS

TABLE OF CONTENTS (CONTINUED)

Section **Page**

TABLE OF CONTENTS (CONTINUED)

Section **Page**

TABLE OF CONTENTS (CONTINUED)

Section **Page**

LIST OF FIGURES*

***Figures are provided as separate portable document format (PDF) files**.

LIST OF TABLES*

***Tables listed above without a page number are provided as separate PDF files.**

LIST OF APPENDICES*

***Appendices are provided as separate PDF files.**

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ABBREVIATIONS AND ACRONYMS

µR/hr	microroentgens per hour
ALSD	Ambrosia Lake Sub-District
ANL	Argonne National Laboratory
APE	area of potential effect
ARARs	applicable or relevant and appropriate requirements
ASPECT	Airborne Spectral Photometric Environmental Collection Technology
AUM	abandoned uranium mines
BHP	Broken Hill Proprietary Company
Bi-214	bismuth-214
BLM	Bureau of Land Management (of the U.S. Department of the Interior)
BRA	background reference area
BTV	background threshold value
Carrizo	Carrizo Mountain Environmental & Herbarium, Inc.
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CO_2e	carbon dioxide equivalent
COC	contaminant of concern
COPC	contaminant of potential concern
COPEC	chemical of potential ecological concern
cpm	counts per minute
CYs	cubic yards
DCGL	Derived Concentration Guideline Level
$DCGL_{emc}$	Derived Concentration Guideline Level – elevated measurement comparison
$DCGL_W$	Derived Concentration Guideline Level – wide area
DOD	Department of Defense
DOE	U.S. Department of Energy
DOJ	U.S. Department of Justice
Dynamac	Dynamac Corporation
Eco-SSL	ecological soil screening level
EE/CA	Engineering Evaluation/Cost Analysis
EPA	U.S. Environmental Protection Agency
EPC	exposure point concentration
ESL	ecological screening level
GMB	Grants Mineral Belt
GMD	Grants Mining District
gpd	gallons per day

ABBREVIATIONS AND ACRONYMS (CONTINUED)

gpm	gallons per minute
GPS	Global Positioning System
GSA	Geographic Sub-Area
Hall Laboratory	Hall Environmental Analysis Laboratory
HASP	Health and Safety Plan
HQ	hazard quotient
IDW	Inverse Distance Weighted
LANL	Los Alamos National Laboratory
MARSSIM	Multiagency Radiation Survey and Site Investigation Manual
MCA	Multi-Channel Analyzer
mg/kg	milligram per kilogram
MTL	maximum tolerable limit
NaI	sodium iodide
NAPL	non-aqueous phase liquids
NAUM	Navajo Area Uranium Mines
NCP	National Contingency Plan
NMAC	New Mexico Administrative Code
NMED	New Mexico Environment Department
NMEMD	New Mexico Energy and Minerals Department
NMEMNRD	New Mexico Energy, Minerals & Natural Resource Department
NMHED	New Mexico Health and Environment Department
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NPV	net present value
NRC	U.S. Nuclear Regulatory Commission
NRCS	U.S. Department of Agriculture Natural Resource Conservation Service
NTCRA	Non-Time-Critical Removal Action
O&M	operation and maintenance
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
pCi/g	picocuries per gram
pCi/l	picocuries per liter
pCi/m^2-s	picocuries per square meter per second
PNEC	predicted no-effect concentrations
PRG	Preliminary Remediation Goal
PRP	Potential Responsible Party
Ra-226	radium-226

ABBREVIATIONS AND ACRONYMS (CONTINUED)

RAML	Rio Algom Mining, LLC
RAO	Removal Action Objective
RCRA	Resource Conservation and Recovery Act
RESRAD	Residual Radiation
RSE	Removal Site Evaluation
RSL	Regional Screening Level
SEMS	Superfund Enterprise Management System
SHPO	State Historic Preservation Office
SLO	State Land Office
SRE	streamlined risk evaluation
SSL	soil screening levels
START	Superfund Technical Assessment and Response Team
TAL	Target Analyte List
TBC	to be considered
TCRA	time-critical removal action
TDD	Technical Direction Document
Th-230	thorium-230
Tl-206	thallium-206
Tl-207	thallium-207
U-235	uranium-235
U-238	uranium-238
UO2	uraninite
U_3O_8	triuranium octoxide
U.S.	United States
USiO4	coffinite
USDA	U.S. Department of Agriculture
USGS	U.S. Geological Survey
UTL95-95	95% upper tolerance limit with 95% coverage
UMTRCA	Uranium Mill Tailings Radiation Control Act
VSP	Visual Sampling Plan
WESTON®	Weston Solutions, Inc.
WRCC	Western Regional Climate Center

EXECUTIVE SUMMARY

Weston Solutions, Inc. (WESTON®), the Superfund Technical Assessment and Response Team (START) contractor, has been tasked by the United States Environmental Protection Agency (EPA) Region 6 under contract EP-S5-17-02, Technical Direction Document (TDD) No. 0001/17-035, to conduct activities associated with a Removal Site Evaluation (RSE) and an Engineering Evaluation/Cost Analysis (EE/CA) at the Tronox Navajo Area Uranium Mines (NAUM), Central Geographic Sub-Area (Central GSA) Mines site (the Site) located in McKinley County, New Mexico (Figure 1-1). The purpose of this Alternatives Analysis Memo (AAM) is to present the site-specific data collected during the RSE, describe the Removal Action Objectives (RAOs), describe the removal alternatives available to address contamination at the Site to meet the RAOs, and provide an analysis of the alternatives. Another purpose of this AAM is to present the information that will be provided in the EE/CA to the stakeholders without the selection of a preferred alternative so that stakeholders can provide input in the remedy selection.

Background and Site Description

In November 2014, the United States (U.S.) District Court for the Southern District of New York approved a settlement agreement to resolve fraudulent conveyance claims against Kerr-McGee Corporation and related subsidiaries of Anadarko Petroleum Corporation. Among other provisions, the settlement provides funding to EPA for the assessment and cleanup of over fifty-four (54) Tronox NAUM sites located in EPA Region 6 and EPA Region 9 jurisdictional areas. The 22 mines in EPA Region 6 jurisdiction are located within the Ambrosia Lake Sub-District (ALSD). Of these 22 eligible mines within the ALSD, only 12 surface operational areas are present due to several of the eligible mines being operated through a common geographically central main shaft. All of these mining surface operational areas have undergone some form of closure actions and removal of surface features. Some of these mines were operated as “wet mines,” where the underground workings were dewatered to allow mining activities and the collected mine water was discharged to nearby surface drainage features such as creeks and arroyos. Little environmental data currently exists on the Tronox NAUM Area Mines in general, or specifically, regarding risks to public health and/or the environment, and/or any threat abatement actions that may be necessary.

The EPA Region 6 Tronox NAUM Area comprises approximately 100 square miles within the ALSD in McKinley County, New Mexico. The ALSD is located within the Grants Mining District (GMD), which is an area of uranium mineralization occurrence approximately 100 miles long and 25 miles wide, encompassing portions of McKinley, Cibola, Sandoval, and Bernalillo counties in the northwestern part of New Mexico. The Central GSA Mines Site is located in the ALSD approximately 18 miles north of Grants, Cibola County, New Mexico, and 5.5 miles north-northwest of the intersection of New Mexico State Highways 509 and 605 (Figure 1-2).

The Central GSA Mines Site comprises four former underground uranium mines originally developed in 1958 and operated by Kermac Nuclear Fuels Corporation: the Section 17 Mine, the Section 19 Mine, the Section 30 Mine, and the Section 33 Mine, and the surface areas impacted by mining-related surface water discharges. Additionally, the Site includes surface areas that may have been impacted by the Phillips Mill located on the eastern border of the Central GSA and one non-Tronox mine located within the southwestern portion of the Central GSA.

The Central GSA Mines were classified as "wet mines," with a combined discharge of water from the mines of up to 1,120 gallons per minute (gpm) or 1.6 million gallons per day (gpd) (Kelly, et al., 1980). This water contained concentrations of radioactive material that were significantly elevated above natural background levels, was largely untreated, and was discharged to the surface water drainage features. The Mines were transferred to Kerr-McGee from 1964 until 1984, when operational control was turned over to Quivira Mining Company, a subsidiary of Kerr-McGee. The Mines were sold to Rio Algom Mining, LLC (RAML) in 1989. Broken Hill Proprietary Company (BHP) acquired RAML in 2000 and has now merged with Billiton to form BHP Billiton. Uranium mining ceased at the four mines by 1985.

The Site is currently undeveloped, though livestock grazing occurs in many sections of the Ambrosia Lake valley. There are currently no residences in the former mining area of the Central GSA Mines Site, however, two residences are located in Section 18, approximately 0.5 mile from the Section 17 Mine. It is highly unlikely that the Central GSA property would be used for residential development due to the remoteness of the area. Cattle ranching is likely to remain the future use of the Site. A rancher may be exposed to radiological contaminants through incidental ingestion of soil, external radiation from contaminants, inhalation of fugitive dusts, and consumption of meat.

Current Central GSA Mines Site

Nature and Extent of Contamination

The nature and extent of the contamination was defined through surface gamma scans and subsurface soil sample collection. Based on the results of the streamlined risk evaluation (SRE), the contaminant of concern (COC) for the Central GSA Mines Site is radium-226 (Ra-226). Ra-226 is typically selected as the radionuclide of interest at uranium mine sites for the following reasons: (1) it is found to be a significant contributor of radiological risk to human health, (2) its decay products give off strong gamma radiation that is easy and cost-effective to measure, (3) a cleanup standard is provided in the State of New Mexico's *Joint Guidance for the Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico* (New Mexico Energy, Minerals & Natural Resource Department [NMEMNRD] et al, March 2016), and (4) Ra-226 is the radionuclide for which historical cleanup limits have been specified.

The total surface area exceeding the action level of 6.1 picocuries per gram (pCi/g) of Ra-226 was established to be 1,299 acres. The total volume of soil exceeding the action level was determined to be 2,467,712 cubic yards (CYs), consisting of a surface area of approximately 1,068 acres (924 acres of non-Section 19 area plus 144 acres of Section 19 only) at a 1foot depth and approximately 231 acres (includes 0 acres in Section 19) at a 2-foot depth. It should be noted that Section 19 had been subdivided into hundreds of individual lots, the majority of which the EPA was unable to attain access agreements due to the convoluted ownership of the parcels and therefore did not survey (Figure 1-10). Areas within Section 19 for which the EPA did have access were surveyed and the data considered applicable to the entire section due to the distribution of accessible areas throughout the section. The removal volume estimate for Section 19 is reported separately as it is subject to potential change as access is gained in the future and RSE activities are conducted therein. These areal and volumetric extent-of-contamination values are summarized in Table ES-1. These values were used to evaluate removal action alternatives and to analyze their associated costs in this EE/CA.

Table ES-1
Soil Removal Volume Estimate
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Zone	Surface Area		Volume
	Square Feet	Acres	Cubic Yards (CYs)
1-foot Depth Excavation Area (Except Section 19)	40,237,825	924	1,490,290
2-foot Depth Excavation Area (Except Section 19)	10,064,681	231	745,532
1-foot Depth Excavation Area (Section 19 Only)	6,261,025	144	231,890
2-foot Depth Excavation Area (Section 19 Only)	TBD	TBD	TBD
TOTAL	56,563,531	1,299	2,467,712

TBD – To Be Determined pending access
CYs – Cubic Yards

Removal Action Objectives

The main objective of this removal action is to mitigate actual or potential risks to human health and/or the environment posed by excess radiological on-site contamination, and, to the extent feasible, reclaim the entire Site for the projected future land use – livestock grazing. The scope of the response action will be to address excess radiological contamination in soil greater than the action level of 6.1 pCi/g for Ra-226, which is inclusive of the Ra-226 background threshold value (1.5 pCi/g). The action level represents a total cancer morbidity risk of 1.3×10^{-4}; this risk is less than the maximum target acceptable site cancer morbidity risk of 3×10^{-4} (3 persons per 10,000 persons) as determined by EPA. The response action is intended to be the final action for the surface and near-surface contaminated soils at the Site and is intended to contribute to any potential remedial actions that may be contemplated for groundwater through source control.

Potential Removal Action Alternatives

The following removal action alternatives were considered as part of this EE/CA. Each of the alternatives was evaluated against the criteria of effectiveness, implementability, and cost.

- Alternative 1: No Further Action – included to satisfy the requirements of the National Contingency Plan (NCP) and to provide a basis for comparison of the remaining alternatives.
- Alternative 2: Excavation and Off-Site Disposal of Radiologically Contaminated Soils at a Licensed, Low-Level Radioactive Waste Facility – assumes that contaminated soils with concentrations of Ra-226 greater than the action level would be excavated and disposed of off-site at a licensed disposal facility permitted to receive the waste. Three potential licensed facilities that are authorized to accept low-level radioactive waste and/or naturally occurring low-level radioactive soil with Ra-226 concentrations ranging from 2 pCi/g to approximately 500 pCi/g were identified within the Western United States.
- Alternative 3: Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Aboveground, On-Site Repository – assumes that radiologically contaminated soils with concentrations of Ra-226 greater than the action level would be excavated, consolidated, and managed in perpetuity at a non-commercial, newly created, aboveground repository located within the boundaries of the Central GSA. The repository would include an engineered cover of the consolidated, contaminated soils.
- Alternative 4: Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Incised (below-ground), Tronox NAUM ALSD Regional Repository (hereafter referred to as ALSD Regional Repository located within the boundary of the Tronox NAUM ALSD Site) – similar to Alternative 3, assumes that radiologically contaminated soils with concentrations of Ra-226 greater than the action level would be excavated, consolidated, and managed in perpetuity at a non-commercial, newly created, *incised* regional repository located within the boundaries of the Tronox NAUM Area. The repository would include an engineered cover of the consolidated, contaminated soils.

Summary of Comparative Analysis

Effectiveness

Alternative 1, No Further Action, does not meet removal action objectives or protectiveness standards and therefore is not effective.

Alternative 2, Excavation and Off-Site Disposal of Radiologically Contaminated Soils at a Licensed, Low-Level Radioactive Waste Facility, provides a high level of long-term effectiveness; however, it has a medium level of short-term effectiveness due to the increased risk of exposure to the public and the environment from long-distance hauling to the licensed, waste disposal facility.

Alternative 3, Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Aboveground, On-Site Repository, provides a medium level of long-term effectiveness to reduce the risk to human health and the environment, since a final cover will require long-term maintenance to prevent exposure to the public and the environment. It will provide a high level of short-term effectiveness, since the hauling distance to the covered repository remains within the Site, reducing greenhouse gas emissions.

Alternative 4, Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Incised, ALSD Regional Repository, also provides a medium level of long-term effectiveness to reduce the risk to human health and the environment, since a cover will require long-term maintenance to prevent exposure to the public and the environment. It provides a high level of short-term effectiveness, since the hauling distance to the covered area remains within the Tronox NAUM ALSD (West, Central, and East) Area (reducing greenhouse gas emissions), although there is a need to travel a public road for approximately 8 miles one way to reach the ALSD Regional Repository.

Costs

Alternative 1 would be very low cost but would require ongoing expenses for maintenance of stormwater controls and fencing. However, it is not protective and, therefore, not effective. Alternative 2 has a low cost-effectiveness rating due to the extremely high capital cost of transportation and disposal in comparison to Alternatives 3 and 4. Alternatives 3 and 4 have a medium cost-effectiveness rating compared to Alternative 2, though both incur costs associated with long-term maintenance and monitoring of repository covers that would lower their cost analysis rating compared to Alternative 2. The present net value cost of Alternative 4 is approximately 9% less than that of Alternative 3. The annual cost of Alternative 4, though, would be spread over a large volume of consolidated, contaminated soils that would include the Tronox NAUM East and Central GSA Mines sites, unlike Alternative 3. Overall, Alternatives 3 and 4 are considered to be equally cost-effective.

Implementability

Alternative 1 is not effective and will not be considered further since it does not meet removal action objectives or protectiveness standards. The very high cost of transportation and disposal of contaminated soils in Alternative 2 is prohibitive. Alternatives 3 and 4 are considered to have medium and high levels of implementability, respectively. Both alternatives have high technical feasibility due to the straightforward nature of the excavation plan, the repository design based on industry standards, and the use of existing surface soils from nearby on-site areas (Alternative 3) or from incising activity (Alternative 4) for the evapotranspiration cover. The administrative feasibility for Alternative 3 is medium, however, due to the aboveground nature of the repository, which does not achieve the State of New Mexico guidelines advocating for an *incised* repository for long-term management of radioactive wastes (NMEMNRD and NMED, 2016).

As discussed above, and as shown in Table 4-1, Alternatives 3 and 4 are rated similarly for short- and long-term effectiveness and cost-effectiveness ratings. Alternative 2 has a lower cost-effectiveness rating than Alternatives 3 and 4. While the technical feasibility of Alternatives 3 and 4 is essentially identical, the administrative feasibility of Alternative 4 is greater than that of Alternative 3. Additionally, Alternative 4 will share operation and maintenance costs of the repository with other Tronox NAUM sites utilizing the repository.

1.0 INTRODUCTION

Weston Solutions, Inc. (WESTON®), the Superfund Technical Assessment and Response Team (START) contractor, has been tasked by the United States Environmental Protection Agency (EPA) Region 6 under contract EP-S5-17-02, Technical Direction Document (TDD) No. 01/17-035, to conduct activities associated with a Removal Site Evaluation (RSE) and an Engineering Evaluation/Cost Analysis (EE/CA) at the Tronox Navajo Area Uranium Mines (NAUM) Central Geographic Sub-Area (Central GSA) Mines site (the Site) located in McKinley County, New Mexico (Figure 1-1). The performance period for this TDD is currently scheduled to end on 2 July, 2022. The Superfund Enterprise Management System (SEMS) number assigned to the Site is NMN000605304. This EE/CA will describe and summarize work performed in support of the RSE and EE/CA field efforts and present removal action alternatives and their evaluation to be completed as part of a Non-Time-Critical Removal Action (NTCRA) at the Site.

The activities conducted under the TDD are associated with abandoned uranium mines (AUMs), including surrounding properties, and are part of an ongoing EPA Region 6 program to assess and remediate Tronox-related abandoned uranium mines (AUMs) within the Grants Mining District (GMD), specifically those within the Ambrosia Lake Sub-District (ALSD) and outside of Navajo lands. A Site Area Map, provided as Figure 1-2, presents an overview of the different AUM Geographic Sub-Areas (GSAs) in the ALSD and highlights the Central GSA Mines Site footprint.

1.1 PURPOSE AND SCOPE

The purpose of this EE/CA is to present the available data collected relative to the Site, to describe the Removal Action Objectives (RAOs), to describe the removal alternatives available to address contamination at the Site to meet the RAOs, and to provide an analysis of the alternatives. This EE/CA was conducted following the basic methodology outlined in 40 Code of Federal Regulations (CFR) §300.415 and further discussed in the EE/CA guidance (EPA, 1993). The report is compiled in accordance with the guidance and standards established under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and guidance issued by the EPA, specifically *Guidance for Conducting Non-Time-Critical Removal Actions* (EPA/540-R-93-057, 1993); and *A Guide to Developing and Documenting Cost Estimates*

During the Feasibility Study (EPA Office of Solid Waste and Emergency Response [OSWER] 9355.0-75; July 2000a). The report is divided into seven sections as described below.

- Section 1: Introduction – Provides background information, summarizes the findings of previous investigations and reports, summarizes the nature and extent of contamination, and presents the results of human health and ecological streamlined risk evaluation (SRE).
- Section 2: Removal Action Objectives – Presents the RAOs, identifies the surface area and volumes of contaminated media, and discusses the removal action schedule.
- Section 3: Removal Action Alternatives – Lists applicable or relevant and appropriate requirements (ARARs), and identifies and describes alternatives to address the removal action goals.
- Section 4: Analysis of Alternatives – Provides an individual analysis of the alternatives using EPA evaluation criteria.
- Section 5: Comparative Analysis of Removal Action Alternatives – Comparatively analyzes the removal action alternatives.
- Section 6: Recommended Alternative – Based on comparative analysis, recommends one alternative from the listed removal action alternatives.
- Section 7: References – Lists the references used in the development of this report.

1.2 Site Description and Background

The EPA Region 6 Tronox NAUM Area comprises approximately 100 square miles within the center of the ALSD of the GMD in McKinley County, New Mexico. The following sections provide overviews of the GMD and ALSD before providing a Site-specific description and background of the Central GSA Mines Site.

1.2.1 Grants Mining District

New Mexico has the second-largest identified uranium ore deposits of any state in the United States after Wyoming (McLemore, 2007). Almost all of its uranium is found in the GMD (formerly and occasionally still referred to by various entities as the Grants Mineral Belt [GMB]), an area of uranium mineralization occurrence approximately 100 miles long and 25 miles wide, encompassing portions of McKinley, Cibola, Sandoval, and Bernalillo counties in the northwestern part of New Mexico. The GMD is composed of geographic sub-districts (defined by the non-regulatory agency New Mexico Bureau of Geology and Mineral Resources, serving as the

New Mexico Geologic Survey) wholly within the Navajo Nation (EPA Region 9 jurisdiction), wholly within EPA Region 6 jurisdiction, and with shared EPA Region 6 and 9 jurisdiction – Ambrosia Lake. A Site Location Map is provided as Figure 1-1.

The GMD (hereafter to mean only those sub-districts wholly within EPA Region 6 jurisdiction or the ALSD shared jurisdiction areas) is within the Navajo and Datil sections of the Colorado Plateau physiographic province. Characteristic land features include rugged mountains, broad flat valleys, mesas, cuestas, rock terraces, steep escarpments, canyons, lava flows, volcanic cones, buttes, and arroyos (EPA, 1975). The Continental Divide extends through the northwest corner of the GMD. Thus, lying east of the Divide, streams and rivers in the GMD eventually flow into the Rio Grande, one of the principal rivers of the Western United States that runs through the length of Central New Mexico approximately 70 miles east of the center of the GMD. Nearly all of the streams in the GMD are intermittent and flow only during periods of heavy precipitation (EPA, 1975).

The uranium ore deposits in the GMD are found in the northward dipping limestone and sandstones that were tilted as a result of the Zuni Uplift, which produced the Zuni Mountains that lie south and generally parallel to the trend of the mineralized zone (Holmquist, 1970). The majority of the uranium ore deposits in the GMD are in sandstone formations (McLemore, 2007). The first large sandstone uranium deposit to be discovered in the GMD was found by Anaconda Company in the early 1950s using aerial prospecting on the Laguna Reservation about 32 miles east of Grants, New Mexico, and about 8 miles north of Highway 66. This discovery, the Jackpile deposit, probably influenced other large companies to investigate the GMD area for important deposits of uranium ore (McLemore, 2007).

Upon the commercial discovery of uranium ore deposits in New Mexico in 1950, the GMD was henceforth the primary focus of uranium extraction and production activities in New Mexico from the 1950s until the late 1990s. Several different companies moved into the region in the 1950s, particularly oil companies. They included Anaconda Company, Phillips Petroleum Company, Rio de Oro Uranium Mines, Inc., Kermac Nuclear Fuels Corporation (a cooperative of Kerr-McGee Oil Industries, Anderson Development Corporation, and Pacific Uranium Mines, Inc.), Homestake Mining Company, Sabre-Pinion Corporation, United Western Minerals Company, J. H. Whitney and Company, White Weld & Co., San Jacinto Petroleum Corporation, Lisbon Uranium Corporation, and Superior Oil Company (McLemore, 2007; TIME, 1957). Five uranium mills, shown on Figure 1-1, operated in the GMD to process ore into triuranium octoxide (U_3O_8), commonly referred to as “yellowcake.” Four of the mills were in the ALSD and one was located in the Laguna Sub-District.

No uranium ore has been actively mined in the GMD since 1998, although Rio Algom Mining, LLC (RAML) continued to recover uranium dissolved in water from its flooded underground mine workings in Ambrosia Lake until 2002. The Navajo Nation, whose reservation contains much of the known ore deposits, declared a moratorium on uranium mining in 2005 (McLemore, 2007).

The GMD contains 97 legacy uranium mines and five former uranium mill and tailing disposal sites that were active during the Atomic Energy Commission uranium purchase (from the 1940s through 1970) and beyond, until the 1990s. Over 52 million tons of uranium ore were extracted from these mines, constituting approximately 68% of the total uranium ore mined in the United States (EPA, 2015a). In the GMD alone, over 300 mining permits were issued by the State of New Mexico on lands consisting of public, tribal, and private property for mine exploration and mining operations. The extraction of uranium-bearing ore deposits occurred through open pits, from underground workings that were extensively connected, and solution mining (EPA, 2015a).

The State of New Mexico has specifically identified that the 97 legacy uranium mines require assessment and possible cleanup. The mines had reportable ore production and surface expression post mining (i.e., waste rock piles, vents/shafts, physical remnants) (EPA, 2015a).

The EPA has identified four categories with respect to entities that should be responsible for addressing the legacy mines and operational impacts within the GMD.

- Mines associated with the Jackpile National Priorities List (NPL) Site (Laguna Sub-District).
- Mines covered by the Tronox settlement (ALSD).
- Mines with potential responsible parties (PRPs).
- Mines without responsible parties (orphans).

Additionally, the Homestake Mining Company NPL Site (former uranium mill) is located within the GMD near Milan, New Mexico.

The Jackpile-Paguate Mine (Figure 1-1) is located in the Laguna Sub-District on the Pueblo of Laguna. The entire mine area was added to the NPL in December 2013 and will be addressed by the EPA's Remedial Program. As stated previously, the EPA Region 6 Tronox NAUM Area lies within the ALSD. A description of the ALSD follows immediately below.

The progress of assessment and cleanup efforts of uranium mines, mills, residential areas, and water supply sources throughout the GMD is tracked by EPA through 5-year plans located on the EPA website at https://www.epa.gov/grants-mining-district/draft-2015-2020-grants-mining-district-five-year-plan.

1.2.2 Ambrosia Lake Sub-District

The ALSD is the largest of the sub-districts within the GMD, comprising approximately 760 square miles and stretching from Interstate Highway 40 to the south, from New Mexico State Highway 371 from Thoreau to Crownpoint to the west, from a line 25 miles north of the Cibola County/McKinley County border to the north, and from the western portion of the Cibola National Forest and approximately 16 miles west of the McKinley County/Sandoval County border to the east. A Site Area Map is provided as Figure 1-2. As referenced above, federal removal jurisdiction is held jointly within the ALSD by EPA Regions 6 and 9. The western one-third of the ALSD is Navajo Nation (within EPA Region 9 jurisdiction) or mixed ownership, and the remainder is private land under EPA Region 6 jurisdiction. The eastern half of the ALSD lies almost wholly within the San Mateo Creek Watershed Basin.

Geology and Hydrogeology

The ALSD is located in the southeast corner of the Navajo section of the Colorado Plateau physiographic province. The geology is characterized by elongated domal uplifts, monoclines, and broad structural platforms. The majority of the regional structure was formed during the late Cretaceous period to the early Tertiary period (Hilpert, 1963) and was probably accompanied by east-west directed tension that produced north- and northwest-trending faults and joints (Santos, 1970). Uranium deposits within the ALSD occur at several stratigraphic levels within the Westwater Canyon Member of the Jurassic Morrison Formation.

The following description of the lithology and hydrology of Ambrosia Lake was taken from a 1977 report by the Los Alamos Scientific Laboratory on the geology and hydrology of Ambrosia Lake (Purtymun et al, 1977). The description follows the order of oldest to youngest formation, i.e., Permian, Triassic, Jurassic, and Cretaceous periods. Figure 1-3 illustrates the rock formations of the ALSD. Figure 1-4 illustrates the major fault zones of the ALSD.

Rocks of the Permian period are the Glorieta Sandstone and the overlying San Andres Limestone. The Glorieta Sandstone is about 16 meters thick and the San Andres Limestone is about 34 meters thick.

The rocks of the Triassic period include the Chinle Formation. The lower part of the Chinle Formation is a silty sandstone, the middle part is a hard sandstone, and the upper part of the Chinle Formation is siltstone and mudstone. The Chinle Formation is about 443 meters thick.

The Morrison Formation, of the Jurassic period, is composed of three members, which, in ascending order, are the Recapture Member, the Westwater Canyon Member, and the uppermost Brushy Basin Member. The Recapture Member is a siltstone whose thickness ranges from 29 meters to about 45 meters. The Westwater Canyon Member is a fine- to coarse-grained, poorly sorted sandstone. The sandstone is cross-bedded and locally contains conglomerate lenses as well as clay chert pebbles and inclusions of petrified wood fragments. The Westwater Canyon Member, whose thickness ranges from 44 meters to about 60 meters, contains extensive deposits of uranium and vanadium ores at several stratigraphic levels. Most of the uranium ore deposits exist in the form of the minerals coffinite ($USiO_4$) and uraninite (UO_2) (Thomson, undated). It also contains trace amounts of molybdenum, iron, and various other metals (Kerr-McGee, undated), and is also the principal aquifer of the ALSD. The uppermost Brushy Basin Member is a mudstone whose thickness ranges from 29 meters to 52 meters.

Rocks of the Cretaceous period are, in ascending order, the Dakota Sandstone and Mancos Shale. The Dakota Sandstone thickness ranges from 18 meters to 24 meters, and outcrops along the southwestern edge of Ambrosia Lake. The overlying Mancos Shale forms the floor of the Ambrosia Lake valley and, in places, is covered by a thin veneer of alluvium. The Mancos Shale is a thick lithologic unit composed of calcareous, fissile clay of marine origin. Interbedded with the shale are three sandstone beds, the Tres Hermanos (designated A, B, and C), each generally less than 9 meters thick. The upper surface of the shale is cut away by erosion, with thicknesses ranging from 52 meters to 158 meters. East of the San Mateo Fault Zone (Figure 1-4), the shale is about 310 meters thick on the downthrown side of the fault. The overlying Crevasse Canyon Formation is composed of shale, claystone, siltstone, minor seams of coal, and tan sandstone. The formation outcrops in the northeastern part of Ambrosia Lake. Quaternary alluvium occurs along the Arroyo del Puerto and in low areas and depressions in the valley. The alluvium is derived from the Crevasse Canyon Formation and the Mancos Shale and is composed of silts, sands, gravels, and a few cobbles and boulders of sandstone. The alluvium may in part be worked by water, and, in places, consists of wind-laid sand. The thickness ranges from a veneer to as much as 30 meters.

Overall, the Ambrosia Lake area is underlain by sedimentary rocks to depths greater than 1,000 meters. These rocks are part of the structural element known as the Chaco Slope, a part of the southern extension of the San Juan Basin. The highlands south of the Chaco Slope, the Zuni Uplift, have flexed the sedimentary rocks so that the general regional dip of these units is northward and north-eastward across the Chaco Slope into the San Juan Basin. There is little, if any, structure in the southern part of the Ambrosia Lake area except the general dip of the sedimentary beds to the northeast at 1 to 3 degrees. The older rocks (Dakota Sandstone) outcrop on the southwestern edge of the area, while the younger rocks (Crevasse Canyon Formation) outcrop to the northeast. Two closely spaced, north-south trending normal faults in the central part of the area are downthrown to the east. The largest fault, the San Mateo Fault, occurs along the eastern edge of the area and is downthrown to the east about 150 meters.

Major drainage through the Ambrosia Lake area is the southeastern trending Arroyo del Puerto that is a tributary of San Mateo Creek. The flow in Arroyo del Puerto is ephemeral but became a perennial stream during the release of water pumped from the uranium mines in the area. The flow extends to San Mateo Creek where it is lost to evaporation and infiltration into the underlying rocks (Purtymun et al, 1977). The gradient on Arroyo del Puerto is low and the arroyo tends to meander. When the mines were being de-watered, large areas of marsh grasses, sedges, and cattails occurred along the channel. Stream flow losses into the Mancos Shale are probably quite small; however, losses are greater where the channel is cut on sandstone units of the Mancos Shale or the Dakota Sandstone near the southern border of the area. Minor amounts of recharge to these sandstone units occur from stream flow in the arroyo.

The principal aquifers in the GMD are the Glorieta Sandstone and San Andres Limestone of the Permian period, the Westwater Canyon Member of the Morrison Formation of the late Jurassic period, the Dakota Sandstone of the Cretaceous period, and alluvium and basalt of the Quaternary period (John and West, 1963). The Westwater Canyon Member furnishes most of the water supply in the ALSD. Contamination of regional private wells with uranium mining-related constituents above drinking water standards has been documented (EPA, 2015a). Shallow alluvial aquifers are also contaminated with uranium mining-related constituents (same; New Mexico Health and Environment Department [NMHED], 1986). Water from the Dakota formation (Upper Cretaceous) and Brushy Basin formation (Upper Jurassic) was pumped out to access the uranium for many mines in the ALSD, including the Central GSA Mines (Holmquist, 1970).

Mining Practices

The following description of mining practices in the ALSD was taken from, “An Overview of the Uranium Industry” (New Mexico Energy and Minerals Department [NMEMD], 1979) and from “Uranium Mining and Processing” (Kerr-McGee, undated). The uranium mines in the ALSD were conventional underground mines. A diagram of a typical underground uranium mine operated by Kerr-McGee Corporation in the ALSD is provided as Figure 1-5. Mine operations included vertical mine shafts sunk to the appropriate ore depth and a station with ancillary drifts, pockets, trenches, and sumps. Shafts were typically around 15 feet in diameter and concrete-lined, with hoisting compartments via skips to bring ore and waste rock to the surface and for the conveyance of miners and materials. Groundwater flowed to the shaft and down to a collecting sump at the bottom of the shaft where it was pumped to the surface.

Aboveground, the main pad area might include main and auxiliary buildings, a shaft-area pad with a head frame up to 100-feet high, oil and fuel storage, a power facilities area, a concrete batch plant, an ore storage pad, a materials storage yard, and a powder magazine. The main building contained the hoist room, warehouse, maintenance shops, and administrative offices.

Mine development included horizontal drifts driven outward from the shaft and beneath the elevation of the ore deposits. The drifts were approximately 9 feet wide by 9 feet high and were supported by rock bolts and wood and/or steel sets. Haulage drifts generally paralleled the long axes of the ore deposits (ore bodies). Short drifts, called crosscuts, were driven normal to the haulage drift as required to reach the extremities of the ore bodies. As drifts extended further from the shaft, ventilation holes of 36-to-72-inches in diameter were drilled to maintain air quality, typically functioning as exhaust while the main shaft functioned as the fresh air intake. The ore bodies were outlined by longhole drilling, which were probed to determine the location of the ore and to dewater the ore bodies.

Extraction (called "stoping") of an ore body began once development was complete. Generally, there were three stoping methods employed: open stopes, room and pillar stopes, and square set stopes. The selection for each ore body depended on the stability of the ground and the size and shape of the ore body. Once mined, drifts and stopes were typically backfilled, sometimes with mill tailings, to prevent collapse.

Mine water recirculation, sometimes referred to as “in situ stope leaching” or “solution mining,” was commonly performed to ALSD mines (NMEMD, 1979). The process is described as follows: In the early years of mining, when retreat began from a worked-out area, the roof collapsed, making it difficult to continue ore recovery using traditional techniques. To further increase recovery, mine owners drilled holes into the top of the collapsed zone and sprayed water through these holes onto the low-grade shattered ore. Mine water is slightly alkaline and a small amount of leaching occurs as the water runs through the shattered zone into collection sumps. The enriched water was then pumped to ion exchange plants where the uranium was removed from the water. The water was then returned for further leaching. After a period of time, no further leaching can occur. The shattered zone was then allowed to "sit" until further oxidation of the ore occurred through natural processes, usually about 2 weeks (NMEMD, 1979).

Uranium mine-related wastes commonly consist of low-grade ore of insufficient quality to process economically, overburden (waste rock) that is removed to access high-grade ore, or residuals from mine dewatering activities. Most of the mines in the ALSD conducted extensive dewatering to access ore below the water table. Most effluent from dewatering received little or no treatment before discharge to the ground or surface drainages during the majority of the mine operational period, causing perennial stream flows in major drainages that were otherwise ephemeral. Treatment of pre-discharge mine waters to extract uranium (ion exchange plants) and Ra-226 (settling ponds with bioremediation) was incorporated into most mine operations beginning in the 1970s. Other environmental impacts may have been caused by erosion and leaching of mine waste materials, some of which were deposited into arroyos where they remain today, and by the reported on-site heap-leach and stope-leaching operations.

Additionally, the mine water effluent infiltrated and recharged the shallow alluvium directly or through impoundment infiltration and overflow. From 30 years of mining operations, approximately 80 billion gallons of mine water was extracted from the subsurface and discharged to surface drainages, the majority being discharged into the San Mateo Creek basin (EPA, 2015a). The effluent discharges may impact regional bedrock drinking water aquifers and shallow alluvial aquifers. These aquifers are accessed by scattered private residences and nearby municipal or community water supply systems. Moreover, extensive dewatering of underground workings during mine operations created a regionally extensive cone of depression into which oxygenated groundwater currently is flowing. The oxygenated groundwater may dissolve and mobilize unmined uranium and associated constituents within the aquifers (EPA, 2015a).

Most of the uranium mine sites in the ALSD have undergone some form of surface reclamation, although some mines still have physical hazards such as open adits, vent holes, and shafts, as well as uncontrolled waste rock and ore piles on-site. Some reclamations occurred prior to the New Mexico Mining Act of 1993, and all occurred prior to the promulgation of uranium mine cleanup and reclamation guidelines by the State of New Mexico in 2016. These guidelines specify a limit of 5.0 picocuries per gram (pCi/g) of Ra-226, averaged over the first 15 centimeters of soil below the surface, averaged over any area of 100 square meters.

A total of four uranium mills operated in the ALSD (Figure 1-1). Milling activities occurred at the Phillips Petroleum Mill from 1958 to 1982, at the Homestake Mill from 1957 to 1990, at the Anaconda-Bluewater Mill from 1953 to 1982, and at the Rio Algom Mill from 1958 to 2002 (EPA, 2015a). The Department of Energy (DOE), with U.S. Nuclear Regulatory Commission (NRC) oversight, is responsible for long-term surveillance and maintenance duties at the Phillips Petroleum Mill and Anaconda-Bluewater Mill. The NRC, in coordination with the EPA and the New Mexico Environment Department (NMED), currently regulates ongoing remedial activities at the Homestake Mill Superfund Site. The NRC also oversees reclamation in coordination with the NMED at the Rio Algom Mill (EPA, 2015a).

Mine Sites in the ALSD

In November 2014, the U.S. District Court for the Southern District of New York approved a settlement agreement to resolve fraudulent conveyance claims against Kerr-McGee Corporation and related subsidiaries of Anadarko Petroleum Corporation. Settlement proceeds were distributed in January 2015, and the EPA received funding for the assessment and subsequent cleanup of over 50 Tronox NAUM sites located in both EPA Region 6 and EPA Region 9 jurisdictional areas.

Twenty-two (22) legacy uranium mines within the EPA Region 6 Tronox NAUM footprint (all located within the ALSD) are eligible for Litigation Trust funding. Of the 22 eligible mines within the ALSD, only 12 surface operational areas are associated with these mines due to several of the eligible mines being operated through a geographically shared central main shaft. All of these mines have undergone some form of closure operations and removal of operational surface features. Some of these mines were operated as “wet mines,” where the underground workings were dewatered and the collected mine water was discharged to nearby surface drainage features such as creeks and arroyos. Little environmental data currently exists on the Tronox NAUM in general, or specifically, regarding risks to public health and/or the environment, and/or any threat abatement actions that may be necessary. EPA Region 6 has been tasked to obtain the data required to evaluate the risks posed by these legacy mine sites and conduct appropriate risk abatement activities.

The Tronox NAUM Area within the ALSD consists of two stand-alone mine sites: the Section 10 Mine and the Spencer Mine (U.S. Department of the Interior’s Bureau of Land Management [BLM] lead); and three GSAs: the East (Sections 35 and 36 Mines), Central (Sections 17, 19, 30, and 33 Mines), and West (Sections 22, 24, and 30 West Mines) GSAs (Figure 1-2). The Tronox Sections 32 and 33 Mines site is located approximately 9 miles west-northwest of the Ambrosia Lake valley but is still within the ALSD. As more information is gathered about orphan mines and mines with PRPs, further geographic sub-areas may be identified.

Land ownership within the Tronox NAUM Area varies predominantly by geographic section; that is, the vast majority of the geographic sections have one landowner. The majority of land in each of the areas referenced above is privately owned. The East GSA Mines site also includes lands owned by the State of New Mexico, the Central GSA Mines site also includes lands owned by the BLM, the West GSA Mines Site also includes lands owned by the Navajo Nation and the BLM, and the Spencer Mine site is located on BLM property. Ownership of the Tronox NAUM Area and surrounding land is illustrated on Figure 1-6.

In addition to the Tronox sites, other SEMS sites in the ALSD include the Ann Lee Uranium Mine, the John Bully Uranium Mine, the Sandstone Uranium Mine, and the Homestake-New Mexico Partners Uranium Mine (Figure 1-2). The PRP for the Ann Lee, John Bully, and Sandstone Mines is United Nuclear, while Homestake Mining Company is the PRP for its namesake mine.

The Central GSA Mines Site is the subject of this EE/CA; activities associated with the East and West GSA Mines, the Sections 32 and 33 Mines, and the Section 10 Mine will be reported under separate EE/CAs.

1.2.3 Site Location

The Central GSA Mines Site is located in the ALSD approximately 18 miles north of Grants, Cibola County, New Mexico, and 5.5 miles north-northwest of the intersection of New Mexico State Highways 509 and 605 (Figure 1-2). The Site area is shown on the Ambrosia Lake and Goat Mountain quadrangles U.S. Geological Survey (USGS) Topographical Map. The Site comprises four former underground uranium mines that are located in Sections 17, 19, 30, and 33, Township 14 North, Range 9 West (T14N, R9W) of the New Mexico Principal Baseline and Meridian. The Site also includes related surface areas impacted by surface water discharges from mine dewatering and associated mining operations at these mines. Additionally, the Site includes surface areas impacted by a non-Tronox mine located on the southern portion of the Central GSA and the non-Tronox former Phillips Petroleum Mill located on the eastern border of the Central GSA (Figure 1-7). The Site includes approximately 3,805 acres or 5.95 square miles. All of the land is privately owned except a portion of Section 20, which is owned by BLM. The formal boundaries of the Site were determined from previous investigations, which are described in Section 1.4.1, and include all or portions of seven geographical sections as illustrated on the Site Layout Map (Figure 1-7).

1.2.4 Operational Status

The Central GSA Mines were developed and operated by Kermac Nuclear beginning in 1958 and transferred to Kerr-McGee from 1964 until 1984 when operational control was turned over to Quivira Mining Company, which was a subsidiary of Kerr-McGee. The mines were sold to RAML in 1989. Broken Hill Proprietary Company (BHP) acquired RAML in 2000 and has now merged with Billiton to form BHP Billiton.

The Section 17 Mine was mined to a depth of 938 feet and was operated from 1958 to 1985 on land that was and is currently owned by RAML or its predecessors. Track drifts were made from the Section 17 Mine into adjoining sections 18 and 20. Approximately 1.5 million tons of uranium ore (including from sections 18 and 20) were removed from the Section 17 Mine shaft (WESTON, 2019). This mine was a “wet mine,” and while it was operational, the mine had a mine water discharge rate of up to 900 gallons per minute (gpm). This water contained concentrations of radioactive material that were significantly elevated above natural background levels and were largely untreated.

Section 19 was subdivided and parcels were sold to hundreds of investors for mineral speculation, first for petroleum production and later for uranium mining. Due to the numerous small tract ownership in Section 19, effective mining required a special State Legislature bill sponsored by Kermac to permit a unitization of the tracts in the section so royalty could be credited to the tracts that Kermac did not control on an acreage basis. The Section 19 Mine was mined to a depth of 762 feet and was operated from 1969 to 1985. Information on water pumped from the mine and tons of ore production from the Section 19 Mine was not available.

The Section 30 Mine was mined to a depth of 762 feet. It was operated from 1959 to 1985 on property owned by RAML or its predecessors. Starting in 1961, mining began in Section 29 through the Section 30 shaft. Approximately 3.1 million tons of uranium ore (including 318,361 tons from Section 29) were removed from the Section 30 Mine shaft (WESTON, 2019). This mine was a “wet mine,” and while it was operational, the mine had an average mine water discharge rate of 100 gpm. This water contained concentrations of radioactive material that were significantly elevated above natural background levels, were largely untreated, and were discharged to the surface water drainage features.

The Section 33 Mine was mined to a depth of 848 feet. It was operated from 1959 to 1985 under a mineral rights lease. The mine is located on property owned by RAML or its predecessors. Starting in 1963, mining began in Section 28 through the Section 33 shaft. Approximately 1.6 million tons of uranium ore (including from ore from Section 28) were removed from the Section

33 Mine shaft (WESTON, 2019). This mine was a “wet mine,” and while it was operational, the mine had an average mine water discharge rate of 120 gpm. This water contained concentrations of radioactive material that were significantly elevated above natural background levels, were largely untreated, and were discharged to the surface water drainage features.

For the four Central GSA Mines, EPA was unable to determine precise locations where mine ore was staged prior to milling. Ore from the Mines was milled at the Rio Algom Uranium Mill (Figure 1-2). EPA was also unable to determine precise locations where waste rock (sub-economic ore and overburden) might have been stored on-site.

Drainage pathways of the Mine water discharges are discussed in Section 1.2.7**.** Reclamation activities conducted by RAML at the mine sites are discussed below in Section 1.2.5.

1.2.5 Structures, Topography, and Vegetation

The Sections 17, 19, 30, and 33 mine sites have all undergone some form of surface reclamation. In each case, the mining-related buildings and structures were removed from the areas surrounding the mine shaft opening, and the foundations of the buildings have been removed and the area has been graded. All that remains on the surface are a few scattered pieces of debris. EPA was unable to obtain information regarding settling ponds associated with the mines.

Section 17 Mine reclamation activities began in 2002 with the backfilling of shafts and ventilation holes. Between 2002 and 2003, approximately 140 leach holes associated with the Section 17 Mine were reclaimed by excavating down approximately 4 feet around the metal pipe at which point the pipe was cut off and capped. A concrete plug approximately 1 foot in diameter was then installed over the capped pipe and the area backfilled to the original grade. RAML reseeded and contoured areas after reclamation activities were completed (RAML, 2005).

Section 19 Mine reclamation activities began in 2003 with the backfilling of the mine shaft and vent holes. The production shaft plug was completed in 2004. In 2005 RAML completed reclamation activities by plugging additional vent holes and leach holes (RAML, 2005).

RAML reclamation activities at the Section 30 Mine commenced with the mine site cleanup in September of 1993. The primary production shaft and 17 ventilation shafts were plugged and covered within a period between 2002 and 2005. Leach hole reclamation was completed in 2005 and included holes located in Sections 20, 25, 29, and 30W that supported the Section 30 Mine operations (RAML, 2005).

Section 33 mine reclamation activities began in 2004 with the backfilling of the mine shaft and vent holes. The production shaft plug was completed in 2004. Leach hole and additional vent hole reclamation was conducted in 2005 (RAML, 2005).

For the Rio Algom Uranium Mill, reclamation under NRC regulation is largely complete. A radon barrier was constructed over Tailings Impoundment 1 in 1999 and the mill was decommissioned in 2005. Additional reclamation tasks were completed in subsequent years, including the construction of a 1,000-year diversion channel for the Arroyo Del Puerto. In 2014 and 2015, RAML demolished all remaining structures at the mill site and consolidated remaining waste material into Tailings Impoundment 2, including waste from the Section 4 ponds (EPA, 2015a).

The Site area lies approximately 6,920 to 7,150 feet in elevation above mean sea level. It is located in the Ambrosia Lake Valley southwest of San Mateo Mesa. The Site area occurs within the Semiarid Tablelands ecoregion, which is characterized by dry plains, mesas, valleys, and canyons formed from sedimentary rocks. A detailed description of Site vegetation is presented in the *Natural Resources Evaluation Report* which summarizes the survey performed by Carrizo Mountain Environmental & Herbarium, Inc. (Carrizo), provided in Appendix A.

As discussed by Carrizo (Appendix A), the Site includes the following vegetative communities: Grassland-Shrub Community, Grasslands Community, Shrubland Community, Southwest Arroyo Shrubland Community, Grassland Swale Community, and Juniper Savannah Community. Noxious weeds or invasive species observed on the Site include Whorled Milkweed, Field Bindweed, Russian Olive, Halogeton, and Saltcedar. No obligate wetland species were observed on the Site.

1.2.6 Site Soils

Soils at the Central GSA Mines Site consist of the following U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS, 2016) map units listed by highest percent occurrence in the study area: 56.1% Penistaja-Tintero complex, 1-to-10% slopes; 24.6% Sparank-San Mateo-Zia complex, 0.0-to-3% slopes; 9.4% Uranium mined lands; 6.3% Hagerwest-

Bond fine sandy loams, 0-to-8% slopes; and 3.6% Berryhill-Casamero clays, 2–to-10% slopes. The site soils have been classified as having very low to very high surface runoff, are generally well drained, and exhibit very slow to moderately rapid permeability. Approximately 21% of the total acreage is within areas of previous disturbance. Soil chemistry parameters were evaluated in 15 soil samples as part of Carrizo's natural resource study. In general, analyses indicate that area soils have low water holding capacity and have a low carbon/nitrogen ratio.

1.2.7 Hydrologic Setting

The Central GSA Mines Site is within the San Mateo Creek local watershed and in the Rio San Jose 8-digit Hydrologic Unit Code 13020207, which occurs in the larger Middle Rio Grande drainage basin. Surface water flow from the mines occurs through sheet flow and a series of unnamed ephemeral streams and arroyos generally to the southwest into the Arroyo del Puerto (Figure 1-8). The Arroyo del Puerto flows into San Mateo Creek approximately 6 miles south-southeast of the Site. The Arroyo del Puerto and San Mateo Creek are intermittent streams in the vicinity of the mines.

1.2.8 Surrounding Land Use and Population

McKinley County, New Mexico, has a total land area of approximately 5,455 square miles and a population of 71,492 (2010 U.S. Census; American Fact Finder, factfinder2.census.gov). The closest community to the Site is San Mateo (Cibola County), which has a population of 161. The Census Tracts immediately surrounding the Site (Census Tracts 9440 and 9460) have populations of 2,186 and 5,677, respectively, with the majority of the population occurring on the Navajo Nation.

There are currently two residences located on Section 18, approximately 0.5 miles from the Section 17 Mine (Figure 1-7). These two residences are part of a ranch that predates uranium mining in the Ambrosia Lake Valley. The next closest residences are located approximately 4 miles to the west-southwest on Navajo land, and approximately 5 miles south of the Site. It is highly unlikely that the Central GSA property would be used for residential development due to the remoteness of the area.

Many sections of the Ambrosia Lake Valley are used for livestock grazing. A RAML representative communicated to EPA that RAML-owned property in Sections 17, 29, 30, 32, and 33 of T14N, R9W are currently leased for cattle grazing. Additionally, Section 20, which is owned by BLM, is sub-leased for grazing. Hunting activities are popular in the area. Although public access to the Site is moderately restricted through perimeter barbed wire fencing and locked gates, trespass hunting activities are possible. It is presumed that hunting likely occurs on these lands, both with and without permission.

1.2.9 Historical/Cultural Resources

In consideration of future corrective actions at the Site, cultural resource surveys were conducted to meet the requirements of Section 106 of the National Historic Preservation Act. A team of archaeologists conducted the survey of the Site from 16-21 May 2018. The Cultural Resources Survey Report is provided as Appendix B. The survey included all areas that were shown to be contaminated above the action level (discussed in Section 2.2.1), plus an additional 50-foot buffer zone around the contaminated area.

The Cultural Resource Survey Report has been submitted to the State Historic Preservation Office (SHPO) and the Trust Archeologist in the State Land Office (SLO) for review. EPA will also extend an invitation for consultation to the tribes that have identified an interest to the New Mexico SHPO in potential consultation on federal undertakings in McKinley County, New Mexico. Any further actions required by the SHPO, the SLO, or from tribal consultation will be considered during final alternative selection and included in final alternative design. A Cultural Resources Protection Plan will be developed prior to the initiation of removal activities and will include protections for historical/cultural resources documented during the survey, as applicable. The plan will include mitigation requirements determined by the stakeholders, including the SHPO and tribes. Removal activities will be scheduled to provide adequate time to institute the mitigation activities to avoid any disturbance to the sites visually identified until clearance is provided to EPA.

1.2.10 Sensitive Ecosystems and Wildlife

As mentioned in Section 1.2.5, a natural resource survey was performed to identify protected species and general wildlife habitat, and general vegetation and vegetative community types for the Site. Information gained during the survey was used during the completion of an Ecological SRE (Section 1.5.3) and development of a draft conceptual reclamation plan (Section 1.4.2.4). The *Natural Resource Evaluation* report is included in Appendix A. Carrizo conducted the survey from 20-25 October 2018. The Site boundary, as outlined in Section 2.3, was adjusted to include the extent of contamination based on the action level discussed in Section 2.2.1. At least 20 bird species and six mammal species were observed at the Site during the survey, with many more species likely occurring throughout the year. No designated or proposed critical habitat occurs within the Site boundary.

Common bird species in the area include scrub jays, dark-eyed juncos, loggerhead shrikes, white-crowned sparrows, western bluebirds, kestrels, ravens, and crows. Several other species of songbirds and raptors are likely present during migration and nesting seasons. The peregrine falcon may pass through the area and the golden eagle occurs year-round, but no suitable nesting habitat is found on the Site for either species. Burrowing owls were noted nesting within prairie dog colonies on the Site.

Six species of mammals were observed, and based on surveys of nearby areas, others could be expected. Large herbivores including elk and mule deer occur in the Ambrosia Lake valley. Predators including bobcat and coyote were confirmed by tracks and droppings. Burrowing mammals including kangaroo rats, pocket gophers, and prairie dogs were observed. Cottontails and jackrabbits were also observed.

An Environmental Protection Plan will be developed prior to the initiation of removal activities and will identify sensitive ecological habitats and species documented during the survey. Removal activities may be scheduled to avoid certain critical periods of the year such as nesting or breeding seasons. The areas of concern will be visually identified to avoid any disturbance until clearance is provided to the EPA.

1.2.11 Regional Climate

Climate at the Site can be described as semi-arid although the mountainous terrain results in a large variation of temperature and precipitation. Monthly climate data is available for the period from 01 April 1918 to 29 February 1988 from a meteorological data station (#297918) at San Mateo, New Mexico. Winter temperatures range from 16 ˚F to 63 ˚F, averaging 49 ˚F during the day.

Summer temperatures range between 31 ˚F to 83 ˚F with an average of 75 ˚F (Western Regional Climate Center [WRCC], 2015).

There is considerable variation in monthly precipitation totals although most of the precipitation in the Site area occurs during late summer thunderstorms. Monthly precipitation generally varies between 0.28 inches (February) and 2.11 inches (August), with an annual average of 8.66 inches (WRCC, 2015).

1.3 PREVIOUS REMOVAL ACTIONS

No removal actions have previously been performed at the Site. RAML conducted reclamation activities at the Site as discussed previously in section 1.2.5.

1.4 NATURE AND EXTENT OF SOIL CONTAMINATION

The nature and extent of soil contamination was defined through surface gamma scans and subsurface soil sample collection as described in Sections 1.4.1 and 1.4.2. Based on the results of the SRE (Section 1.5), the contaminant of concern (COC) for the Site is Ra-226.

1.4.1 Previous Investigations

A Pre-assessment Screen and Determination: Rio Algom Mines and Quivira Mill Site, McKinley County, New Mexico, was performed by the New Mexico Office of Natural Resources Trustee in September 2010. This report documents the pathways by which natural resources have been adversely affected by a release from various RAML mines and mills in McKinley County, New Mexico, including those mines in the Central GSA (New Mexico Office of Natural Resources Trustee, 2010).

In 2011, as part of the EPA San Mateo Creek Basin assessment activities, the EPA Airborne Spectral Photometric Environmental Collection Technology (ASPECT) platform (airplane) conducted an aerial gamma screening survey of the ALSD, including the Site (Dynamac, 2011). The ASPECT survey indicated high levels of gamma radiation, ranging from 20 microroentgens per hour (μR/hr) to 435 μR/hr, and a terrestrial background between 5-to-10 μR/hr on the four mines that comprise the Site. Results of the survey indicated that wastes from these mines have migrated off-site and onto adjacent properties (Figure 1-9).

1.4.2 Current Investigations

EPA initiated an RSE of the Site, including the development of a background reference area (BRA), completion of surface gamma surveys, and collection of surface and subsurface soil samples. The RSE was submitted to EPA in September 2019 (WESTON, 2019). The RSE determined the nature and extent of contamination above an action level. The following sections describe the activities included in each stage of the investigation. As discussed previously in Section 1.2.3, Section 1.2.4, Section 1.2.7, and Section 1.2.8, a natural resource evaluation and a cultural resource survey of the Site were also performed.

1.4.2.1 Background Reference Area Study

To provide a point of reference by which Site conditions can be compared to "pre-mining" conditions, a background radiation level was established by the EPA. Site cleanup levels are typically established as concentrations in excess of background levels that have been characterized in carefully selected BRAs. Selection criteria for the BRA are provided in Section 4.5 of the Multiagency Radiation Survey and Site Investigation Manual (MARSSIM) and include absence of contamination; and similarity in physical, chemical, geological, radiological, and biological characteristics to the contaminated areas being evaluated.

Several areas were evaluated for the Site to meet the MARSSIM guidelines. Gamma scans were conducted in several locations to identify a potential BRA. Ultimately, an area south of the Site with no known impact from mining activities (i.e., haul roads, stockpiles) in the southeastern quadrant of Section 26 of Township 14 North, Range 10 West was selected (3.1 miles, 2.0 miles, 1.8 miles, and 3.6 miles from Sections 17, 19, 30, and 33 Mines, respectively; see Figure 1-7). The identified BRA exhibits similar physical, chemical, geological, radiological, and biological characteristics as the Site.

A square area of approximately 1.5 acres was selected within Section 26 to represent the BRA. On 03 March 2016, 1-minute, stationary gamma measurements using a 2-inch by 2-inch sodium iodide (NaI) detector and collocated surface soil samples were each collected from 20 evenly-spaced points within a rectangular-shaped grid in the BRA. The starting point for the grid was randomly generated. Soil samples were sent to a qualified commercial laboratory for gamma spectroscopy analysis.

EPA conducted radiation toxicity modeling using two different models that considered contribution to human health impacts from all of the isotopes in the uranium-238 (U-238) and uranium-235 (U-235) decay chains. Ra-226, a daughter product in the U-238 decay chain, was found to be the predominant contributor of radiological risk to human health (Section 2.2.1), and is the radionuclide for which historical cleanup limits have been specified.

Statistical analysis of the background data set was performed using ProUCL 5.1 (EPA, 2015b). The average concentration for Ra-226 in the 20 samples is 1.12 pCi/g, the median is 1.10 pCi/g (indicating lack of skewness), and the standard deviation is 0.179 pCi/g. The coefficient of variation was 0.160 indicating a homogeneous background data set in accordance with MARSSIM guidance. The statistical analysis of the background data set, including a goodness-of-fit test, indicated that the data set was normally, lognormally, and gamma distributed. However, the normal distribution was selected as the most appropriate model. Dixon's outlier test did not identify any outliers. A histogram, box plot, and quantile-quantile plot were generated and visual inspection indicated a well-behaving data set without outliers, which confirmed a normal distribution. Finally, a background threshold value (BTV) was calculated at a 95% upper tolerance limit with 95% coverage (UTL95-95). This BTV of 1.5 pCi/g Ra-226 represents the upper limit of the background data set such that 95% of background values are less than 1.5 pCi/g with 95% confidence. The UTL95-95 was selected as an appropriate and defensible BTV because, when added to the Derived Concentration Guideline Level (DCGL), the resulting action level is within the acceptable range that EPA manages cancer risk. See section 2.2.1 for further discussion of the DCGL and the EPA acceptable cancer risk range.

The average of the 20 1-minute gamma measurements was 9,427 counts per minute (cpm), with a standard deviation of 199 cpm. Again, using ProUCL, a normal distribution was confirmed and a UTL95-95 of 9,904 cpm was calculated as the BTV. A summary of background laboratory analytical results and field measurements is provided in Table 1-1. The background laboratory analytical results are provided as Appendix C. The background ProUCL statistical results are provided as Appendix D.

1.4.2.2 Surface Gamma Survey

As part of the RSE, the EPA determined the lateral extent of surface contamination at the Site by conducting a gamma scanning survey (February 2017 through December 2017) using a 2-inch by 2-inch NaI detector paired with a Global Positioning System (GPS) device. The NaI detector and backpack-mounted GPS unit were carried by Site personnel over transects in a walk-over survey. The distance between transects varied depending on whether the area being scanned was clearly contaminated, not contaminated, or on the border of contamination and non-contamination based on initial gamma measurements. Initial transects were approximately 200 feet apart until these distinctions became apparent. Areas at the borders of contamination and non-contamination received the most tightly spaced transects, ranging approximately 20 feet to 30 feet apart. Non-contaminated and contaminated areas successively received less tightly spaced transects, respectively. Maximum distances between transects in clearly contaminated areas ranged from approximately 150 feet to 200 feet; distances between transects in non-contaminated areas were approximately 100 feet.

The gamma scanning survey included the entirety of Sections 17, 20, 29, and 33, as well as the eastern portion of Sections 30 and 32 and selected areas in Section 19. The western portion of Section 30 was considered to be a part of the West GSA (TDD No. 0001/17-036) and surveyed during field activities associated with that site. The western portion of Section 32 included the Homestake-New Mexico Partners Mine (Section 32 Mine). The portion of Section 32 west of New Mexico State Highway 509 was not surveyed because it was addressed by RAML during the cleanup of the RAML uranium mill. Section 19 had been subdivided and parcels were sold to hundreds of investors for mineral speculation, first for petroleum production and later for uranium mining. RAML has obtained access to portions of Section 19 through quitclaim deeds and provided access to EPA on those portions. The portions of Section 19, to which RAML and EPA have access, are shown in Figure 1-10. Due to the complexities in researching property ownership within Section 19 (hundreds of properties and thousands of owners due to transfers to heirs), the EPA surveyed the areas for which RAML has access and has contacted the U.S. Department of Justice (DOJ) to coordinate gaining access of the remaining portions.

The results of the gamma scanning survey were plotted in cpm on a map using color-coded icons to represent the detector measurements (Figure 1-11). Measurements were displayed in six ranges of values, two of which were relative to the BTV and the action level. Derivation of the action level in pCi/g of Ra-226 and its conversion to cpm is described in detail in Section 2.2.1. The figure reflects areas below the BTV, areas of contamination above the BTV but below the action level, and areas above the action level. The maximum surface gamma measurement was 916,593 cpm, approximately 93 times the BTV and 46 times the action level. Survey data presented in the Central GSA RSE (WESTON, 2019) was modified slightly by adjusting one parameter value used in the calculation of the DCGL (see Section 2.2.1). The modification of the parameter resulted in a small increase to the calculated surface area above the action level and a corresponding increase to the overall volume of contaminated soils.

The results of the gamma scanning survey were then plotted on a second map in pCi/g of Ra-226 using color-coded icons to represent the converted measurements (Figure 1-12). Scan values greater than the BTV were converted to pCi/g of Ra-226 using a methodology described in Section 2.2.1. Similar to the gamma scan survey results presented on Figure 1-11, the survey results presented on Figure 1-12 show a small increase in the surface area with survey results above the action level of a similar area presented in the RSE, due to a change in one parameter value from that in the RSE used in the calculation of the DCGL (see Section 2.2.1).

1.4.2.3 Soil Sample Collection

The EPA Team collected a surface soil grab sample from the Site to verify that radioactive contamination existed in areas of elevated gamma scanning survey measurements. The surface soil grab sample was collected from Section 17. Additionally, 16 surface soil composite samples were collected during the development of the correlation between field gamma readings in cpm and specific activity of Ra-226 in the soil measured in pCi/g (Section 2.2.1). The surface soil sample results were also used in the human health and ecological SREs (Section 1.5). The surface soil sample analytical results are presented in Table 1-2 and the surface soil sample locations are shown on Figures 1-13 through 1-19.

To determine vertical extent of contamination, subsurface soil samples were collected from 22 March 2017 through 08 March 2018. Sample locations were distributed in “mine impact” (direct impact from surface-related mining operations) and “sheet flow” (mining operation surface water discharge) areas throughout the surface-contaminated areas using the Visual Sample Plan

(VSP) program (Pacific Northwest National Laboratory, Version 7.7). The samples were collected in “mine areas” at a density of one sample for each 2 acres. The samples were collected in “sheet flow areas” at a density of one sample for each 8 acres. The samples were collected by digging a 1-foot-deep hole and collecting a sample from the bottom of the hole using a bucket auger. A total of 234 subsurface samples, plus 25 field duplicates, were collected, including 42 samples plus 3 duplicate samples from Section 17; 16 samples plus 2 duplicate samples from Section 20; 37 samples plus 5 duplicate samples from Section 29; 50 samples plus 5 duplicate samples from Section 30; 27 samples plus 3 duplicate samples from Section 32; and 62 samples plus 7 duplicate samples from Section 33. The subsurface soil sample analytical results are summarized in Table 1-3. The subsurface soil sample locations are shown on Figures 1-13 through 1-18.

The subsurface soil samples were dried, ground/pulverized as necessary, sieved, and then analyzed in EPA’s field laboratory using gamma spectroscopy with an on-site Multi-Channel Analyzer (MCA) for Ra-226. The MCA measured the gamma radiation emitted by bismuth-214 (Bi-214) rather than Ra-226, since Ra-226 does not emit a strong gamma signal. Samples were held in a sealed Marinelli jar for a minimum of 21 days to ensure that the Bi-214 and Ra-226 were in equilibrium before being analyzed with the MCA. The surface sample and 32 (13%) subsurface samples were sent to an off-site analytical laboratory for gamma spectroscopy analysis of Ra-226 as verification of the on-site MCA results. Of the 32 subsurface samples analyzed by both the MCA and the off-site analytical laboratory, MCA results ranged from 289% greater than to 14% less than the off-site laboratory result, with the larger percent deviation occurring at concentrations well below the action level of 6.1 pCi/g of Ra-226. Of the 11 samples for which laboratory results were greater than 4.0 pCi/g of Ra-226, MCA results ranged from 40% greater than to 14% less than the off-site laboratory result. One subsurface sample with an MCA result greater than the action level had an off-site laboratory result less than the action level. For all samples analyzed by both methods, off-site laboratory results were used for decision-making. MCA and off-site laboratory results were within quality assurance/quality control parameters and achieved the Data Quality Objectives established for the Site. Soil sample results ranged from 0.9 to 319 pCi/g of Ra-226.

Additionally, a total of eight surface samples plus one duplicate sample were collected, including two samples in Section 17, two samples in Section 19, two samples in Section 30, and two samples plus one duplicate sample in Section 33, and were submitted to Hall Environmental Analysis Laboratory (Hall Laboratory) in Albuquerque, New Mexico, for Target Analyte List (TAL) metals plus uranium analysis. The metals analytical results were used in the human health and ecological SRE (Section 1.5) and are provided in Table 1-4. The sample locations are provided on Figures 1-13, 1-16, 1-18, and 1-19. The Hall Laboratory analytical data package is provided as Appendix E.

1.4.2.4 Conceptual Reclamation Plan

A conceptual reclamation plan based on current conditions and projected post-removal conditions was developed for the remediation actions contemplated by this EE/CA. The final reclamation plan will be developed for implementation after reviewing and updating, as necessary, the conceptual reclamation plan with actual post-removal conditions. The conceptual reclamation plan is composed of two parts: (1) site-specific, natural regrading, modeling runs developed using Carlson Natural Regrade with GeoFluv™ software (a fluvial geomorphic landform design algorithm); and, (2) the draft revegetation plan.

Natural Regrading Plan

A conceptual site-specific natural regrading plan was developed using a Digital Elevation Model with one-third arc-second accuracy from USGS and projected excavation values. The term “natural regrading” is defined as using fluvial geomorphic landform design algorithms to develop site-specific reclamation plans that return the topography of the Site to a pre-disturbed (pre-mining) natural state. This method subscribes to the theory that prior to disturbance by man, the natural contours of the Site were in balance with the hydrology and resulted in a stable landform. The benefits of using the reclamation plan developed through the Carlson Natural Regrade software would be to provide: erosion-resistant slopes and stream channels; efficiencies in the utilization of on-site materials for contouring; placement of infrastructure to minimize environmental impact and increase efficiency; and a decrease in long-term operation and maintenance costs.

Currently, on-site drainage flows primarily from the northeast to the southwest through sheet flow and a series of unnamed ephemeral streams into the Arroyo del Puerto. The Arroyo del Puerto is located west of the Central Site and flows south for approximately 5 miles into San Mateo Creek.

Drainage from the four Central GSA mines flow southwest through unnamed ephemeral streams into Arroyo del Puerto (Figure 1-8).

The conceptual site-specific model produced by the Carlson Natural Regrade software indicates that the most stable hydrology for the Site and surrounding areas would consist of a single channel from the northeast flowing into Arroyo del Puerto, as shown in Figure 1-20. The channel morphology design (i.e., river pattern, longitudinal, and cross-section profiles) is related to relatively small, but frequently recurring annual flood events. The channel is shaped to keep its sediment load and stream flow in balance during these low-flow events, as well as during extreme events. The landforms depicted in the model output provide longitudinal slopes from ridgelines in a convex-to-concave design to prevent straight gradients.

The final site-specific regrading plan will update the conceptual plan by calculating all of the post-excavation and restoration requirements and provide the constructors with a cut and fill plan that best uses materials present on-site. The final grading plan will be exported to GPS-machine-controlled heavy equipment to more accurately execute the plan.

Draft Revegetation Plan

Based on the results of the site-specific natural resource evaluation (Appendix A) and the associated soil and vegetation sample analytical results, a draft revegetation plan was prepared by NV5 as part of the EE/CA (NV5, 2018). The assumed objectives considered in developing the draft revegetation plan were to re-establish grazing capacity, improve suitability for wildlife use, and develop a sustainable ecosystem. The draft revegetation plan was developed to comply with the standards of:

- NMED and NMEMNRD *Joint Guidance for Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico*, March 2016 (Attachments 1 and 2).
- New Mexico State Land Office Reclamation Plan for State Mineral Lease Rule 5 Template (7-14-15).

The draft revegetation plan details the proper times of the year for specific activities to minimize the disturbance to wildlife and to maximize the potential for plants to become established. The plan also specifies soil amendments and nutrients to prepare the soil for reseeding, the use of specific seed mixes in each unit, mulching, and watering schedules. The plan also calls for planting rooted plants and improving a stock tank as a water retention feature in Section 17. The Draft Revegetation Plan is included in Appendix F.

1.4.2.5 Comingled Contamination Investigation

The surface gamma survey identified contaminated areas in the eastern portion of Sections 29 and 32 that were not downgradient of any known uranium mines but were adjacent to the former Phillips Petroleum Uranium Mill (Figures 1-7, 1-8, and 1-11). If radioactive contamination is present from two or more different sources (i.e. mine and mill, or mines with different owners/operators), the contamination is considered “comingled.” Comingled contamination can lead to funding and liability issues if two or more PRPs are involved; consequently, a comingled contamination investigation will be necessary if the source of soil contamination in these areas is to be identified definitively as either mine or mill waste, or comingled.

During the milling process, ore is ground to particles the size of sand before extraction of uranium. After extraction, the spent ore particles (mill tailings) are stockpiled on the mill site where they are subject to dispersion by strong winds. Mill tailings have had uranium removed through extraction, but uranium decay-chain daughters, including thorium and radium, remain, and thus, uranium will not be in equilibrium with its daughter radioisotopes. Conversely, soil contaminated by uranium mining waste will generally exhibit uranium decay-chain daughter isotope concentrations in equilibrium, with the possible exception of water from de-watered mines, where certain radioisotopes such as Ra-226 might have been removed selectively via treatment/extraction techniques. When elements in a radioactive decay chain are in equilibrium, all of the elements will have nearly the same specific activity as measured in pCi/g.

By collecting soil samples and conducting an analysis that measures the specific activity of key radioisotopes in the uranium decay series, instances of disequilibrium can be found. Samples that are not in equilibrium suggest that they may represent radioactive contamination at least partly from sources other than mine waste, or from processed mine water, and are potential evidence for comingled contamination. A Draft Comingled Contamination Investigation Work Plan was developed incorporating this methodology, and is provided as Appendix G.

1.5 HUMAN HEALTH AND ECOLOGICAL STREAMLINED RISK EVALUATION

Streamlined risk evaluations were performed to evaluate the potential impacts of Site-derived contaminants on human health and the environment in the event that no cleanup action is taken. Results of the human health and ecological SRE were used to determine whether residual levels of contaminants in Site media are protective of human health and the environment and may be left in their current state, or if a cleanup action should be considered. Calculations and methodology used in performing the human health and ecological SRE are described in Appendix H.

1.5.1 Screening to Identify Contaminants of Potential Concern

Analytical results of soil samples collected during the RSE (WESTON, 2019) at the Central GSA Mines Site served as input data for the human health and ecological SRE. These samples were analyzed for radioisotopes via gamma spectroscopy, and some samples were also analyzed for TAL metals. The metals analysis was performed to assess the actual or potential risk from sub-economic or proto-ore, which was brought to surface during the mining operations but was not sent to the mill for further processing. The analytical results used in the risk evaluations are summarized in Appendix H, Tables H-1 and H-2. All of the metals sampling results were screened against the EPA (2020a) Regional Screening Levels (RSLs) (https://www.epa.gov/risk/regional-screening-levels-rsls-generic-tables), the New Mexico Environment Department (NMED, 2019) generic soil screening levels (SSLs) for residential land use, and the local background concentrations to determine the contaminants of potential concern (COPCs). Appendix H, Table H-2 summarizes the metals data screening process, showing contaminants that were considered, the minimum and maximum concentrations detected, associated RSLs, and background concentrations. It either identifies each contaminant as a COPC or explains why it was screened from consideration. Aluminum, cobalt, iron, and manganese exceeded RSLs but did not exceed background levels. While the maximum arsenic concentration (10 milligrams per kilogram [mg/kg]) exceeds the mean concentration (5.9 mg/kg), it does not exceed two times the mean background (11.8 mg/kg). Similarly, the maximum vanadium concentration (98 mg/kg) exceeds the mean concentration (71.4 mg/kg) but is less than two times the mean background (142.8 mg/kg). Arsenic and vanadium are considered to be representative of background. However, uranium was identified as a non-radionuclide human health COPC in soil because its maximum concentration exceeded its RSL and background. Uranium was evaluated further in the SRE to determine if it should be identified as a COC. The radioisotopes of the U-235 and U-238 decay chains were carried through an SRE to determine if they should be identified as COCs to be addressed in a cleanup action.

A separate screening procedure was performed in the ecological streamlined risk evaluation. The results of the screening level ecological risk characterization are included in Appendix H, Table H-4 for radionuclides and Table H-5 for metals. Literature-based ecological screening benchmark values for direct contact and food-chain evaluations are used to characterize potential ecological effects. The ecological streamlined risk evaluation is detailed in Section 1.5.3.

1.5.2 Human Health Streamlined Risk Evaluation

Cancer is the major effect of concern from radionuclides. The potential excess lifetime cancer risk on human receptors from exposure to radium in soil was assessed for the Site. The potential for non-carcinogenic adverse health effects on human receptors was also assessed for the non-radionuclide chemicals identified as COPCs in soil at the Site (i.e., uranium). Radionuclides and other chemicals in the soil may be absorbed by plants and consumed by livestock and humans. Persons working at the Site may be exposed to contaminated dust by inhalation of particulate matter. Whole body (external) radiation may be experienced by people on or near the Site itself.

Many sections of the Ambrosia Lake valley are used for grazing cattle, although some sections are not currently grazed due to the radioactive contamination in the surface soil. There are currently no residences in the former mining area of the Site, and it is unlikely that the property would be used for residential development due to the remoteness of the area. Cattle ranching is considered to remain as the future use of the Site. A rancher may be exposed to radiological contaminants through incidental ingestion of soil, external radiation from contaminants, inhalation of fugitive dusts, and meat (Site-grown beef) consumption taking into account the potential future land use of grazing and associated ranching activities.

1.5.2.1 Human Health Streamlined Risk Evaluation Assumptions

The current and future use of the Site is cattle ranching. Risk estimates were calculated based on a ranching land-use scenario for isotopes in the U-235 and U-238 decay chains (calculated from measured Ra-226 concentrations in soil). Again, the ranching land-use scenario considers routes of exposure to radioisotopes to be soil incidental ingestion, external radiation from contaminants in soil, inhalation of fugitive dust, and consumption of Site-grown beef. Note that a radon inhalation pathway for outdoor radon is not addressed (as opposed to *indoor* radon, which is) in EPA's guidance on conducting radiological risk assessments at CERCLA sites (EPA, 2014). An EPA review of radon data collected at uranium mine and mill sites in the vicinity of the Site verified that clean-air dilution of radon emissions from those sites rapidly reduces the airborne concentrations to inconsequential levels (less than the EPA recommended limit for indoor concentrations of 4 picocuries per liter [pCi/l]) (RAML, 2016).

The risk characterization considered all isotopes of the U-235 and U-238 decay chains defined by the EPA Preliminary Remediation Goal (PRG) Calculator for Radionuclides (EPA, 2019a). The human health SRE identified Ra-226 as the most significant radiological human health COPC. Ra-226 is typically selected as the radionuclide of interest at uranium mine sites for the following reasons: (1) it is found to be a significant contributor of radiological risk to human health, (2) its decay products give off strong gamma radiation that is easy and cost-effective to measure, (3) a cleanup standard is provided in the State of New Mexico's *Joint Guidance for the Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico* (NMEMNRD et al, March 2016), and (4) Ra-226 is the radionuclide for which historical cleanup limits have been specified. Since soil samples were collected from numerous sections within the Site (i.e., Sections 17, 19, 20, 29, 30, 32, and 33), risk was characterized by section. Additional human health risk assumptions and details about the SRE process are presented in Appendix H.

1.5.2.2 Human Health Risk Estimates

The PRG Calculator was used to calculate exposure route-specific PRGs for outdoor ranching activities, for ranching activities inside a truck, and for the consumption of Site-raised beef. Applying these PRGs, the sum-of-ratios approach was used to estimate human health risk by dividing the section-specific exposure point concentration (EPC) by its exposure-route-specific PRG and multiplying this ratio by 10^{-4} to calculate a cancer risk estimate. Individual cancer risk estimates are summed to represent a total cancer risk for each section. Applying maximum and average (mean) Ra-226 concentrations, risk estimates were calculated to assess the range of potential risk for a rancher potentially exposed to radionuclides in soil. EPA manages risk to achieve 10^{-6} to 10^{-4} overall excess cancer risks. As shown in Appendix H, Table H-1, the current total cancer risk for isotopes of the U-235 and U-238 decay chains for the Site equals or exceeds the 10^{-4} excess cancer risk level in all sections except subsurface soils in Sections 20, 29, and 32. The lowest risk was at $4x10^{-5}$ for Section 29 subsurface soil and the highest risk was at $3x10^{-3}$ for Section 17 surface soil. These results indicate the need for a response action to control releases and prevent radionuclide exposure. Note that these risk estimates also include contribution of background levels as calculated from the Ra-226 BTV of 1.5 pCi/g (Appendix H, Table H-1).

The RSL Calculator (EPA, 2020b) was used to develop the non-radionuclide risk estimates for the outdoor ranching activities (Appendix H, Table H-3). As shown in Table H-3, using maximum non-radionuclide chemical concentrations in soil, the total non-radionuclide hazard index was less than one. As the non-cancer hazard index for non-radionuclide COPC exposure is less than the threshold of one, adverse non-cancer health effects from exposure to uranium in soil at the Site are not likely.

1.5.3 Ecological Risk Evaluation

The Site is located in a remote area with the revegetated, previously disturbed mine area potentially providing habitat for ecological receptors. Wildlife inhabiting the Site may directly ingest radionuclides and chemicals, which may then be transported to organs or other sites within the wildlife receptors. Radionuclides and chemicals in the soil may be absorbed by plants consumed by wildlife. Radionuclides such as uranium and daughter progeny, including radium, may be inhaled on dust particles, creating alpha-particle-emitting sources in the lungs of wildlife receptors. A screening level ecological risk assessment or SLERA (i.e., Steps 1 and 2 of the EPA's 8-step ecological risk assessment process [EPA, 1997]) was performed as the ecological SRE to assess potential risk to ecological receptors from both radionuclide and non-radionuclide chemical contaminants. The results of the screening level ecological risk characterization are included in Appendix H, Table H-4 for radionuclides and Table H-5 for metals. A refinement of conservative screening level assumptions (i.e., Step 3a of the EPA's 8-step ecological risk assessment process [EPA, 2001]) was also performed to consider how the risk estimates would change if more realistic assumptions were used. The results of the refined ecological risk characterization are included in Appendix H, Tables H-6 through Table H-8. The process and conclusions are described below.

1.5.3.1 Ecological Risk-Based Screening Values

Literature-based ecological screening benchmark values for direct contact and food-chain evaluations are used to characterize potential ecological effects. The following sources were used to identify proposed ecological screening benchmark values for radionuclides and non-radionuclide chemicals:

- EPA Ecological Soil Screening Levels (Eco-SSLs) (EPA, 2019b)
- Los Alamos National Laboratory (LANL) ECORISK Database, Release 4.1 (LANL, 2017).
- USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (EPA, 2018) – Soil Screening Values for Hazardous Waste Sites (https://www.epa.gov/risk/regional-ecological-risk-assessment-era-supplemental-guidance), Table 3 Screening Level.
- New Mexico Environment Department (NMED, 2017). Risk Assessment Guidance for Site Investigations and Remediation. Volume II-Soil Screening Guidance for Ecological Risk Assessments. March 2017. Tier 1 ecological screening level (ESL).
- Sheppard, Steve C., Marsha I. Sheppard, Marie-Odile Galler, and Barb Sanipelli. 2005. Derivation of ecotoxicity thresholds for uranium, *Journal of Environmental Radioactivity*, Volume 79 (1), pages 55-83).

The Eco-SSLs include values for plant, soil invertebrate, bird, and mammal exposure to metals through direct contact and the food chain. The Eco-SSLs are based on no-effect toxicity values to (1) ensure risks are not underestimated, and (2) provide a defensible conclusion that negligible ecological risk exists, or that certain contaminants and exposure pathways can be eliminated from consideration (EPA, 1997).

The LANL ECORISK database includes ESLs for avian, mammalian, earthworm, and plant exposure models for radionuclides and non-radionuclide chemicals in soil. The LANL ECORISK database provides both no-effect and low-effect ESLs. The no-effect ESL is protective of wildlife populations and sensitive individuals because it represents an exposure that is not associated with adverse impacts of low-level, long-term chemical effects (i.e., adverse effects on ability of individuals to develop into viable organisms, search for mates, breed successfully, and produce live and equally viable offspring). The low effect ESL applies a lowest-observed adverse-effect level-based toxicity reference value that is the lowest chronic effect level and is generally considered to be protective of wildlife populations (LANL, 2017).

The NMED has developed Tier 1 ESLs protective of the plant community, deer mouse, horned lark, kit fox (evaluated at sites greater than 267 acres), pronghorn (evaluated at sites greater than 342 acres), and red-tailed hawk (evaluated at sites greater than 177 acres). The key receptors selected as the representative species symbolize the primary producers as well as the three levels of consumers (primary, secondary, and tertiary) for the most common receptors found at hazardous waste sites in New Mexico. For plants, the Tier 1 screening level is based on an effect concentration for plant communities. For wildlife receptors, the Tier 1 screening level is based on NOAEL-based toxicity reference values (NMED, 2017).

The EPA Region 4 has compiled soil ecological screening values for soil, surface water, and sediment (EPA, 2018). Soil screening values that are intended to protect plants, soils invertebrates, avian wildlife, or mammalian wildlife are reported from various sources. The Region 4 soil screening values typically address toxicity through direct exposure (e.g., toxicity to soil invertebrates such as earthworms and plants). For those chemicals that biomagnify, screening values may be back-calculated to derive screening values for avian or mammalian wildlife by considering trophic transfers from the abiotic medium to prey items.

The Sheppard et al (2005) study summarizes the literature available to set predicted no-effect concentrations (PNECs) for chemical toxicity of uranium to non-human biota. Values for terrestrial plants and other soil biota are used in this evaluation.

1.5.3.2 Ecological Risk Estimates

Screening level risk characterization was performed using the hazard quotient (HQ) method to compare maximum soil concentrations to ecological screening benchmarks. An HQ of less than one indicates that the concentration is unlikely to cause adverse ecological effects. An HQ greater than one indicates that the potential for ecological risk is present and the risk assessment process should continue (EPA, 2005). The screening process considered the isotopes of the U-235 and U-238 decay chains, though ecological screening values were not available for all isotopes. The ecological SRE indicates potential for risk to ecological receptors from Ra-226, thorium-230 (Th-230), aluminum, lead, mercury, selenium, and vanadium (Appendix H, Table H-4 for radionuclides and Table H-5 for metals). Concentrations of aluminum, lead, and mercury were below background levels (Appendix H, Table H-6), and, as a result, are not considered to be chemicals of potential ecological concern (COPEC).

A SLERA uses conservative screening-level assumptions such as 100% site use, 100% bioavailability, 100% diet consisting of the most contaminated dietary media, and no-effect toxicity data to evaluate risk to populations of upper level organisms. Under more realistic site use conditions, the potential risk to individual organisms would be reduced. The representative average soil concentration and low-effect ecological screening values were used to refine these risk estimates. The maximum surface and subsurface soil concentrations of Ra-226 exceed the low-effect ESLs for soil invertebrates and birds, indicating potential risk to these receptor groups. Maximum concentrations of aluminum, lead, and mercury do not exceed low-effect ESLs for any receptor group, indicating these metals are not considered to pose a risk to populations of higher level organisms. The maximum concentrations of selenium and vanadium exceeds low-effect ESLs for birds and, additionally, of selenium for plants and mammals (Appendix H, Table H-6). Since soil samples were collected from numerous sections within the Site (i.e., Sections 17, 19, 20, 29, 30, 32, and 33), refined risk estimates are also presented by section. The refined ecological risk evaluation indicates potential for risk to ecological receptors from exposure to Ra-226 in Sections 17, 30, and 33 (Appendix H, Table H-7); selenium in Sections 19 and 33; and vanadium in Sections 17, 19, 30, and 33 (Appendix H, Table H-8).

Ecological benchmark levels for radionuclides are higher (less stringent) than the proposed action level for protection of human health. Thus, it is anticipated that Site actions to address radionuclide exposure by human receptors will be protective for exposure of ecological receptors to both radionuclides and non-radionuclide chemicals.

1.5.4 Evaluation of Grazing of Forage by Domesticated Animals and Wildlife

EPA collected 15 vegetative metals uptake samples to determine the current vegetative nutrient values and uptake of potentially hazardous constituents available to grazing animals (domesticated animals and wildlife). Tissue samples were analyzed for nutrients (iron, zinc, copper, and manganese) and for toxic metals (molybdenum, uranium, vanadium, and selenium).

The results of the evaluation of the vegetative metals uptake samples are included in Appendix H, Table H-9, and sample locations are illustrated on Figure 1-21. Tissue concentrations were compared to maximum tolerable limits (MTLs) developed by the National Research Council's Committee on Minerals and Toxic Substances in Diets and Water for Animals (National Research Council, 2005). The MTL is defined as "the dietary level that, when fed for a defined period of time, will not impair animal health or performance." Tissue concentrations are also compared to concentrations of trace elements in mature leaf tissue that are considered sufficient or normal and excessive or toxic (Kabata-Pendias and Pendias, 1992). As shown in Appendix H, Table H-9, with the exception of iron, nutrient (iron, zinc, copper, and manganese) concentrations are less than MTLs for animals and within normal concentrations for plants. The iron concentrations ranged from 129–1,193 ppm. Iron is an essential nutrient; iron toxicity is dependent on absorption (National Research Council, 2005). The average and the maximum within the area of potential effect (APE) for molybdenum exceeded their respective MTLs for poultry and swine feed. Molybdenum toxicity is often associated with inadequate available copper; cattle show overt toxicosis when dietary molybdenum level is at 100 mg/kg or higher regardless of dietary copper or sulfur levels (National Research Council, 2005). No molybdenum concentrations in tissue exceed 100 mg/kg. The average and the maximum within the APE for selenium and iron exceeded their respective MTLs for animal feed (i.e., rodents, poultry, swine, horse, cattle, and sheep). The maximum within the APE for zinc exceeded its MTL for sheep feed.

The average molybdenum and selenium concentrations and the maximum zinc concentration in tissue samples fall between the excessive/toxic levels for plants. While selenium is a common micronutrient supplement for cattle and sheep, it can be toxic at elevated concentrations. Native selenium has been found in the sandstone formations of the GMB area (Brookins, 1982) and as an impurity, it may have been a waste metal in the uranium mine tailings. Tissue samples for uranium (toxic metals) do not exceed thresholds. Molybdenum is commonly associated with uranium in the GMB deposits (Brookins, 1982).

2.0 REMOVAL ACTION OBJECTIVES

The first step in developing removal alternatives is to establish RAOs. These objectives are typically based on anticipated land use, ARARs, and the findings of the human health and ecological SRE. General response actions are then developed to describe measures that will satisfy the RAOs. This includes estimating the areas or volumes to which the response actions may be applied.

The main objective of this removal action is to mitigate the actual or potential risks to human health and/or the environment posed by the excess radiological on-site contamination, and to the extent feasible, reclaim the entire Site for the expected future land use of livestock grazing. Removal action alternatives will address mine wastes and surface soils that were contaminated by mine wastes or mine water discharges as part of mine operations. Although the Site remains under State of New Mexico compliance orders for groundwater contamination, the removal action alternatives do not address groundwater contamination directly. The risk posed by potential contaminant migration to groundwater will be addressed by the EPA Region 6 Remedial Branch as part of a San Mateo Creek Basin groundwater investigation; proposed actions are, however, consistent with and will contribute to any contemplated future remedial actions regarding groundwater through source control by greatly reducing or eliminating the potential for contaminants to migrate from the surface to groundwater. Removal action alternatives also do not address any potential contamination from mill tailings directly, though indirect address may occur.

As previously stated in Section 1.5.2, there are currently no residences on the Site. Due to the remoteness of the area, it is unlikely that the property will be used for residential development after the radioactive contamination is removed from the soil. Many sections of the Ambrosia Lake valley are used for livestock grazing, although some sections are not currently grazed due to the radioactive contamination in the surface soil. Consequently, it is more likely that the property will continue to be used for livestock grazing rather than converted to future residential use.

2.1 STATUTORY LIMIT

Pursuant to Section 104(c)(1), CERCLA places statutory limits of 2 million dollars and 12 months on Fund-financed removal actions. The statutory limits do not apply to this action since the selected action will be funded by proceeds of a settlement from an enforcement action and not by the Fund.

2.2 REMOVAL ACTION SCOPE

The scope of the response action will be to address excess radiological contamination in surface and subsurface soils and is intended to be the final action for the soils at the Site. Options to be analyzed include response actions that would allow unrestricted/uncontrolled grazing use and associated ranching activities. Characterization of the Site identified the primary environmental concern to be radiological contamination.

2.2.1 Action Level

In June 2014, EPA issued OSWER 9285.6-20, *Radiation Risk Assessment at CERCLA Sites:Q&A* (EPA, 2014). According to this guidance, risks from radionuclide exposures at CERCLA sites should be estimated in a manner analogous to that used for chemical contaminants. The estimates of intake values for parameters associated with site-specific routes of exposure estimated for land use should be coupled with the appropriate slope factors for each radionuclide and exposure pathway. The guidance further recommends the use of EPA's on-line PRG Calculator for this assessment. When calculating radiological cleanup levels, the total incremental lifetime cancer risk attributed to radiation exposure is estimated as the sum of the risks from all radionuclides in all exposure pathways. Accordingly, the EPA used the PRG Calculator and coordinated with the national radiation expert in EPA's Office of Superfund Remediation and Technology Innovation to calculate a site-specific soil DCGL.

The DCGL is a term referenced in MARSSIM, a document prepared collaboratively by four federal agencies having authority and control over radioactive materials: EPA, NRC, DOE, and Department of Defense (DOD). The MARSSIM, published in 2000, provides a nationally consistent, consensus approach to conducting radiation surveys and investigations at potentially contaminated sites. In addition to planning, conducting, and assessing radiological surveys of surface soils and building surfaces, the document provides a decision-making process to determine if Site conditions are in compliance with dose-based or risk-based regulatory criteria. As defined by MARSSIM, the DCGL is a radionuclide-specific soil concentration determined through pathway modeling that would result in a risk equal to the release criterion above background (EPA, 2000b). EPA used a cancer morbidity risk of $1x10^{-4}$ as the release criterion *above,* or *exclusive of*, background.

Four exposure pathways were considered to develop the action level: (1) incidental ingestion of soil; (2) inhalation of soil particulates; (3) external exposure to gamma radiation in soil; and (4) Site-raised beef consumption. These four exposure pathways were considered to be the only pathways applicable for the Site, taking into account its potential future land use of cattle grazing and associated ranching activities. Note that a radon inhalation pathway for outdoor radon is not addressed (as opposed to *indoor* radon, which is) in EPA's guidance on conducting radiological risk assessments at CERCLA sites (EPA, 2014).

A combination of three land-use scenario templates in the PRG Calculator were used to develop the action level: the "Composite Worker", to model outdoor ranching activities; the "Indoor Worker", to model ranching activities inside a Truck; and the "Farmer," to model the consumption of Site-raised beef. Two cattle ranchers who operate on lands near the Site were interviewed to determine a reasonable maximum amount of time a cattle rancher might spend on this activity. Consequently, EPA used a value of 400 hours per year (1.6 hours per day [interview] for 250 days per year [PRG Calculator default value for Composite and Indoor Worker]) for annual exposure frequency. EPA used a value of 25 years for lifetime exposure duration, which is the PRG Calculator default value for a Composite Worker and Indoor Worker. Of the 1.6 hours per day spent on ranching activities, 50% (0.8 hours) were determined to be spent outdoors and the remaining 0.8 hours were determined to be spent inside a truck. This determination was made from Table 16-24 of the 2011 Exposure Factors Handbook (Time Spent in Truck/day, Western Census Region, 95th percentile, revealing a figure of approximately 50% of an 8-hour day) (EPA, 2011). A truck was estimated to provide a gamma shielding factor of 0.7 (Appendix H, Attachment 2). EPA used PRG Calculator default values representing a Composite Worker for soil ingestion and inhalation rates. PRG Calculator default values represent reasonable maximum exposure to broad-based populations, typically 90 to 95 percentile values, which are well above the mean.

EPA used PRG Calculator default values for beef consumption (165.3 grams per day) for 350 days per year. Cattle were considered to graze annually on-site 38% of the time, based on research citing that rangeland experts suggest only 25% to 50% of arid rangeland in fair to good condition should be consumed or used by livestock to leave sufficient vegetation for regeneration and wildlife use (Hurd et al, 2007). Note that in the RSE, a value of 32% was used inadvertently to represent the time cattle were considered to graze annually on Site. EPA considered that a rancher would consume 48% of beef from on-site animals, based on the percent consuming home-produced meats value for “Western households who farm” presented in Table 13-19 of EPA’s Exposure Factors Handbook (EPA, 2011). EPA used PRG Calculator Beef default values for fodder and soil intake rates. A summary table of PRG Calculator inputs and their sources is provided in Appendix I.

The radiological contaminants of concern include the entire U-238 decay chain up to, and including, thallium-206 (Tl-206), of which Ra-226 is a member, and the entire U-235 decay chain up to, and including, thallium-207 (Tl-207). It is assumed the U-238 and U-235 decay chains exist in secular equilibrium and that the U-235 concentration is 2% of the total uranium (U-238, U-235, and U-234) concentration (Argonne National Laboratory, 2007). The PRG Calculator-produced output is provided in Appendix I.

The action level established for the Site for a ranching land-use scenario is 6.1 pCi/g for Ra-226, reflecting a PRG Calculator-derived DCGL of 4.6 pCi/g above the Ra-226 BTV of 1.5 pCi/g. Note that in the RSE, the DCGL was calculated to equal 4.9 pCi/g of Ra-226; the change in value is due to the change in one exposure parameter value, described previously as the amount of time cattle were considered to graze annually on-site. The action level of 6.1 pCi/g of Ra-226 thus also reflects a concomitant change from the action level of 6.4 pCi/g of Ra-226 presented in the RSE. The action level calculations are presented in Appendix I.

Although the cumulative PRG Calculator result of 4.6 pCi/g represents the concentration of each radioisotope in the U-238 decay chain, which together represent a cancer morbidity risk of one person in 10,000 persons (commonly referred to as a $1x10^{-4}$ risk), the action level is established for Ra-226 because, (1) Ra-226 was found to be a significant contributor of radiological risk to human health (44% [Ra-226 plus short-lived daughter progeny through polonium-214]; see Appendix I for calculation); (2) the U-238 decay chain is in equilibrium, with analysis of Ra-226 (or specifically, its short-lived daughter radioisotope Bi-214), which provides a cost-effective method to determine the equilibrium concentration due to Bi-214's readily identifiable gamma ray energy signature via gamma spectroscopy; (3) a cleanup standard is provided in the State of New Mexico's *Joint Guidance for the Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico* (NMEMNRD et al, 2016); and (4) Ra-226 is the radionuclide for which historical cleanup limits have been specified. Note that when addressing contamination associated with Ra-226, contamination associated with the full U-238 and U-235 decay chains will also be addressed, as they are co-located with Ra-226.

An action level of 6.1 pCi/g represents a cancer risk of 1.3×10^{-4}, inclusive of background conditions. This risk-based action level is proposed for the following reasons:

- It is within the risk range (10^{-6} to 10^{-4} overall excess cancer risks) cited in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (40 CFR 300.430(e)(2)(i)(A)).
- It is distinguishable from background and therefore measurable in the field.
- It is above the analytical detection limit.
- It meets the standard (5.0 pCi/g of Ra-226 above the background level, averaged over the first 15 centimeters of soil below the surface, averaged over any area of 100 square meters) set forth in the State of New Mexico's *Joint Guidance for the Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico* (NMEMNRD et al, 2016).

Under a ranching land-use scenario, and at the low end of the range within which EPA manages risk (1×10^{-6}), a PRG Calculator-derived DCGL for Ra-226 equals 0.05 pCi/g. This concentration is below the analytical detection limit of 0.1 pCi/g for Ra-226.

As surface soil contamination was measured during the RSE in part via gamma scanning, a scanning-equivalent DCGL in cpm was calculated by the results of a study that was conducted to determine a correlation between field gamma readings in cpm and specific activity of Ra-226 in the soil measured in pCi/g. Sixteen correlation plots were identified, representing a range of gamma readings from approximately 13,000 to 42,000 cpm. In each 10-meter-by-10-meter plot, a walking gamma scan was conducted with the 2x2 NaI detector using 1-meter transects. Surface soil samples were collected from both the center of the plot (one grab sample) and from five aliquots throughout the plot (one composite sample). The samples were submitted to a laboratory for gamma spectroscopy analysis. Using statistical analysis, a regression line $Y = 0.000463(X) - 3.008$, where 'Y' is the Ra-226 value in pCi/g and 'X' is a gamma value in cpm, was calculated to provide an estimate of the specific activity of Ra-226 in the soil based on field gamma readings (WESTON, 2019). Using this formula, a cpm-equivalent action level of 19,728 was calculated to correlate to the action level of 6.1 pCi/g.

2.2.1.1 RESRAD Calculator

The OSWER 9285.6-20 guidance document states that although EPA recommends using the PRG Calculator to model radionuclide risk to ensure consistency with CERCLA, the NCP and EPA's Superfund guidance for remedial sites, an alternative model may be used if justification is developed (EPA, 2014). Justification should include the model runs using both the recommended EPA PRG Calculator and the alternative model. Pursuant to this goal as an independent check of PRG Calculator results, although other modeling programs are available, EPA also modeled radiological risk and calculated a soil action level using the Residual Radiation (RESRAD) On-Site 7.2 software (Argonne National Laboratory [ANL], 2016). PRG Calculator input values, including default values for all parameters across the four exposure pathways noted previously, as well as the U-238 and U-235 decay-chain COCs, were replicated in RESRAD to the maximum extent possible to comport with OSWER 9285.6-20 guidance. The same four exposure pathways considered in the PRG Calculator, described in the preceding sub-section, were duplicated in RESRAD.

The RESRAD model outcome of 10.1 pCi/g Ra-226, when added to the BTV of 1.5 pCi/g, results in an action level of 11.6 pCi/g for Ra-226. EPA policy is to use the value determined by the PRG Calculator, since the PRG Calculator was designed by EPA for the specific needs of the agency. The RESRAD output is provided in Appendix I.

2.2.2 Principal Threat Waste

The EPA *Guidance on Principal Threat and Low Level Threat Waste* recommends treatment of principal threat waste when practicable (EPA, 1991a). The guidance aligns with, and supports, the NCP, promulgated on 08 March 1990, that states that EPA expects to use 'treatment to address the principal threats posed by a site, wherever practicable (40 CFR Section 300.430(a)(1)(iii)). The expectation is derived from the mandates of CERCLA § 121 and the guidance was developed to communicate the types of remedies that the EPA generally anticipates to find appropriate for specific types of wastes. It reflects EPA's belief that certain source materials are addressed best through treatment because of technical limitations to the long-term reliability of containment technologies or the serious consequences of exposure should a release occur.

The concept of principal threat waste and low-level threat waste as developed by EPA in the NCP is to be applied on a site-specific basis when characterizing source material. Source material is defined as that which includes or contains hazardous substances, pollutants, or contaminants that act as a reservoir for migration of contamination to groundwater, to surface water or to air; or that act as a source for direct exposure. Examples of source material include drummed wastes, contaminated soil and debris, “pools” of dense non-aqueous phase liquids (NAPLs) submerged beneath groundwater or in fractured bedrock, NAPLs floating on ground water, and contaminated sediments and sludges. Principal threat wastes are, in turn, source material considered to be highly toxic or highly mobile that generally cannot be reliably contained, or would present a significant risk to human health or the environment, should exposure occur. Source material include liquids and other highly mobile materials (e.g., solvents) or materials having high concentrations of toxic compounds. No “threshold level” of toxicity/risk has been established to equate to “principal threat”; however, where toxicity and mobility of source material combine to pose a potential risk of 10^{-3} or greater, generally, treatment alternatives should be evaluated. In summary, determinations as to whether a source material is a principal or low-level threat waste should be based on the inherent toxicity as well as the consideration of the physical state of the material, the potential mobility of the wastes in the particular environmental setting, and the lability and degradation products of the material.

These determinations serve as general guidelines and do not dictate the selection of a particular remedial alternative. In fact, the preamble to the NCP (55 FR at 8703, March 8, 1990) states that there may be situations where wastes identified as constituting a principal threat may be contained rather than treated due to difficulties in treating the wastes. Specific situations that may limit the use of treatment include:

- Treatment technologies are not technically feasible or are not available within a reasonable time frame.
- The extraordinary volume of materials or complexity of the site make implementation of treatment technologies impractical.

- Implementation of a treatment-based remedy would result in greater overall risk to human health and the environment due to risks posed to workers or the surrounding community during implementation.
- Implementation of treatment would cause severe effects across environmental media.

Aside from the expectation that treatment would be used to address principal threat waste when practicable, the selection of an appropriate waste management strategy is determined solely through the remedy selection process outlined in the NCP (i.e., all remedy selection decisions are site-specific and must be based on a comparative analysis of the alternatives using the nine criteria in accordance with the NCP). Independent of the expectation, selected remedies must be protective, ARAR-compliant, and cost-effective; and must use permanent solutions or treatment to the maximum extent practicable.

For the Site, Ra-226 is not characterized as a *principal threat waste* based on the following analysis of RSE data and all the guidance document criteria.

- Three distinct, highly elevated 'hot spots' exist within the 1,299-acre removal estimate footprint; the highest average Ra-226 concentration of the three hot spots equals approximately 44 pCi/g. This represents an excess cancer-incidence risk, inclusive of background, of approximately $1x10^{-3}$. However, as discussed above, toxicity is not the sole determining factor in defining a waste material as a principal threat waste. In particular, mobility of the waste should be considered.
- There exists no highly mobile wastes at the Site. Specifically, there exists no threat of contaminant migration to groundwater or surface water at the Site.
- Contaminant mobility to air or direct exposure to the contaminant has been nullified effectively and reliably through containment technologies at numerous DOE sites with similar contaminants, specifically through repository cells with engineered caps.
- There is not a feasible treatment method for Ra-226 in soil (see Section 3.1).

For these reasons, based on the RSE data for the Site, EPA has determined that Ra-226 does not meet the criteria established in the guidance document referenced above for a *principal threat waste* on this Site.

2.3 SURFACE AREA AND VOLUME ESTIMATE OF CONTAMINATED MEDIA

The lateral and vertical extent of areas exceeding the action level were determined via gamma scanning and soil sampling, respectively, then by plotting the results geographically using ESRI's

ArcGIS ArcMap version 10.3. The lateral and vertical extent of contamination that requires corrective action is based on comparisons to the action level, (sums of 19,728 cpm [lateral extent] and 6.1 pCi/g of Ra-226 [vertical extent]). EPA employed the Inverse Distance Weighted (IDW) interpolation method to demarcate the areal extent of vertical contamination above the action level, given the nature of soil sampling providing less than 100% assessment coverage.

The total surface area exceeding the action level was established to be 1,299 acres. The total volume of soil exceeding the action level was determined to be 2,467,712 CY, consisting of a surface area of approximately 1,068 acres (924 acres of non-Section 19 area plus 144 acres of Section 19 only) at a 1-foot depth and approximately 231 acres (includes 0 acres in Section 19) at a 2-foot depth. It should be noted that although Section 19 includes parcels of land for which the EPA did not have access and therefore did not survey; the estimate of the area exceeding the action level in Section 19 includes unsurveyed parcels because they are interspersed within surveyed areas that exceeded the action level, making it reasonably likely they also would exceed the action level. The removal volume estimate for Section 19 is reported separately as it is subject to potential change as access is gained in the future and RSE activities are conducted therein. The total surface area and volume of soil exceeding the action level presented here represent a small increase from that presented in the RSE due to a change in one parameter value from that in the RSE used in the calculation of the DCGL (see Section 2.2.1). These areal and volumetric extent-of-contamination values are summarized in Table 2-1.

Table 2-1
Soil Removal Volume Estimates
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Zone	Surface Area		Volume
	Square Feet	Acres	Cubic Yards (CYs)
1-foot Depth Excavation Area (Except Section 19)	40,237,825	924	1,490,290
2-foot Depth Excavation Area (Except Section 19)	10,064,681	231	745,532
1-foot Depth Excavation Area (Section 19 Only)	6,261,025	144	231,890
2-foot Depth Excavation Area (Section 19 Only)	TBD	TBD	TBD
TOTAL	**56,563,531**	**1,299**	**2,467,712**

*TBD – To Be Determined
CYs – Cubic Yards

2.4 REMOVAL ACTION SCHEDULE

The NCP requires a public comment period of at least 30 days following release of the EE/CA report by the EPA (40 CFR 300.415(n)(4)(iii)). The EPA will respond to significant comments received during the public comment period and will publish an Action Memorandum following the response to comments. The Action Memorandum will address the threat to public health and the environment posed by the Site. The EPA will begin removal operations within 6 to 9 months of the signed memorandum. The removal start date will be contingent on multiple factors including weather, contract approval, and funding availability. The EPA will provide public notification of the schedule for this process upon issuance of the Action Memorandum.

3.0 REMOVAL ACTION ALTERNATIVES

EPA guidance for preparing EE/CAs suggests identifying and assessing a limited number of alternatives appropriate for addressing the RAOs (EPA, 1993). Removal technologies applicable to each alternative are identified and discussed with respect to their effectiveness and implementability. Technologies that were initially considered, but were screened as infeasible for technical reasons, are presented and discussed in Section 3.1. A discussion of ARARs is provided in Section 3.2. The applicable technologies are then assembled into removal alternatives in Sections 3.4 through 3.7. Based on knowledge and experience with removal actions at similar sites, the following four removal action alternatives were evaluated for the Site:

Alternative 1: No Further Action

Alternative 2: Excavation and Off-Site Disposal of Radiologically Contaminated Soils at a Licensed, Low-Level Radioactive Waste Facility

Alternative 3: Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Aboveground, On-Site Repository located within the boundary of the Central GSA

Alternative 4: Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Incised (Below-Ground), Regional Repository located within the boundary of the Tronox NAUM ALSD Site

The alternatives have been developed to mitigate potential threats by controlling human exposure to wastes with concentrations of Ra-226 above the action level. These alternatives were also developed based on federal guidance as described in Section 3.2. Sections 4.0 and 5.0 evaluate the alternatives individually and comparatively using the criteria established by EPA. Figure 2-1 illustrates the excavation areas and presents the volumes of contaminated soil (also see Table 2-1 for removal volume estimates) that would be transferred off-site for Alternative 2, or would be relocated to an on-site or ALSD regional repository for Alternatives 3 and 4, respectively. Several other alternatives were considered but ruled out as not viable, as described below in Section 3.1.

The conceptual design assumptions used for each alternative are discussed in the following sections. As described in Section 2.3, the area and depth estimates used to calculate the removal action volumes were determined through Arc-GIS analysis based on plotting in situ gamma scanning measurements and soil sampling data. As additional Site data are obtained, it is anticipated that the volume estimate would be refined. However, EPA considers the volume estimates summarized in Table 2-1 and Figure 2-1 to be sufficiently accurate for the purposes of comparing costs and conceptual designs in this EE/CA.

3.1 ALTERNATIVES SCREENED FROM CONSIDERATION

The process of identifying and evaluating alternatives to meet the RAOs began with an initial screening of alternatives to determine if any were considered to be technically or administratively infeasible. The following alternatives were screened from consideration during the prescreening process for the East GSA EE/CA (TDD 0001/17-040) (WESTON, 2020), which also apply to this Site. See Section 3.1 of the East GSA EE/CA for a detailed discussion and reasoning for screening the following alternatives from consideration:

- Institutional Controls
- Vegetative Extraction (Phytoremediation)
- Soil Washing
- Soil Sorting

Restricting residential activities for future land use is not warranted as an institutional control because RAML has placed voluntary deed restrictions that would prevent any residential activities on the Site.

One additional alternative was screened from consideration for the Site.

- Capping of Contaminated Soils in Place – EPA, per discussion with project stakeholders, determined that consideration of a Capping of Contaminated Soils in Place removal action alternative for the Site is similar enough to Alternative 3 — Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Aboveground, On-Site Repository, as to be redundant. Moreover, based on costs presented in the Tronox NAUM, East GSA Mines Site EE/CA (TDD No. 0001/17-040) for a similar Capping of Contaminated Soils in Place alternative as compared to costs for an aboveground on-site repository, EPA determined that a Capping of Contaminated Soils in Place alternative for the Site would be, prima facie, less cost-effective than Alternative 3.

3.2 APPLICABLE or Relevant and Appropriate Requirements (ARARs)

This EE/CA was developed following the basic methodology outlined in 40 CFR §300.415 and further discussed in the EE/CA guidance (EPA, 1993). Section 121(d) of CERCLA requires that response actions comply with state and federal ARARs unless a waiver is justified. ARARs are used to assist in determining the appropriate extent of site cleanup, to scope and formulate removal action alternatives, and to govern the implementation of a selected response action (EPA, 1988 and 1989). The following sections provide a definition of ARARs and describe the ARARs that are specific to the Site.

3.2.1 Terms and Definitions

The NCP provides that response actions must attain ARARs to the extent practicable, considering the exigencies of the situation (40 CFR 300.415(j)). As discussed in the EPA *Guidance on the Consideration of ARARs during Removal Actions* (EPA, 1991b), NTCRAs will generally, where practicable, allow for greater compliance with ARARs than time-critical removal actions (TCRAs).

In the course of conducting the EE/CA for the Site, ARARs and other “to be considered” (TBC) criteria were identified from policy or guidance documents that may be pertinent to evaluating and implementing removal options. ARARs and TBC criteria are defined as follows:

- Applicable Requirements are cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental laws that specifically address a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site.
- Relevant and Appropriate Requirements are cleanup standards, standards of control, and other substantive requirements, criteria, or limitations promulgated under federal or state environmental laws that, while not "applicable" to a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance at a CERCLA site, address problems or situations sufficiently similar to those encountered at the CERCLA site and are well suited to the particular site.
- TBC Criteria consist of advisories, criteria, or guidance that were developed by EPA, other federal agencies, or states that may be useful in developing CERCLA remedies, and include non-promulgated guidance or advisories that are not legally binding and that do not have the status of potential ARARs. TBCs generally fall within three categories: health effects

information with a high degree of credibility, technical information on how to perform or evaluate site investigations or response actions, and policy.

The EPA has divided ARARs into three categories: chemical-specific, location-specific, and action-specific. The three categories are described below:

- Chemical-Specific ARARs are usually health- or risk-based numerical values or methodologies that, when applied to site-specific conditions, result in the establishment of numerical values. These values establish the acceptable amount or concentration of a chemical that may be found in, or discharged to, the ambient environment.
- Location-Specific ARARs apply to the geographical or physical location of the site. These requirements limit where and how the removal action can occur.
- Action-Specific ARARs include performance, design, or other controls on the specific activities to be performed as part of the removal action for a site.

ARARs and TBC criteria for the Site, along with a brief description of each, are provided in Tables 3-1, 3-2, and 3-3, respectively.

3.2.2 Other Considerations and Assumptions

The following additional considerations and assumptions were made during the ARAR identification process.

3.2.2.1 Occupational Safety and Health Administration

The Occupational Safety and Health Administration (OSHA) has promulgated standards for the protection of workers who may be exposed to hazardous substances at Resource Conservation and Recovery Act (RCRA) or CERCLA sites (29 CFR Parts 1910.120 and 1926.65). EPA requires compliance with OSHA standards in the NCP (40 CFR 300.150), but not through the ARAR process. Therefore, OSHA standards are not considered ARARs. Since the requirements, standards, and regulations of OSHA are not ARARs and cannot be waived, they will be complied with during the removal action.

3.2.2.2 Uranium Mill Tailings Radiation Control Act

The Uranium Mill Tailings Radiation Control Act (UMTRCA) programs are categorized under Title I and Title II. Title I addresses specific inactive uranium processing sites, and Title II addresses active sites that are required to have a license from the NRC. Under UMTRCA, EPA was directed to devise standards for both the control and cleanup of excess radiation from uranium mill tailings. The mines located in the Site are not a listed site under Title I of UMTRCA, nor would waste from the Site be classified under Title II. However, UMTRCA requirements may be TBCs under certain circumstances, as reflected in Table 3-1.

3.2.2.3 Multi-Agency Radiation Survey and Site Investigation Manual

The activities of this removal action shall be conducted in a manner consistent with MARSSIM specifications to facilitate implementation of a final status survey at the completion of removal activities. MARSSIM is guidance, not a promulgated standard, and thus is not an ARAR, though it may be applied as a TBC.

For the purposes of the final status survey, the DCGL referenced in MARSSIM will be equivalent to 4.6 pCi/g of Ra-226, a value equivalent to the PRG Calculator result (see section 2.2.1). The DCGL is a radionuclide-specific soil concentration that would result in a risk equal to the release criterion (i.e., 4.6 pCi/g above background). If radioactivity is relatively evenly distributed over a large area, MARSSIM considers the average concentration over the entire area (termed $DCGL_W$; meaning DCGL for a "wide area") (EPA, 2000b). Thus, more specifically, the $DCGL_W$ will be equivalent to 4.6 pCi/g of Ra-226.

Concentrations greater than the $DCGL_W$ are allowed provided that the average concentration over the survey area is less than the $DCGL_W$. The MARSSIM approach allows for calculation of a higher DCGL, for small areas of concentrated radioactivity within the "wide area," based upon "area weighting factors." This value is termed the $DCGL_{emc}$ ('emc' represents the elevated measurement comparison). The $DCGL_{emc}$ is typically a multiple of the $DCGL_W$ and will differ depending on the distance between sample points collected during the MARSSIM final status survey (survey method used to determine whether release criterion is achieved) in each survey unit. This approach accounts for the fact that the resident will receive a greater dose from a smaller area of contaminated soil than from the more homogenously contaminated "wide area," but because the $DCGL_{emc}$ is not exceeded, the average dose to a receptor is still in compliance with the release criterion, assuming the survey unit passes an appropriate statistical test. Calculations of $DCGL_{emc}$ values will be calculated post-remediation as part of final status surveys.

3.3 ENGINEERING AND LOGISTICAL CONCERNS APPLICABLE TO MOST ALTERNATIVES

Alternatives 2 through 4 each require the following common components and activities:

- Plans and submittals
- Mobilization and site setup
- Clearing and grubbing
- Site security and access controls
- Road and haul route improvements
- Road and haul route maintenance
- On-site traffic control
- Air monitoring and dust control
- Stormwater management, erosion control, and maintenance
- Site reclamation

The costs for these common activities are included in the estimated cost for each alternative (Appendix J).

3.3.1 Plans and Submittals

Prior to mobilization activities, construction plans, drawings, and specifications would need to be prepared for Alternatives 2 through 4. Work Plans, construction drawings, and specifications will consider information presented in the Natural Resources Evaluation Report (Appendix A) and Cultural Resource Survey as well as recommendations or requirements from the New Mexico SHPO, New Mexico SLO, or tribal consultation.

A Removal Action Work Plan would be required and would include a Health and Safety Plan (HASP), Environmental Protection Plan, Quality Assurance Project Plan, Field Sampling/Monitoring Plan, Site Access and Security Plan, Traffic Control Plan, Stormwater Management and Erosion Control Plan, Cultural Resource Protection Plan, Dust Control Plan, and Final Status Survey Plan.

The design process will also require an evaluation of the potential environmental footprint of the project, prepared in accordance with the EPA guidance document *Methodology for Understanding and Reducing a Project's Environmental Footprint* (EPA, 2012) and the *ASTM International Standard Guide for Greener Cleanups, E2983-16e1* (ASTM 2016).

3.3.2 Mobilization and Site Setup

An RSE has been completed to delineate the areas to be excavated. Temporary on-site facilities for project management and project controls would be mobilized to the Site for the duration of the project. Temporary on-site facilities would be constructed for decontamination of personnel and equipment (e.g., tools, salvageable equipment, passenger vehicles, and heavy equipment). Aboveground electrical lines and active water lines cross the Site. A subsurface utility survey would be necessary to identify and/or verify the location of buried utilities. Areas scheduled for utility surveys would include excavation, borrow and transfer areas, heavy equipment traversing paths, areas slated for drainage way improvements, and areas where material may be stockpiled.

To prepare the Site for implementation of Alternatives 2 through 4, the ecological and cultural resource surveys of both the Site and the proposed repository area would be reviewed prior to mobilization. If necessary, additional surveys would be performed by EPA-approved biologists or archeologists. Based on the information gathered in the completed survey, and for the purposes of this EE/CA, and consistent with other CERCLA actions taken in this area, it is assumed that cultural resources can be avoided or protected during Site work activities.

As stated in Section 1.2.10, three threatened bird species may possibly be present on the Site: peregrine falcon, golden eagle, and gray vireo. If vegetation clearing during a removal action is completed prior to the onset of the general migratory bird nesting season (March 15 to September 30), individuals and nests would not be directly impacted. However, potential indirect impacts associated with noise and activity during construction might be unavoidable once excavation and subsequent revegetation actions begin if the species is nesting within approximately 0.25 mile of the Site. It is recommended that species-specific surveys for gray vireo be conducted (male territorial calls played at intervals) during the nesting season (May 15 to September 30) prior to any planned fall/winter clearing to determine whether the species is nesting in the immediate area.

3.3.3 Site Security and Access Control

Security would be maintained during all non-working hours during the removal action. The Site Manager and the Health and Safety Officer would be responsible for personnel while they are on the Site. To restrict access, the Site would remain completely fenced throughout the duration of construction activities using Alternatives 2 through 4, along with appropriate signage designating potential hazards, and contacts to obtain additional information. Temporary fencing would be used when the permanent fence must be removed for construction access. Alternate entrances that may be required for portions of the work would be secured when not in use. If work is occurring at the Site and the repository simultaneously, then security would need to be maintained at both locations.

The EPA and its authorized representatives, including its contractors, would have access to the Site at all times. A Site Access and Security Plan would describe the activities used to monitor and control access to the Site during implementation of the response actions using Alternatives 2 through 4 and the periods of work performance.

3.3.4 Road and Haul Route Improvements

Currently, there is a basic network of roads present on the Site that was used for mining and/or mining related operations in the past. Prior to any work occurring, the current road network will be evaluated to determine its feasibility for use in its current condition for Alternatives 2 through 4. Appropriate improvements will be made to the existing road network, if necessary, to sustain the anticipated removal activities on the Site.

All roads for long-term use during the removal action will have appropriately sized gravel surfacing, which would need to be maintained for the duration of the removal action. Without surfacing, many of the Site roads would become unusable during precipitation events due to the high clay content of the soils composing those roads.

3.3.5 Road and Haul Route Maintenance

The Alternatives being considered, Alternatives 2, 3, and 4, require an extensive amount of haul traffic both on-site and off-site, over several years, to achieve completion. During transport, traffic controls would be necessary for on-site and off-site haulage. A Traffic Control Plan will be developed and followed throughout the removal action operations.

It is possible that rail transportation may be an alternative for off-site disposal of the waste at a licensed, low-level radioactive waste facility (Alternative 2); however, the cost estimate in this report assumed truck transport of the waste materials to an approved disposal facility. Table 3-4 presents cost estimates of different transportation options at these facilities.

Off-road haul routes would be maintained so that dust, debris, or mud are not created, and so that these items are not tracked onto paved surfaces. Earthen haul routes would be shaped or otherwise improved so that they are free draining and would not easily erode. Signs and barriers would be provided, if necessary, to contain traffic along the designated routes.

3.3.6 Air Monitoring and Dust Control

As part of the Site Sampling and Analysis Plan, specific methods and procedures would be included for air quality monitoring, and for collecting, analyzing, and evaluating air samples within and at the perimeter of work zones as described for Alternatives 2, 3, and 4. Prior to commencing dust generating activities in the contaminated excavation areas, perimeter work zone samples would be collected to establish background alpha and beta activity concentrations in ambient air. The background air samples would be used to establish the COPC activity concentrations that are naturally occurring in the air and are unrelated to the removal activities occurring at the Site. Perimeter and work zone air monitoring stations would be positioned and operated to monitor emissions during grubbing, excavation, stockpiling, loading of bulk-carriers, stockpile management, and Site reclamation.

The Dust Control Plan, referenced in Section 3.3.1, will detail how air monitoring results and dust suppression measures would be implemented to document that potential off-site migration of contaminants at unacceptable radiological activity concentrations does not occur; to maintain compliant air quality conditions and a safe working environment; and to protect the health of workers, the general public, and the environment during removal operations under Alternatives 2, 3, and 4. Dust controls would also be used to minimize fugitive dust generated from soil imported from off-site borrow sources. Perimeter air monitoring would be performed during earthmoving activities associated with Site reclamation. Frequent water or water/tackifier solution spraying would be used during soil moving activities at the Site and during construction and waste placement work at the repository, if selected. Appropriate Stop Work protocols will be incorporated in the Dust Control Plan for seasonal high-wind events when dust suppression using watering or a water/tackifier solution is ineffective.

Water for dust suppression is locally available from existing water rights for an on-site source that was used and maintained by RAML during the construction activities associated with the closure of the RAML mill. Prior to initiation of any removal construction activities on the Site, EPA will collect water samples from the on-site source to verify the current quality of the water for the purposes of the various removal construction and reclamation activities. It is assumed that the available source of groundwater will require some form of treatment to remove excess radionuclides, excess metals, and/or other particulate matter requiring an on-site water treatment and storage facility. For costing purposes, it was assumed that a 200-gpm treatment system housed in an on-site structure to prevent freezing during cold weather events during the removal process, along with twenty 20,000-gallon storage tanks, would provide sufficient treatment and storage of water for the duration of the removal action. Management and disposal of treatment system by-products is included in cost estimations for this alternative. To reduce the size and cost of the treatment system, it is assumed the various tasks of the removal action will be evaluated for the use of treated water as a critical or non-critical component of the removal action. An example of treated water as a critical component is irrigation for revegetation, while treated water is not a critical component to construct the on-site repository.

3.3.7 Stormwater Management, Erosion Control, and Maintenance

As described above, the Site is located in an arid to semi-arid area of New Mexico. While thunderstorms and significant moisture events are generally confined to the monsoon season, significant snow events can occur, along with flash flooding events. Stormwater management and erosion control are of significant concern based on the size and the extent of the excavation activities associated with Alternatives 2, 3, and 4 of this removal action. As referenced in Section 3.3.1, a Stormwater Management and Erosion Control Plan will be prepared to address stormwater management and erosion control procedures during the duration of the removal activities on the Site.

Excavated areas would be graded and re-contoured to reduce overland and low-energy-concentrated flow rates and patterns as per the Carlson Natural Regrade conceptual model discussed in Section 1.4.2.4 The natural regrading design integrates the post-removal reclaimed area topography and existing drainage patterns to facilitate the development of a stable land surface for the development of a viable post removal ecosystem. All removal-related activities at the Site must be evaluated for potential impacts on federally-listed species and critical habitat for certification to meet the substantive requirements of the Notice of Intent, under the National Pollutant Discharge Elimination System (NPDES) Multi-Sector General Permit. Once the Site has been stabilized, monitoring of construction stormwater runoff would cease and post-removal Site controls would be initiated. The cost estimates include provisions for ongoing cover maintenance, and fence inspection and repair at the final repository for Alternatives 3 and 4.

3.3.8 Site Reclamation

Prior to initiation of reclamation activities, topographical and meteorological data for the Site would be entered into the Carlson Natural Regrade modeling software to produce a conceptual plan for reclamation. The plan would strive to return the topography of the Site to pre-mining conditions, which would provide a stable land surface, reduced erosion effects, and a sustainable ecosystem. The plan would also provide strategies for using on-site fill materials to reduce costs associated with importing backfill. The outputs from the plan would be available for review by stakeholders prior to commencement of activities.

Grading where excavation of mine or mine-related waste materials has occurred during implementation of Alternatives 2 through 4 would be performed with the objective of mitigating erosion by contouring slopes to 4H:1V or flatter. Contouring the Site would include cutting soil from adjacent areas and filling the excavations to blend with the existing terrain, and to restore stable drainage conditions. Although some on-site, clean backfill soil may be imported for re-contouring the terrain, it is assumed that balanced cut and fill soil can be obtained from the area immediately surrounding the excavation areas. The material would be compacted and in-place soil density and moisture testing would be performed to achieve a minimum of 85% relative compaction.

Revegetation of excavated, contaminated areas would be completed to reduce erosion potential by applying an approved seed mix with the objective of improving grazing suitability and wildlife habitat. Areas to be revegetated will require tilling and soil amendments following re-contouring efforts. As summarized in Section 1.4.2.4, a draft revegetation plan was developed for the Site. The Draft Revegetation Plan is included in Appendix F.

Vegetation establishment would help to minimize erosion and increase the durability of the excavation fill and final cover of the repository. Vegetation should attempt to emulate the local ecological conditions, including structure, function, diversity, and dynamics of native plant communities in the area. Diverse mixtures of native and naturalized plants would maximize water usage efficiency and remain more resilient given variable and unpredictable changes in the environment resulting from pathogen and pest outbreaks, disturbances (e.g., grazing, fire), and climatic fluctuations. Therefore, the revegetation plan for the excavation fill and repository cover would include species that are sustainable, once established, under typical climate and resource-use patterns.

3.4 ALTERNATIVE 1: NO FURTHER ACTION

Under Alternative 1, no new treatment, containment, or removal action would occur at the Central GSA Mines Site. The no further action alternative has been included as a requirement of the NCP and to provide a basis for the comparison of the remaining alternatives.

3.4.1 Site Work Activities

This alternative would include no new Site work activities. Impacted materials would be left in place. The current Site conditions such as slope, surface treatment, and aspect that have been graded would not be modified. Since the current Site conditions do not provide a radon or gamma radiation barrier, future Site visitors may be exposed to radiation hazards. The potential for contact with eroded radioactive material, or exposure to fugitive dust, may also occur due to a lack of stabilization measures.

3.4.2 Post-Excavation and Site Reclamation Activities

Since there would be no new work activities at the Site under this alternative, there would be no Site reclamation.

3.4.3 Site Controls and Security

The public and livestock are currently restricted access to the Central GSA Mines Site by barbed wire fencing. However, the fence can be easily damaged or bypassed, presenting a potential exposure to gamma radiation, fugitive dust, and radon emissions for unauthorized personnel and livestock.

3.4.4 Stormwater and Erosion Control

No new stormwater or erosion control activities would be implemented under Alternative 1.

3.4.5 Operation and Maintenance Activities

The Site would require operation and maintenance (O&M) to ensure that the current level of protectiveness provided by the existing fencing is maintained. Existing stormwater and erosion controls would be maintained as necessary.

3.5 ALTERNATIVE 2: EXCAVATION AND OFF-SITE DISPOSAL OF RADIOLOGICALLY CONTAMINATED SOILS AT A LICENSED, LOW-LEVEL RADIOACTIVE WASTE FACILITY

Alternative 2 assumes that contaminated soils with concentrations greater than the action level of 6.1 pCi/g for Ra-226 would be excavated and disposed of off-site at a licensed disposal facility permitted to receive the waste, or at a processing mill that would reprocess and then dispose of the soil.

The following three licensed disposal facilities within the Western United States are authorized to accept low-level radioactive waste and/or naturally occurring low-level radioactive soil with Ra-226 concentrations ranging from 2 pCi/g to approximately 500 pCi/g:

- Clean Harbors, Deer Trail, Colorado (545 miles one way from the Site [one way])
- U.S. Ecology, Beatty, Nevada (605 miles one way)
- U.S. Ecology, Grand View, Idaho (830 miles one way)

The Clean Harbors facility in Colorado was chosen as the basis of the cost estimate given its closest proximity to the Site.

Disposal pricing from December 2019 was used (See Table 3-4) to develop the detailed cost estimates included in Appendix J. The estimates assume a disposal fee of $75.00 per ton at the Clean Harbors facility. Transportation costs were estimated separately based on the expected fleet of trucks and transportation distance.

3.5.1 Off-Site Rule

Alternative 2 would require compliance with the Off-Site Rule of CERCLA. In general, the Off-Site Rule requires facilities that accept contaminated or hazardous wastes from a CERCLA site to be in compliance with all applicable regulations and laws (i.e., they must be approved by and be in compliance with the applicable federal, state, and local requirements to receive wastes). A licensed disposal facility for Alternative 2 would have existing approval under the Off-Site Rule.

3.5.2 Site Work Activities

The initial Site removal work includes clearing and grubbing to remove vegetation and debris. Stormwater controls would be implemented during these activities and continued throughout the excavation and backfill processes. Contaminated soil would be excavated by a combination of heavy equipment, including scrapers, bulldozers, graders, excavators, front-end loaders, and haul trucks. Contaminated soil would be loaded onto haul trucks for transport directly to the final disposal facility.

Transportation by rail or a combination of trucking and rail is an option but was not considered for the EE/CA since the disposal fee would be a much more significant portion of the total cost. Waste material would need to be trucked from the Site to a rail line approximately 20 miles south of the Site in Milan, New Mexico, where a transfer station would need to be established. The waste material could then be loaded to rail cars and shipped to the selected disposal facility.

Contaminated areas of the Central GSA Mines Site in Sections 17, 19, 20, 29, 30, 32, and 33 of township and range 14N-9W (as shown in Figure 2-1) would be excavated and removed. The on-site construction, including excavation, trucking, and reclamation activities, are estimated to take approximately 2 years and 3 months, assuming a year-round construction season. Planning is expected to take an additional 8 months before construction mobilization, for a total time of approximately 2 years and 11 months before completion.

Waste loading and transportation would occur continuously throughout the course of the removal action with five soil-loading crews and 335 highway-rated haul trucks (20 tons per load) loaded per day. Approximately 148,100 truckloads over 442 days would be required to transport the waste material from the Site to the disposal facility. Traffic controls would be in place to maintain safe driving conditions for equipment and vehicles entering and leaving the Site.

3.5.3 Post-Excavation and Site Reclamation Activities

Concurrent with the excavation activities, confirmation testing of the bottom and side soils in each excavated area would help determine the remaining vertical and lateral extent of contamination. Excavation would continue until the action level is met.

After the mine and mine-related waste is removed from the Central GSA Mines Site, the area would be reclaimed for livestock grazing and wildlife habitat. Clean fill soil would be cut from the adjacent area and used to fill the excavated area (see Section 3.3.8). Disturbed areas, including the filled-in excavation, would be contoured to blend grades into the existing terrain and graded to promote positive drainage. Soil amendments would be tilled into the soil to serve as growing media. Revegetation efforts would follow the final Revegetation Plan developed from the draft Revegetation Plan (Appendix F) and modified for final post-removal conditions. Progressive revegetation would occur for disturbed and reclaimed areas after completion of removal activities in each removal unit.

3.5.4 Site Controls and Security

During the Alternative 2 removal and reclamation activities, Site access would be restricted by a newly installed perimeter fencing to prevent domestic livestock from entering the Site until reclaimed. Once vegetation is re-established and the Site has stabilized, perimeter fencing may be removed. Reclamation activities may take 5 years or more before adequate vegetation is re-established in place and final stabilization is achieved.

3.5.5 Stormwater and Erosion Control

Stormwater management and erosion control are of significant concern based on the size and the extent of the excavation activities associated with Alternative 2. As referenced in Sections 3.3.1

and 3.3.7, a Stormwater Management and Erosion Control Plan would be prepared to address stormwater management and erosion control procedures during the duration of the removal activities on the Site. Modeling using Carlson Natural Regrade would be conducted to develop a reclamation plan that would return the Site to a sustainable topography with natural features to reduce the risk of erosion.

Excavated areas would be graded and re-contoured to reduce overland and low-energy concentrated flow rates and patterns as per the Carlson Natural Regrade conceptual model (see Section 3.3.8). The natural regrading design integrates the post-removal, reclaimed-area topography and existing drainage patterns to facilitate the development of a stable land surface for the development of a viable post-removal ecosystem. All removal related activities at the Site must be evaluated for potential impacts on federally-listed species and critical habitat for certification to meet the substantive requirements of the Notice of Intent, under the NPDES Multi-Sector General Permit. Once the Site has been stabilized, monitoring of construction stormwater runoff would cease and post-removal Site controls would be initiated.

3.5.6 Operation and Maintenance Activities

Operation and maintenance of the Site during the removal and reclamation activities would be the responsibility of the EPA. After completion of reclamation activities, O&M would be conveyed to RAML at a date to be determined. RAML is expected to inspect and maintain stormwater and erosion control features for perpetuity. Monitoring and maintenance of revegetation efforts would occur for an estimated 12 years following revegetation (Appendix F).

3.6 ALTERNATIVE 3: EXCAVATION, CONSOLIDATION, AND LONG-TERM Management of Radiologically Contaminated Soils at an aboveground, On-site Repository

In Alternative 3, contaminated mine and mine-related wastes greater than the action level of 6.1 pCi/g of Ra-226 would be excavated, transported, and consolidated into a non-commercial, newly created repository located on the Site. EPA evaluated several locations within the Site and the associated ALSD for a suitable on-site repository. Repository siting criteria considered included suitable ownership; suitable geology (alluvium over Mancos Shale of sufficient thickness) verified by on-site geotechnical borings; sufficient acreage to house the repository; and no historical, underground mining activity.

3.6.1 Engineering Design

Alternative 3 would implement an engineered cover placed over consolidated waste soil as part of the removal solution. The conceptual model used for the capping options included in the cost analysis for this alternative is described below. Appendix L illustrates the final grading plan of the preliminary design of an approximately 2.47-million-CY, 62-acre repository.

Regarding the remediation of mine wastes, Title I UMTRCA standards (Subpart A of 40 CFR 192(d)), which are TBCs, offer the following guidance. Remediation should:

- Be designed to be effective for up to 1,000 years to the extent reasonably achievable, but at a minimum for up to 200 years.
- Provide reasonable assurance that releases of radon-222 will not exceed an average release rate of 20 picocuries per square meter per second (pCi/m^2-s).

Several critical factors were considered in designing a cover. These design elements are discussed briefly below and assumptions are made to prepare the cost analysis for the alternative. These assumptions may change upon further investigation of the Site. Ultimately, the containment design would be based on comprehensive planning and Site-specific risk analysis.

- **Longevity of the Cover –** The engineered cover would be designed to be effective for up to 1,000 years to the extent reasonably achievable, but at a minimum for up to 200 years; this lifespan is highly dependent upon continuing maintenance of the cover and would require long-term monitoring. The net present value (NPV) for the long-term inspections and maintenance of the cover for 100 years is included in the cost estimate.
- **Protection from Radon Emanation** – The final cover thickness for Alternative 3 would be determined based on NRC guidance and by using Regulatory Guide 3.64, Calculation of Radon Flux Attenuation by Earthen Uranium Mill Tailings Covers (NRC, 1989). Preliminary calculations were performed for this report following State of New Mexico Guidance limiting the release rate of radon-222 through the cover to 20 pCi/m^2-s, which resulted in a cover thickness of 0 feet (Appendix K).
- **Water Infiltration –** The cover must protect the contaminated soils and reduce leachate development by minimizing the infiltration of water from precipitation. The cover design would incorporate drainage features and use evapotranspiration to limit water infiltration.

- **Erosion Control –** Cover shaping, sloping, and proper drainage patterns are also important to ensure stability of the final consolidated material. The current area has had problems with erosion of cover soils. For this reason, the cost estimates presented for this alternative use a maximum 20H:1V slope ratio and incorporate drainage features. Water diversion, velocity breaks, rock intermixed with the surface layer, and placement of rip rap or other protective lining in concentrated flow areas are expected to be the most effective surficial erosion mitigation measures. The repository would be positioned at a sufficient distance from any surface water features to be protective of surface waters. Similarly, information obtained during the ecological and cultural resource surveys would be considered in the repository location placement.
- **Cover Design –** The cost estimate assumes an evapotranspiration type of cover system composed of a three-foot-thick evapotranspiration cover. The cover would be comprised of a 30-inch-thick layer of native or borrow soil material and overlain by a 6-inch-thick erosion protection layer of soil. The erosion control layer would be composed of both rock and organic material to promote revegetation and control erosion.

  Although the final design may vary, the major cost factors—thickness of cover and source of material—would likely not be significantly different from the cost estimate assumptions. Final design parameters for the consolidation repository would be determined by EPA in consultation with the State of New Mexico and other key stakeholders, as necessary. All engineering and design parameters for the proposed repository are consistent with the *Joint Guidance for the Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico* (NMEMNRD, et al, 2016).

3.6.2 Site Work Activities

The initial Central GSA Mines Site removal work includes clearing and grubbing that involves removal of vegetation and organic debris within the excavation and repository areas. Stormwater controls would be implemented during these activities and continued throughout the excavation and Site reclamation processes. Contaminated soil would be excavated by using heavy equipment such as scrapers, bulldozers, graders, excavators, front-end loaders, and haul trucks. Contaminated soil would be transported by scrapers for short distances (less than 5,000 feet) or loaded onto haul trucks at the Site for transport directly to the repository. As described for Alternative 2, excavation and removal would include impacted areas in Sections 17, 19, 20, 29, 30, 32, and 33 of township and range 14N-9W (as shown in Figure 2-1).

During the course of the removal action, it is estimated that approximately 68% of waste (1,678,000 CY) would be transported by scrapers a short distance (less than 5000 feet) to the on-site repository. At a daily production rate of 5,100 CY, transportation of waste via scrapers will take 329 days. The remaining 32% of waste (947,600 CY) would be transported by 34-CY-capacity off-road haul trucks from the farther excavation areas to the repository site over a span of 124 days. The largest equipment that can reasonably be used on-site, with efficient travel times, and that would cause minimal damage to access routes, should be considered to maximize efficiency. Under Alternative 3, the majority of traffic would use the existing and upgraded section of roads to move the waste soil to the proposed repository Site. The preferred route would be developed in consultation with RAML during the design phase.

The on-site excavation and trucking activities are estimated to take approximately 2 years and 9 months (assuming a year-round construction season), with planning expected to take an additional 12 months before construction mobilization, for a total implementation time of approximately 3 years and 9 months before completion.

3.6.3 Post-Excavation and Site Reclamation Activities

Site reclamation activities are consistent between Alternative 3 and those described for Alternative 2 in Section 3.5.3.

3.6.4 Site Controls and Security

During the Alternative 3 removal and reclamation activities, Site access would be restricted by perimeter fencing. Domestic livestock would not be allowed to enter the Site until reclamation activities have been completed. Once vegetation is re-established and the Site has stabilized, perimeter fencing may be removed. Reclamation activities may take 5 years or more before adequate vegetation has been re-established and final stabilization is achieved. In regard to future land use controls, RAML has placed voluntary deed restrictions that would prevent any residential activities on the Site.

3.6.5 Stormwater and Erosion Control

As with Alternative 2, stormwater management and erosion control are of significant concern based on the size and the extent of the excavation activities associated with Alternative 3. Controls for Alternative 3 would be consistent with those previously described for Alternative 2 (Section 3.5.5).

3.6.6 Operation and Maintenance Activities

Operation and maintenance of the Site during the removal and reclamation activities would be the responsibility of EPA. After completion of reclamation activities, O&M would be conveyed to RAML at a date to be determined. RAML is expected to inspect and maintain stormwater and erosion control features for perpetuity. Monitoring and maintenance of revegetation efforts would occur for an estimated 12 years following revegetation (Appendix F). The repository grades/slopes, cover condition, cover vegetation, erosion control measures, access roads, fencing, and other Site O&M would require more frequent inspections and a higher level of scrutiny than the other reclaimed and revegetated areas of the Central GSA Mines Site. The cover would be inspected for differential settling, erosional rilling and gullying, wildlife damage, unauthorized access, and revegetation success. Repairs and maintenance would be completed accordingly.

3.7 ALTERNATIVE 4: EXCAVATION, CONSOLIDATION, AND LONG-TERM MANAGEMENT OF RADIOLOGICALLY CONTAMINATED SOILS AT AN INCISED (BELOWGROUND), TRONOX NAUM ALSD REGIONAL REPOSITORY

As with Alternative 3, Alternative 4 contaminated mine and mine-related wastes greater than the action level of 6.1 pCi/g of Ra-226 would be excavated, transported, and consolidated into a non-commercial, newly created repository. For Alternative 4, however, the repository would be the Tronox NAUM ALSD Regional Repository. Similar removal action alternatives are included in the Tronox NAUM, East and West GSA EE/CA reports (TDD Nos. 0001/17-040 and 0001/17-036, respectively); as such, the ALSD Regional Repository is conceptualized to accept contaminated radioactive soils from, at a minimum, the three current GSAs that partially comprise the Tronox NAUM sites in the ALSD (East, West, and Central GSA Mines sites). The ALSD Regional Repository, although not located on the Central GSA Mines Site, is exempt from the CERCLA Off-Site Rule as described in Section 3.5.1. That is, the Tronox NAUM Area, as described in Section 1.2.2 and within which the repository is located, consists of waste from the same ore body with a single PRP and thus is considered ‘*on-site*’ in regard to this rule.

3.7.1 Engineering Design

No additional engineering design would be required under Alternative 4 since the proposed, incised, ALSD regional repository will be built with sufficient volume to dispose of the Central GSA Mines Site soils (4 million CY storage capacity). See *Draft Engineering Evaluation Cost/Analysis; Tronox Navajo Area Uranium Mines, East GSA Mines Site* (WESTON, 2020) for a discussion of the engineering specifications and a preliminary design of the ALSD regional repository.

3.7.2 Site Work Activities

The Site work activities for Alternative 4 would be similar to those described for Alternative 3 in Section 3.6.2., with the primary difference being the haul routes and distances to the ALSD Regional Repository.

During the course of the removal action, it is estimated that approximately 148,100 truckloads (assuming 20-CY-capacity off-road haul trucks) would be required to transport waste material from the excavation site to the incised repository over a span of 433 days. The largest equipment that can reasonably be used on-site, with efficient travel times, and that would cause minimal damage to access routes, should be considered to maximize efficiency. Under this alternative, the majority of traffic would use the existing and upgraded section roads to move the waste to the proposed repository. The preferred route would be developed in consultation with RAML during the design phase.

The on-site excavation and trucking activities for this alternative is estimated to take approximately 2 years and 3 months with planning expected to take an additional 8 months before construction mobilization, for a total implementation time of approximately 2 years and 11 months before completion.

3.7.3 Post-Excavation and Site Reclamation Activities

Site reclamation activities are consistent between Alternative 4 and those described for Alternative 2 in Section 3.5.3.

3.7.4 Site Controls and Security

Site controls and security would be consistent between Alternative 4 and those described for Alternative 3 in Section 3.6.4.

3.7.5 Stormwater and Erosion Control

Similar to Alternative 2, stormwater management and erosion control are of significant concern based on the size and the extent of the excavation activities associated with Alternative 4. Controls for Alternative 4 would be consistent with those previously described for Alternative 2 (Section 3.5.5).

3.7.6 Operation and Maintenance Activities

Operation and maintenance of the Site would be consistent between Alternative 4 and those described for Alternative 3 in Section 3.6.6.

4.0 ANALYSIS OF ALTERNATIVES

The detailed analysis of alternatives is intended to provide the relevant information required to select a preferred remedy. Each alternative was evaluated on the basis of effectiveness, implementability, and cost, as set forth in the NCP and EPA guidance on conducting an EE/CA for a removal action (EPA, 1993). A summary of the analyses of the individual alternatives is included as Table 4-1.

4.1 ALTERNATIVE ANALYSIS APPROACH

4.1.1 Effectiveness

Effectiveness refers to the ability of an alternative to meet the RAOs. The following criteria are used to evaluate effectiveness:

Overall Protection of Human Health and the Environment – This criterion provides a final check to assess whether each alternative provides adequate protection of human health and the environment. The assessment of overall protection draws on the evaluation of the other criteria, especially long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

Evaluation of the overall protectiveness of an alternative would focus on whether a specific alternative achieves adequate protection and would describe how Site risks posed through each pathway addressed by the EE/CA are eliminated, reduced, or controlled through treatment, engineering, or institutional controls. This evaluation would allow for consideration of whether an alternative poses any unacceptable short-term or cross-media impacts.

Long-Term Effectiveness and Permanence – This criterion evaluates results of the removal action in terms of the risk remaining at the Site after response objectives have been met. The primary focus of this evaluation would be the extent and effectiveness of the controls that may be required to manage the risk posed by treatment residuals and/or untreated wastes remaining at the Site.

Short-Term Effectiveness – This criterion evaluates the effects that the alternative would have on human health and the environment during its construction and implementation phase. It includes both radiation exposure risks to the contaminated soils and risks to the workers and communities from construction work and traffic during implementation and the time necessary to complete the action.

Compliance with ARARs – This criterion is used to determine whether each alternative would meet the identified ARARs. The detailed analyses would summarize which requirements are applicable or relevant and appropriate to an alternative and describe how the alternative meets these requirements.

4.1.2 Implementability

This criterion evaluates the technical and administrative feasibility of implementing an alternative and the availability of various services and materials required to construct and provide O&M. The following criteria are used to evaluate implementability:

- Technical feasibility
- Administrative feasibility
- Availability of services and materials

Also considered is the reliability of the technology, the ability to monitor the effectiveness of the remedy, and the ease of undertaking additional remedial actions, if necessary.

4.1.3 Cost

Cost estimates were prepared for Alternatives 2 through 4 to compare the alternatives and support remedy selection. The types of costs that were assessed in accordance with 40 CFR 300.430 (e)(9)(iii)(G) include the following: (1) capital costs, including both direct and indirect costs; (2) annual operations and maintenance costs; and (3) NPV of capital and O&M costs. Capital costs were included as 2020 dollars. In accordance with EPA guidance, the cost estimates were prepared with a level of accuracy in the range of 50% greater to 30% lower than actual costs.

An NPV analysis relates costs that occur over different time periods to present costs by discounting all future costs to the present value. This allows the cost of removal alternatives to be compared on the basis of a single figure that represents the capital required in 2020 dollars to construct, operate, and maintain the removal alternative throughout its planned life. The NPV calculations were based on a discount rate of 7% (EPA, 2000a), which represents the average rate of return on private investment, before taxes and after inflation. Cost estimate details are located in Appendix J.

The scope and costs presented for the various alternatives are based on the best available information regarding current Site conditions and readily available information on the applicability and effectiveness of the selected removal actions. However, uncertainties and data gaps remain because the Site characterization was based on a limited number of samples, observations, and analyses. In preparing the cost estimates, conservative assumptions have been used and an overall contingency has been added to each alternative to account for these uncertainties. Changes in the cost elements are likely as new information is available and Site conditions change during the removal action design. Cost assumptions are included in Appendix J.

Actual costs may vary from these estimates depending on variations in actual Site conditions from those estimated, such as weather conditions; inflation; actual fuel costs; actual insurance and bonding costs; the availability and market costs of materials, equipment, and labor; changes in regulatory requirements; and other factors that are difficult to estimate or control.

4.2 UNAVOIDABLE IMPACTS COMMON TO ALL ALTERNATIVES

Except for Alternative 1 (No Further Action), each of the removal action alternatives would result in an overall improvement to the local environment. However, for Alternatives 2 through 4, it is important to note that there would be some unavoidable impacts. These include:

- Short-term inconvenience to local populations using New Mexico State Highways 509 and 605; general disturbance from heavy equipment activity for the assumed construction periods; and increased truck traffic in the area.
- Disruption of cattle grazing and wildlife access to the removal action areas due to the construction activities and vegetation re-establishment.
- Long-term O&M activities required for maintenance of the cover, stormwater diversion measures, revegetation efforts, and fencing.
- Increased risks of traffic fatalities due to off-site trucking of waste material (Table 4-2).
- Increase in greenhouse gas emissions calculated as a carbon dioxide equivalent (CO_2e) due to off-site and on-site trucking of waste material and clean fill material (Table 4-2).

4.3 ALTERNATIVE 1: NO FURTHER ACTION

The No Further Action alternative does not provide protection to human health or environmental exposure, nor is it considered a permanent remedy because it does not reduce the concentration, volume, or mobility of the hazardous waste on the Site. The No Further Action alternative has been included as a requirement of the NCP and to provide a basis for the comparison of the remaining alternatives. No new activities would occur at the Site under this alternative; however, implementation of Alternative 1, No Further Action, would require the following O&M steps to maintain the existing level of protection:

- Erosion and stormwater-control maintenance
- Fencing maintenance and repair

4.3.1 Effectiveness

Alternative 1 would not minimize the potential exposure to, or migration of, contaminated soils from the Central GSA Mines Site. This alternative would not provide control through treatment of soils with concentrations of Ra-226 above the action level or reduce volume or mobility of contaminants, and thus would not reduce risks to human health or the environment. The resultant risks associated with the No Further Action Alternative would be similar to those that existed at the time of the RSE. Therefore, increased protection of human health and the environment would not be achieved under this alternative.

Surface water discharge from the Site would have continued potential to transport contaminated soils to the downstream watershed. Site workers and visitors would continue to be potentially exposed to windborne and waterborne contaminants. The Site would continue to be unacceptable for livestock grazing use.

Other than routine stormwater pollution prevention plan and fence maintenance, no controls or long-term measures would be implemented to control contaminated soils at the Site under the No Further Action Alternative; therefore, this alternative offers no long-term or short-term effectiveness in reducing potential risks to human and ecological receptors.

The effectiveness of the No Further Action Alternative is considered low for achieving the removal action goals.

4.3.2 Implementability

Alternative 1 is easily implemented because there are no construction or permitting considerations. EPA guidance requires that the reliability of the technology be considered along with feasibility. Since No Further Action is inherently an unreliable remedy, this criterion is rated low.

4.3.3 Cost

The NPV cost of Alternative 1 is estimated to be $9,383,000 (Appendix J, Table J-1 [cost detail in Appendix J, Table J-2]). There are no new direct or indirect capital costs, and annual O&M costs are estimated to be $819,000 per year (for the first 12 years) and $203,000 per year subsequently. Because the overall effectiveness of Alternative 1 is low, the cost analysis rating of Alternative 1 is low.

4.4 ALTERNATIVE 2: EXCAVATION AND OFF-SITE DISPOSAL OF RADIOLOGICALLY CONTAMINATED SOILS AT A LICENSED, LOW-LEVEL RADIOACTIVE WASTE FACILITY

Implementation of Alternative 2, excavation and off-site disposal of contaminated soils at a licensed, low-level radioactive waste facility, would require the following steps:

- Excavation of all elevated, radiologically contaminated wastes on the Site (Figure 2-1).
- Off-site disposal of excavated, contaminated wastes.
- Site reclamation with erosion and stormwater controls, re-contouring and revegetation.

4.4.1 Effectiveness

Alternative 2 would provide a high level of protection to human health and the environment. Soils above the action level would be excavated within the Site boundary and removed for off-site transportation and disposal at a licensed, low-level radioactive waste facility. This alternative would significantly minimize potential exposure to contaminated soils from the Site. This alternative would provide control of waste mobility and a reduction in risk to human health and the environment at the Site. Potential exposures during excavation, transport, and at the final disposal site would be managed through engineering controls.

Federal and state ARARs would be met for the Site under Alternative 2. The activities set forth for the removal action would provide compliance with location-specific ARARs. A Cultural Resources Protection Plan would be developed for monitoring protocols during work activities and would include a review and evaluation of potential impacts to historical properties and locations. Natural resource (e.g., biological and botanical) surveys have been conducted at the Site and information from these surveys would be included in the Environmental Protection Plan. The plan would include a review and evaluation of potential impacts on government-protected species and critical habitats.

The removal action would provide compliance with action-specific ARARs, including federal and state hazardous waste management regulations to the extent applicable; federal and state standards for protection of workers, the public, and the environment from low-level radioactivity; the New Mexico Administrative Code (NMAC) 20.2 for air quality control regulations; and federal rules and regulations pertaining to the on-site accumulation of wastes in stockpiles and the control of stormwater discharges during construction activities. The U.S. Department of Transportation rules and regulations on manifesting and the on-site and off-site transport of hazardous materials would also be action-specific ARARs for implementation of Alternative 2. Federal requirements for hazardous waste disposal would be ARARs if the removal action encounters wastes subject to these requirements.

Short-term effectiveness under Alternative 2 is medium because of the disturbance of the entire waste area and the large amount of trucking to transport the entire waste amount. The primary considerations for short-term effectiveness are protection of the community and workers, and protection against environmental impacts during and after implementation. Alternative 2 involves excavation, material transfer, stockpile development/management, loading of bulk carriers, and Site reclamation activities. Heavy construction equipment would be used to clear and grub, excavate, transfer, load, and grade impacted materials. Potential exposure and protection procedures for workers engaged in these activities would be addressed in detail under a Site HASP. During excavation and material handling activities, measures would be taken to reduce fugitive dust emissions and associated impacts to workers. Water would be obtained on-site for dust control, and workers in the controlled area would don the appropriate safety equipment and implement safety practices such as air monitoring. Work areas would be secured (e.g., marked or fenced) to ensure access by authorized personnel only.

Bulk carriers hauling the removal action-derived contaminated wastes off-site would be covered, secured, and weighed to document compliance with total and axle load limits. Truck traffic would be coordinated under an Off-Site Transportation Plan for routes, times of operation, and on-site traffic rules. Emergency spill containment and cleanup contingencies would also be included in the Transportation Plan to address material spills. Due to the large number of truckloads (approximately 148,100 loads of contaminated soil leaving the Site) and the long drive to the disposal facility (up to 10 hours one way), it is estimated that the time period of implementation of Alternative 2 would be 2 years and 3 months, following 8 months of planning and permitting. This alternative also has the highest amount of trucking and heavy equipment use in vehicle hours; therefore, it has the highest potential for additional vehicular accidents, for increased wear and tear on infrastructure, for the production of the highest amount of air pollution (from particulate matter in vehicle exhaust), and for the use of the greatest amount of fossil fuels. A risk of 2.55 additional fatalities and 291,794 metric tons of CO_2e emissions are estimated due to the increased truck traffic (see Table 4-2).

Long-term effectiveness of this alternative is high. Since all contaminated soils would be excavated and removed from the Site, potential exposure reductions to those accessing the Site would be permanent. Alternative 2 is expected to effectively mitigate the long-term effects on potential on-site human and ecological receptors.

4.4.2 Implementability

Alternative 2 rates medium in technical and administrative implementability. Although it is technically feasible and would use conventional techniques, materials, or labor for the excavation and associated activities, the extended schedule (approximately 2 years and 3 months) to complete excavation and disposal reduces its implementability rating. Excavation would be scheduled and performed to maximize direct loading and ensure worker and public safety. Engineering controls for fugitive dust and Site monitoring would be used to control potential exposures to sensitive receptors. Profiling and manifesting of the material would be done in coordination with the transporters and off-site disposal facility. Rail shipment is a possibility; a transload facility to transfer material from trucks to railcars could be established as close as 20 miles from the Site. The cost of setting up the facility, stationing an excavator with scaling bucket, maintaining a water supply for dust control, providing security at the Site, and scheduling would need to be evaluated against the cost of trucking.

Alternative 2 would be administratively feasible since the shipping of waste is fairly common and would only require scheduling and obtaining the necessary permits. However, the large number of trucks required to efficiently haul the material would depend on the availability of the labor and equipment. All contaminated soil is anticipated to be accepted by permitted facilities, although due to the large quantity of material to be disposed off-site, it is possible that one facility may not ultimately be able to accept all of the waste.

The excavation of contaminated material would be accomplished using a variety of conventional equipment. Heavy construction equipment needed for this project such as scrapers, excavators, bulldozers, loaders, and compactors and/or bulk carriers are commercially available. Working space is available for establishing temporary-construction office trailers. Electricity is already available at the Site and portable sanitary services and refuse disposal are locally available. Construction materials for the Site reclamation activities (localized drainage structures, erosion control, re-contouring, and seeding), and an off-site laboratory for sample analysis, are commercially available.

Trained and experienced labor is available for Site work activities. Special certifications and training requirements are commercially available. Health and safety training to comply with OSHA regulations, including radiation and hazardous material handling training, is available.

On-site water would be required for construction and is readily accessible. On-site water would require treatment using commercially available equipment and would require on-site storage in a water farm.

4.4.3 Cost

The total NPV cost of Alternative 2 is estimated to be $908,098,000 (Appendix J, Table J-1 [cost detail in Appendix J, Table J-3]). The overall effectiveness is compared to cost to determine whether the remedy is cost-effective. The long-term effectiveness and permanence are high while the short-term effectiveness is medium. Because the cost is very high, the cost analysis rating of Alternative 2 is low.

4.5 ALTERNATIVE 3: EXCAVATION, CONSOLIDATION, AND LONG-TERM MANAGEMENT OF RADIOLOGICALLY CONTAMINATED SOILS AT AN ABOVEGROUND, ON-SITE REPOSITORY

Implementation of Alternative 3, excavation, consolidation, and long-term management of radiologically contaminated soils at an aboveground, on-site repository, would require the following steps:

- Design, siting, and construction of an aboveground repository.
- Excavation of all elevated, radiologically contaminated wastes on the Site (Figure 2-1).
- Transportation of contaminated wastes and their placement in the constructed repository.
- Construction of an engineered, clean-soil cover over the repository.
- Site reclamation with erosion and stormwater controls, re-contouring, and revegetation.

4.5.1 Effectiveness

Alternative 3 would protect human health and the environment as all contaminated soils would be placed in a covered and naturally lined (Mancos Shale) repository. These activities would prevent direct contact between wastes, humans, and the environment in the future. Long-term maintenance of the cover and stormwater infrastructure would be necessary.

Federal and state ARARs would be met for the Site under Alternative 3. The repository design would include an evapotranspiration and radon flux cover to fully contain and isolate contaminated soils. Stormwater controls would be included in the design so that surface water would be diverted from the area. The cover is a physical barrier that protects contaminated soils from water infiltration, protects groundwater resources, and also provides adequate shielding from radon flux to protect human health and the environment.

The activities set forth for the removal action would provide compliance with location-specific ARARs. A Cultural Resources Protection Plan would be developed for monitoring protocols during work activities and would include a review and evaluation of potential impacts to historical properties and locations. Natural resource (e.g., biological and botanical) surveys have been conducted at the Site and information from these surveys would be included in the Environmental Protection Plan. The plan would include a review and evaluation of potential impacts on government-protected species and critical habitats.

The removal action would provide compliance with action-specific ARARs. These include federal and state hazardous waste management regulations, to the extent applicable; federal and state standards for protection of workers, the public, and the environment from low-level radioactivity; the NMAC 20.2 for air quality control regulations; and federal rules and regulations pertaining to on-site accumulation of stockpiled wastes, protection and monitoring of groundwater, and the control of stormwater discharges during construction activities, to the extent applicable.

Short-term effectiveness under Alternative 3 is high. The primary considerations in the rating for short-term effectiveness are protection of the community, of workers, and from environmental impacts during and after implementation. Alternative 3 involves excavation, material transfer, stockpile development/management, loading of bulk carriers, and Site reclamation activities. Heavy equipment would be used to clear and grub, excavate, transfer, load, and grade impacted materials. Potential exposure and protection procedures for workers engaged in these activities would be addressed in detail under a Site HASP. During excavation and material handling activities, measures would be taken to reduce fugitive dust emissions and associated impacts to workers. Water would be available on-site for dust control, and workers in the controlled area would don the appropriate safety equipment and implement safety practices such as air monitoring. Work areas would be secured (e.g., marked or fenced) to control access by authorized personnel only.

On-site truck traffic would be coordinated under the previously referenced Traffic Control Plan for the Site. On-site truck accidental spill containment and cleanup procedures would be included in the aforementioned plan. Due to the volume of waste to be moved from the Site to the repository, it is estimated that the time period of implementation of Alternative 3 would be approximately 2 years and 9 months following 12 months of planning. A risk of 0.00 additional fatalities and 303 metric tons of CO_2e emissions are estimated due to the increased truck traffic (see Table 4-2).

The long-term effectiveness of Alternative 3 is medium because it is dependent on the future maintenance activities at the repository. If properly maintained, the cover and stormwater diversion structures would minimize water infiltration into the cap and would prohibit human or animal disturbance to the contaminated soils.

4.5.2 Implementability

Alternative 3 rates high in technical implementability. It is technically feasible and would require conventional techniques, materials, and labor for the excavation and associated activities since the individual mine sites are readily accessible. Excavation would be scheduled and performed to maximize direct loading and ensure worker and public safety. Engineering controls for fugitive dust and Site monitoring would be used to control potential exposure to human and environmental receptors.

The excavation of contaminated material would be accomplished using a variety of conventional equipment. Heavy mining equipment needed for this project such as scrapers, excavators, bulldozers, loaders, and compactors and/or bulk carriers are commercially available. Working space is available for establishing temporary construction office trailers. Electricity is already available at the Site and portable sanitary services and refuse disposal are locally available. Construction materials for the cover and Site reclamation activities (re-contouring and seeding) and an off-site laboratory for sample analysis are commercially available. During non-construction periods, best management practices would be employed in accordance with stormwater control plans to help secure the Site during extreme storm events to protect human health and wildlife. On-site water would be required for construction water and is readily accessible. Water would need to be treated and stored on-site in a water farm.

Alternative 3 is rated medium for administrative feasibility. Trained and experienced labor is available for Site work activities. Special certifications and training requirements are commercially available. Health and safety training to comply with OSHA regulations, including radiation and hazardous material handling training, is available. Additionally, the contaminated soils would be transported within the Site boundary, which would include the repository. Transportation permits would not be necessary. Construction of an engineered cover would not require permitting because contaminated soils are considered low-level radioactive materials and are not an RCRA hazardous waste. In addition, permits are not required for on-site CERCLA actions, which must comply with the substantive requirements of any state or local permit, but not with the administrative requirements. However, the State of New Mexico guidelines advocate for establishing *incised* repositories of radioactive wastes to address the need to limit erosion over long periods of time (NMEMNRD and NMED, 2016). Overall implementability of Alternative 3 is medium.

4.5.3 Cost

The total NPV cost of Alternative 3 is estimated to be $205,502,000 (Appendix J, Table J-1 [cost detail in Appendix J, Table J-4]). The overall effectiveness is compared to the cost to determine whether the remedy is cost-effective. The long-term effectiveness is medium, and the short-term effectiveness is high. The cost is also medium, so the cost analysis rating of Alternative 3 is medium.

4.6 ALTERNATIVE 4: EXCAVATION, CONSOLIDATION, AND LONG-TERM MANAGEMENT OF RADIOLOGICALLY CONTAMINATED SOILS AT AN INCISED (BELOW-GROUND), ALSD REGIONAL REPOSITORY

Implementation of Alternative 4, excavation, consolidation, and long-term management of radiologically contaminated soils at an incised ALSD regional repository, would require the following steps:

- Design, siting, and construction of an incised (i.e., partially below ground) repository.
- Excavation of all excess radiologically contaminated wastes on the Site (Figure 2-1).
- Transportation of contaminated wastes and their placement in the constructed repository.
- Construction of an engineered, clean-soil cover over the repository.
- Site reclamation with erosion and stormwater controls, re-contouring, and revegetation.

4.6.1 Effectiveness

The effectiveness of Alternative 4 would be consistent with that of Alternative 3 as described in Section 4.5.1. It is estimated that the time period of implementation of Alternative 4 would be approximately 2 years and 3 months following 8 months of planning. A risk of 0.04 additional fatalities and 4,732 metric tons of CO_2e emissions are estimated due to the increased truck traffic (see Table 4-2).

4.6.2 Implementability

Alternative 4 would be consistent with that of Alternative 3 for technical feasibility, rated high, as described in Section 4.5.2. Alternative 4 is also ranked high for administrative feasibility. Similar to Alternative 3, trained and experienced labor is available for Site work activities. Special certifications and training requirements are commercially available. Health and safety training to comply with OSHA regulations, including radiation and hazardous material handling training, is available. Additionally, the contaminated soils would be transported within the Tronox NAUM programmatic boundary, which would include the repository. Transportation permits would not be necessary. Construction of an engineered cover would not require permitting because contaminated soils are considered low-level radioactive materials and are not a RCRA hazardous waste. In addition, permits are not required for on-site CERCLA actions. On-site CERCLA actions must comply with the substantive requirements of any state or local permit, but not the administrative requirements. However, dissimilar to Alternative 3, Alternative 4 achieves the State of New Mexico guidelines advocating for an *incised* repository when used for long-term storage of radioactive materials (NMEMNRD and NMED, 2016). Overall implementability of Alternative 4 is high.

4.6.3 Cost

The total NPV cost of Alternative 4 is estimated to be $188,785,000 (Appendix J, Table J-1 [cost detail in Appendix J, Table J-5]). The overall effectiveness is compared to the cost to determine whether the remedy is cost-effective. The long-term effectiveness is medium, and the short-term effectiveness is high. The cost is also medium, so the cost analysis rating of Alternative 4 is medium.

5.0 COMPARATIVE ANALYSIS OF REMOVAL ACTION ALTERNATIVES

This Section of the EE/CA provides a comparison of the four removal action alternatives and options as described in Section 3, using the analyses presented in Section 4. Alternatives screened from further consideration are not compared. In addition, based on EPA guidance, there are five core (key) elements in “greener cleanup activities” that should be considered throughout the remedy selection process (EPA, 2016). These key elements include: minimizing total energy use and maximizing renewable energy use; minimizing air pollutants and CO_2e emissions; minimizing water use and negative impacts to water resources; improving materials management and waste reduction efforts by reducing, reusing, or recycling whenever feasible; and protecting ecosystem services (EPA, 2012). This consideration compares the effects each removal action alternative (Section 3) has on the five key “green” elements. Each of the five elements was qualitatively scored for each alternative using a numerical ranking system of 1 through 5, with a 1 being best and a 5 being worst (i.e., low scores are greener cleanup alternatives). The alternative’s Greener Cleanup Assessment Score was derived from the sum of the five scores for that alternative. The results of this assessment are summarized in Appendix L.

5.1 EFFECTIVENESS

Alternative 1: No Further Action does not protect human health of on-site ranchers nor does it protect the environment; it is therefore rated low for this metric. Alternative 2: Excavation and Off-Site Disposal of Radiologically Contaminated Soils at a Licensed, Low-Level Radioactive Waste Facility; Alternative 3: Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Aboveground, On-Site Repository; and Alternative 4: Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Incised, ALSD Regional Repository each protect human health of on-site ranchers and the environment, and are individually rated high. The Site would be suitable for unrestricted livestock grazing use under Alternatives 2, 3, and 4. Any chance of exposure would occur prior to and during removal activities. Grazing and open-space use may or may not be limited based on erosion and vegetation performance and cover maintenance requirements.

Alternatives 2, 3, and 4 comply with the ARARs and are equal under this criterion. Alternative 1 retains the greatest chance for contaminant mobility and would, therefore, rank below the other alternatives.

The short-term effectiveness is considered medium for Alternative 2 and high for Alternatives 3 and 4. Alternatives 2, 3, and 4 require excavation of the entire, or nearly the entire, contaminated soil area (approximately 96% for Alternative 3 due to the repository placement over contaminated soil); however, Alternative 2 requires a massive transportation effort to transport contaminated soils off-site. Alternatives 3 and 4 do not require off-site transport of the waste, but contaminated soils would need to be transported to the on-site repository under Alternative 3, with Alternative 4 requiring farther transport to an ALSD regional repository. Alternatives 2, 3, and 4 would have a potential impact to workers and on-site visitors during construction activities. The number of trucks required to transport the contaminated soil off-site would increase the risk of traffic fatalities and increase the carbon footprint for Alternative 2, whereas Alternatives 3 and 4 would introduce a much lower risk for traffic fatalities and CO_2e emissions. Between Alternatives 3 and 4, the risk for traffic fatalities is essentially equivalent; however, Alternative 4 would produce approximately 15.6 times more CO_2e emissions than Alternative 3.

Under each of the action alternatives, engineering controls would prevent off-site impacts from materials such as windborne dust and runoff. Alternative 1 has the lowest long-term effectiveness, is not considered a permanent solution, and is ranked low for this metric. Alternative 2, ranked high, provides better long-term effectiveness and permanence because the waste would be managed in a location with waste from other sites and would be managed by a third party. Alternatives 3 and 4 ranked medium for long-term effectiveness and permanence. Although waste would be managed in an engineered repository, maintenance of the cover would be required.

5.2 IMPLEMENTABILITY

Implementation of Alternative 1 is ranked low because no action is taken. Alternative 2 is technically feasible to implement and would use conventional techniques, materials, and labor for the excavation and associated activities. However, Alternative 2 requires a large amount of off-site trucking, and providing enough trucks each day to maintain production levels may be difficult to schedule and obtain. Alternative 2 is ranked medium for implementability.

Alternatives 3 and 4 are easily implemented as they are technically feasible and would use conventional techniques, materials, or labor for the excavation and associated activities. Alternatives 2, 3, and 4 require a large amount of water for dust control and revegetation efforts. Water is readily available on-site but would require treatment for radionuclides before use. Construction of a water farm would be required to store sufficient water for use over time. Construction of a treatment system and water farm is technically and administratively feasible.

Alternative 4 is ranked high for administrative feasibility, since it meets the State of New Mexico guidelines advocating for an *incised* (below grade) repository, whereas Alternative 3, for the opposite reason, is ranked medium for this metric. Consequently, Alternative 3 is ranked medium and Alternative 4 is ranked high for implementability.

5.3 COST EFFECTIVENESS

Alternative 1 only involves O&M costs to maintain existing fencing and stormwater/erosion control measures and is the least expensive option but is also the least cost-effective option because it does not address risks posed by leaving contaminated soils in their current state. Alternative 2, removing the waste from the Site and transporting it off-site for disposal at a licensed, low-level radioactive waste facility, has the highest long-term effectiveness; however, because of the very high cost associated with this alternative (NPV approximately 4 to 5 times that of Alternatives 3 and 4), it has a low cost analysis rating compared to Alternatives 3 and 4. Alternatives 2, 3, and 4 would allow unrestricted ranching at the Site. Alternative 4 is the least costly alternative in NPV, approximately 9% less than that of Alternative 3. In terms of short-term effectiveness, Alternative 3 produces less CO_2e emissions than Alternative 4. The most cost-effective alternative, however, is Alternative 4, which involves consolidation of wastes with other similarly contaminated soils from the Tronox NAUM, East and Central GSA Mines sites into an ALSD regional repository, which would allow the sharing of O&M costs of the repository cover between the Site and other Tronox NAUM sites utilizing the repository. Although scoring the same medium cost analysis rating as Alternative 3, Alternative 4's administrative implementability is higher than Alternative 3 due to achieving the State of New Mexico guidelines advocating for an *incised* repository for long-term storage of radioactive wastes to address the need to limit erosion over long periods of time. Use restrictions would be applicable at the repository, but the Site would be restored for controlled and restricted access for perpetuity under the stipulations of a federal enforcement document.

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FIGURES

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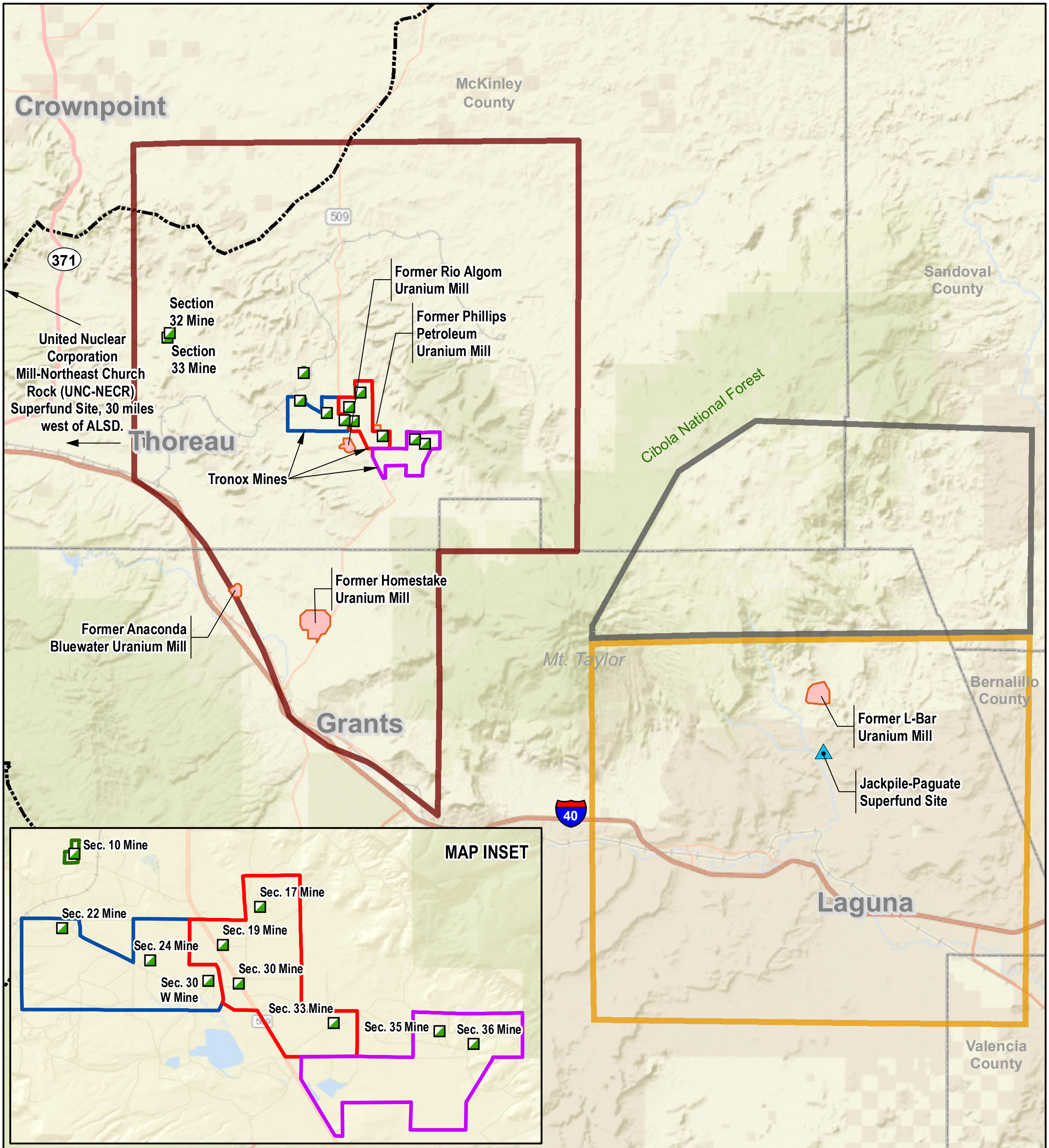


LEGEND

- Ambrosia Lake Sub-District of the Grants Mining District
- Laguna Sub-District of the Grants Mining District
- Marquez Sub-District of the Grants Mining District
- West GSA Mines Site
- Central GSA Mines Site
- East GSA Mines Site
- Section 10 Mine Site
- Former Uranium Mill Site
- County Boundary
- Continental Divide
- Tronox Surface Expression

0 7.5 15
Miles

New Mexico

N

SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: WORLD STREET MAP; ESRI

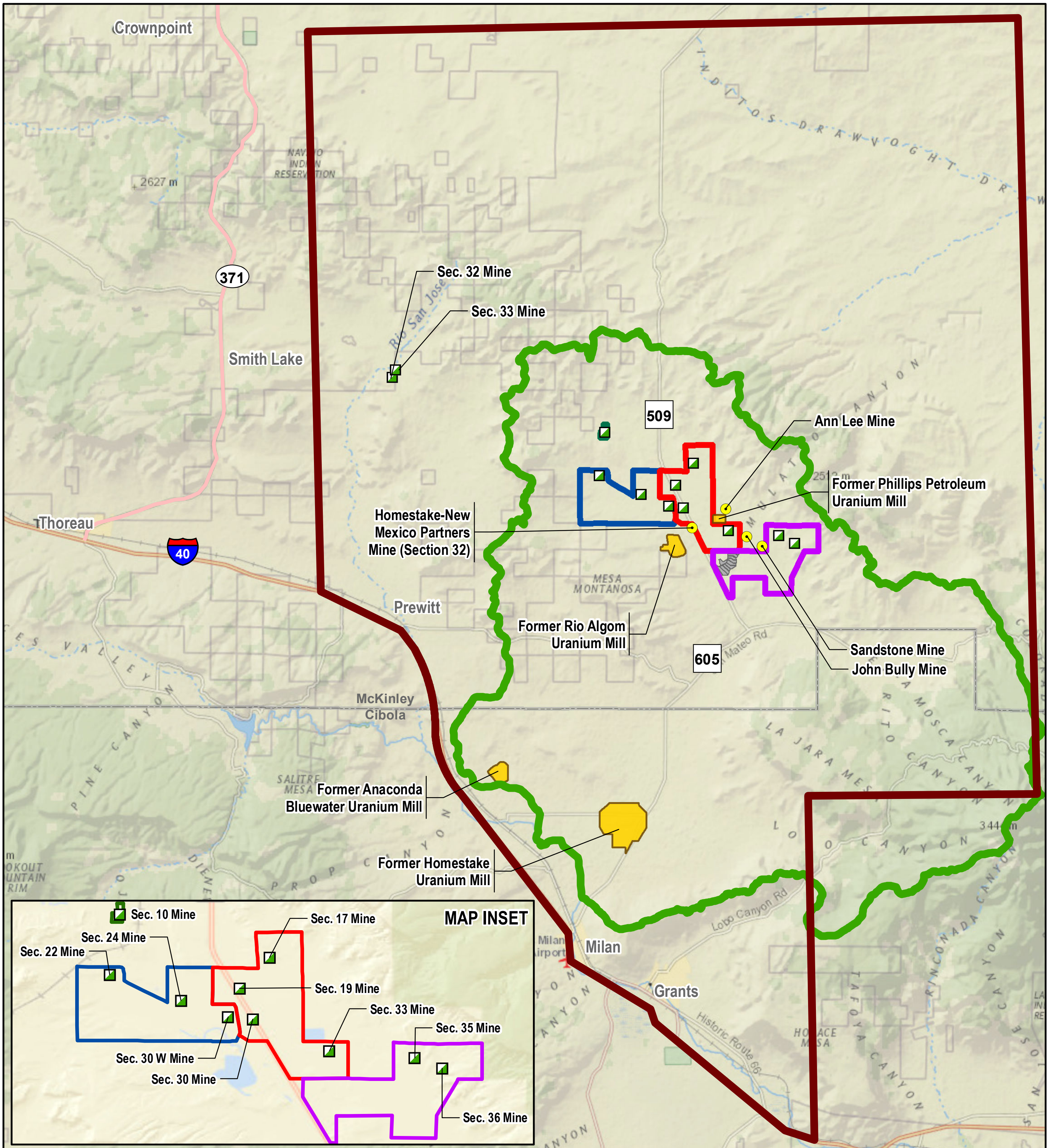
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

USEPA REGION 6

FIGURE 1-1
SITE LOCATION MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-1 - Site Location Map.mxd 10:52:35 AM 9/23/2020 GRANTSGIS



LEGEND

- Ambrosia Lake Sub-District
- San Mateo Creek Basin
- West GSA Mines Site
- Central GSA Mines SIte
- East GSA Mines Site
- Section 10 Mine Site
- Former Uranium Mill Site
- Former Rio Algom Uranium Mill Evaporation Ponds
- Tronox Surface Expression
- Non-Tronox Surface Expression (SEMS Site)

0 2 4 6 8
Miles

New Mexico

N

SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: NATIONAL GEOGRAPHIC TOPO; ESRI

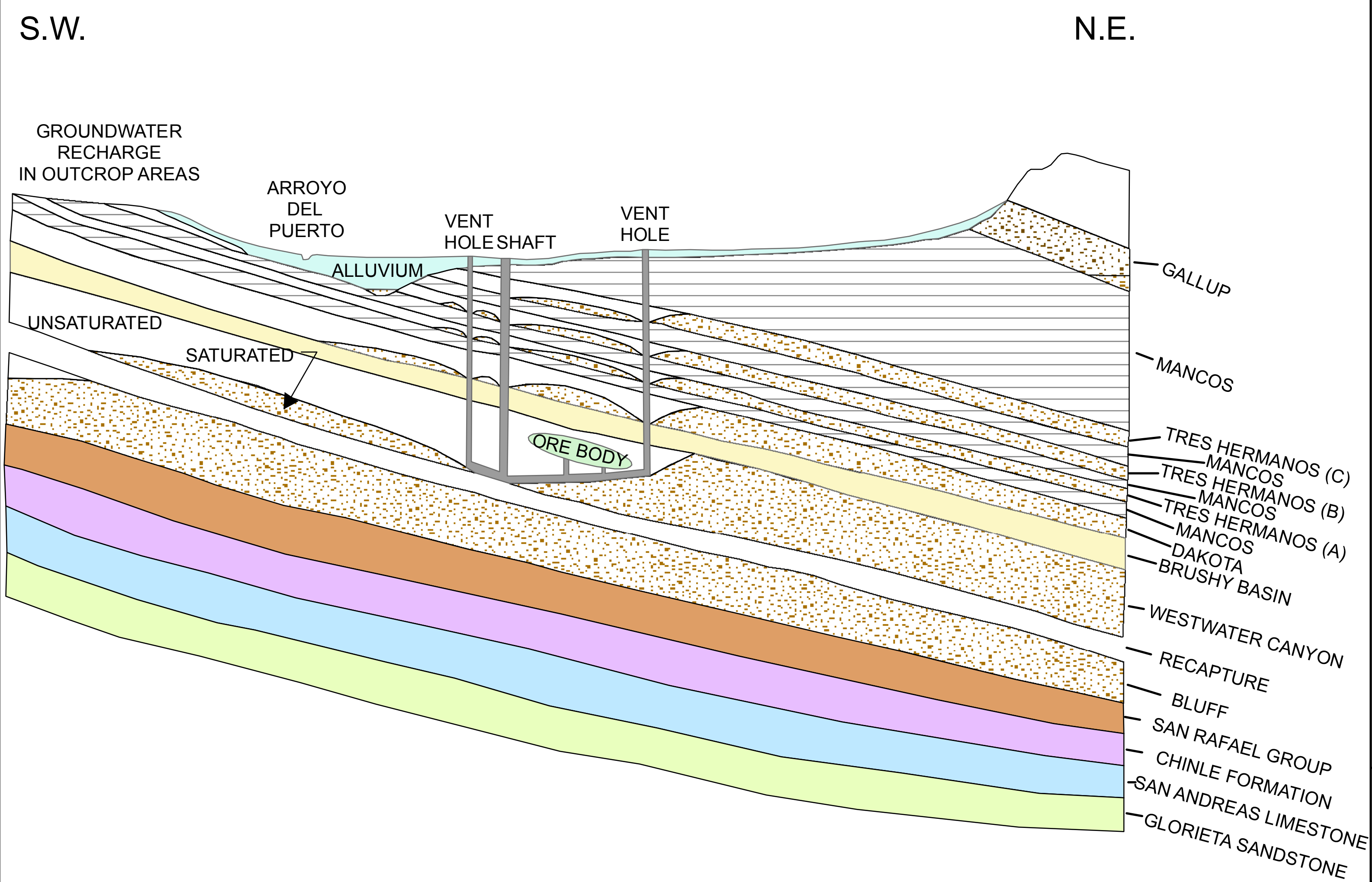
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

USEPA REGION 6

FIGURE 1-2
SITE AREA MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-2 - Site Area Map.mxd 10:57:55 AM 9/23/2020 GRANTSGIS



GENERALIZED CROSS-SECTION OF AMBROSIA LAKE AREA

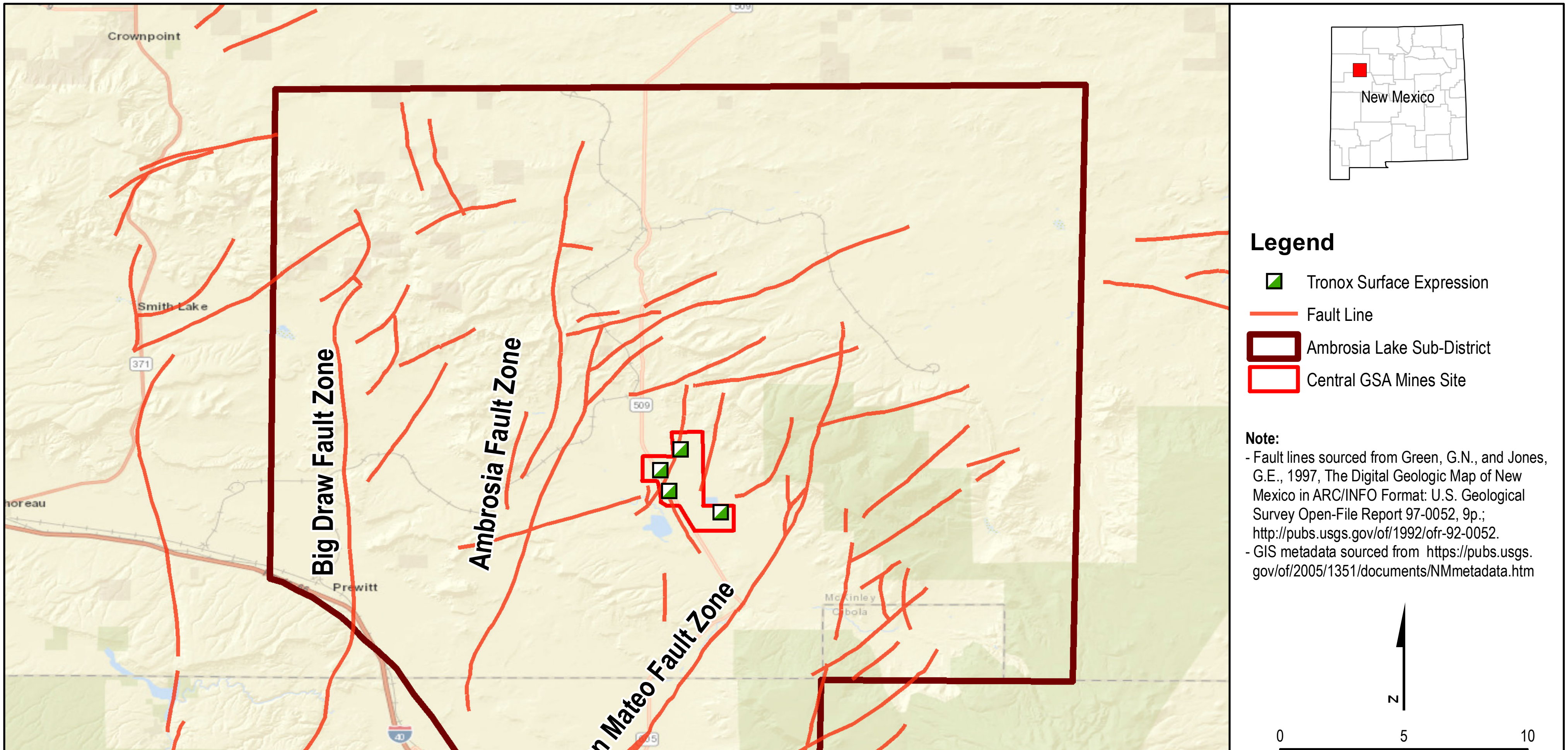
SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: Los Alamos Scientific Laboratory, 1977. "Geology and Hydrology in the Vicinity of the Inactive Uranium Mill Tailings Pile, Ambrosia Lake, New Mexico"

USEPA REGION 6

FIGURE 1-3
AMBROSIA LAKE GEOLOGIC CROSS-SECTION
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	NOT TO SCALE

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-3 - Ambrosia Lake Geologic Cross-section.mxd 11:00:10 AM 9/23/2020 GRANTSGIS



Note:
- Fault lines sourced from Green, G.N., and Jones, G.E., 1997, The Digital Geologic Map of New Mexico in ARC/INFO Format: U.S. Geological Survey Open-File Report 97-0052, 9p.; http://pubs.usgs.gov/of/1992/ofr-92-0052.
- GIS metadata sourced from https://pubs.usgs.gov/of/2005/1351/documents/NMmetadata.htm

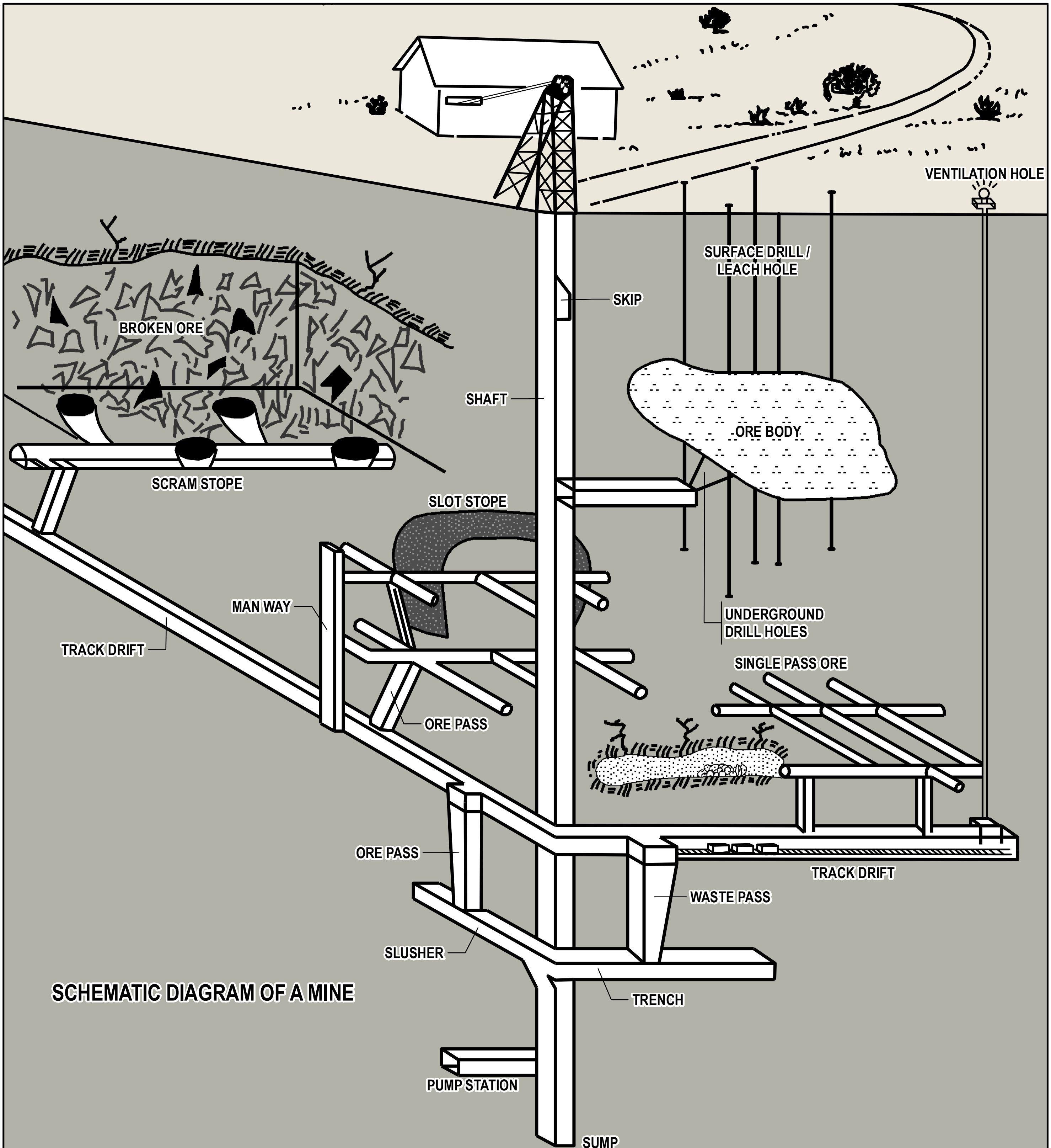
SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: WORLD STREET MAP; ESRI

USEPA REGION 6

FIGURE 1-4
AMBROSIA LAKE FAULT ZONE MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-4 - Ambrosia Lake Fault Zone Map.mxd 11:06:46 AM 9/23/2020 GRANTSGIS



USEPA REGION 6

FIGURE 1-5
TYPICAL UNDERGROUND URANIUM MINE DIAGRAM
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	NOT TO SCALE

SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: Kerr McGee Nuclear Corporation, Undated. “Uranium Mining and Processing”

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-5 - Typical Underground Uranium Mine Diagram.mxd 11:08:28 AM 9/23/2020 GRANTSGIS

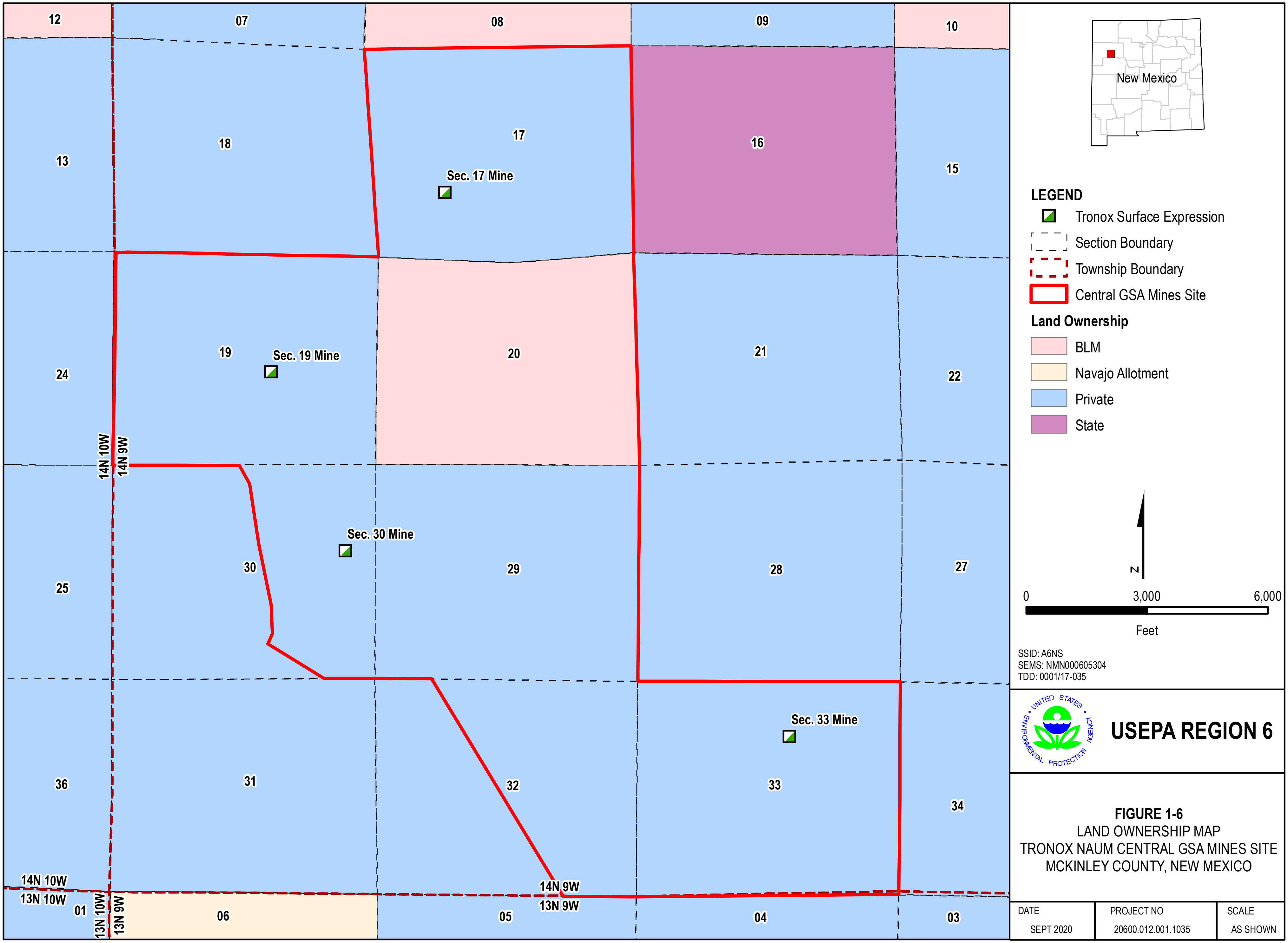
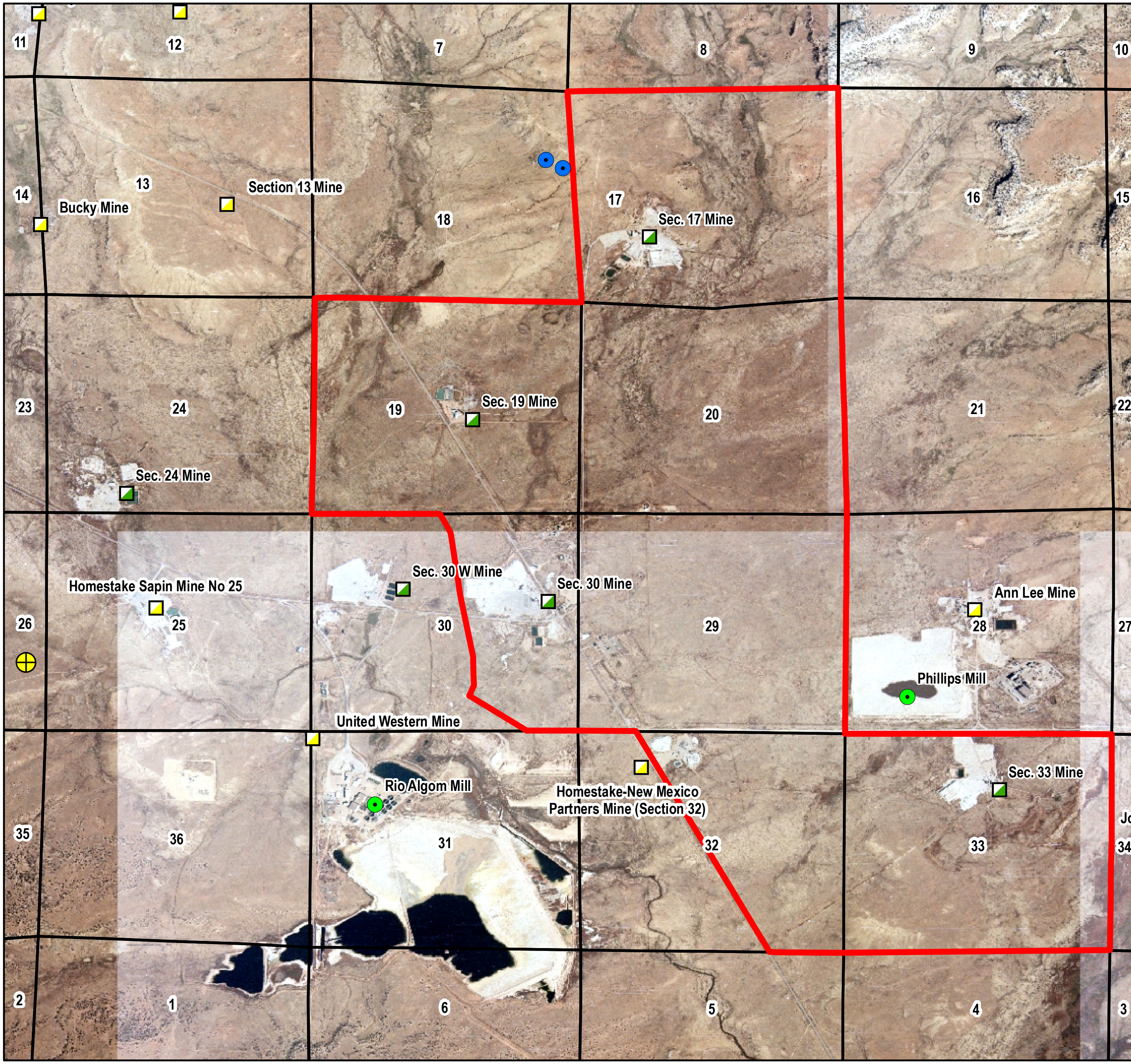


FIGURE 1-6
LAND OWNERSHIP MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-6 - Land Ownership Map.mxd 11:09:43 AM 9/23/2020 GRANTSGIS



LEGEND

- Background Location
- Non-Tronox Surface Expression
- Tronox Surface Expression
- Former Uranium Mill
- Section 18 Residences
- Section Boundary
- Central GSA Mines Site

NOTE
- Historical Aerial Imagery Dated 1973

N

0 0.5 1

Miles

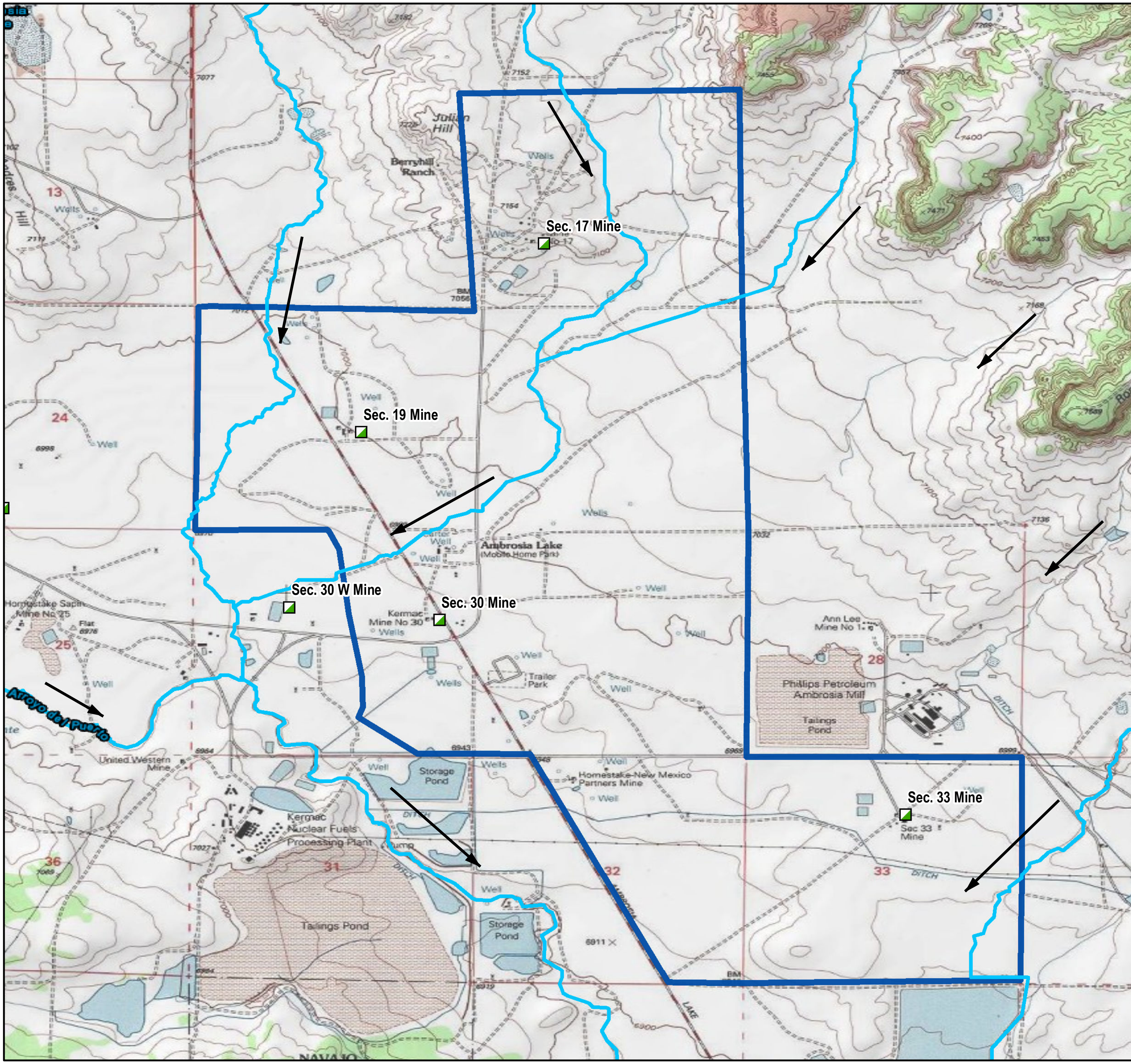
SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: USGS EarthExplorer

USEPA REGION 6

FIGURE 1-7
SITE LAYOUT MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-7 - Site Layout Map.mxd 11:11:55 AM 9/23/2020 GRANTSGIS



LEGEND

- Tronox Surface Expression
- Surface Water Flow
- Surface Drainage
- Central GSA Site

N

0 3,250 6,500

Feet

SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: USA TOPO MAPS; ESRI

USEPA REGION 6

FIGURE 1-8
SURFACE DRAINAGE MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-8 - Surface Drainage Map.mxd 11:14:42 AM 9/23/2020 GRANTSGIS

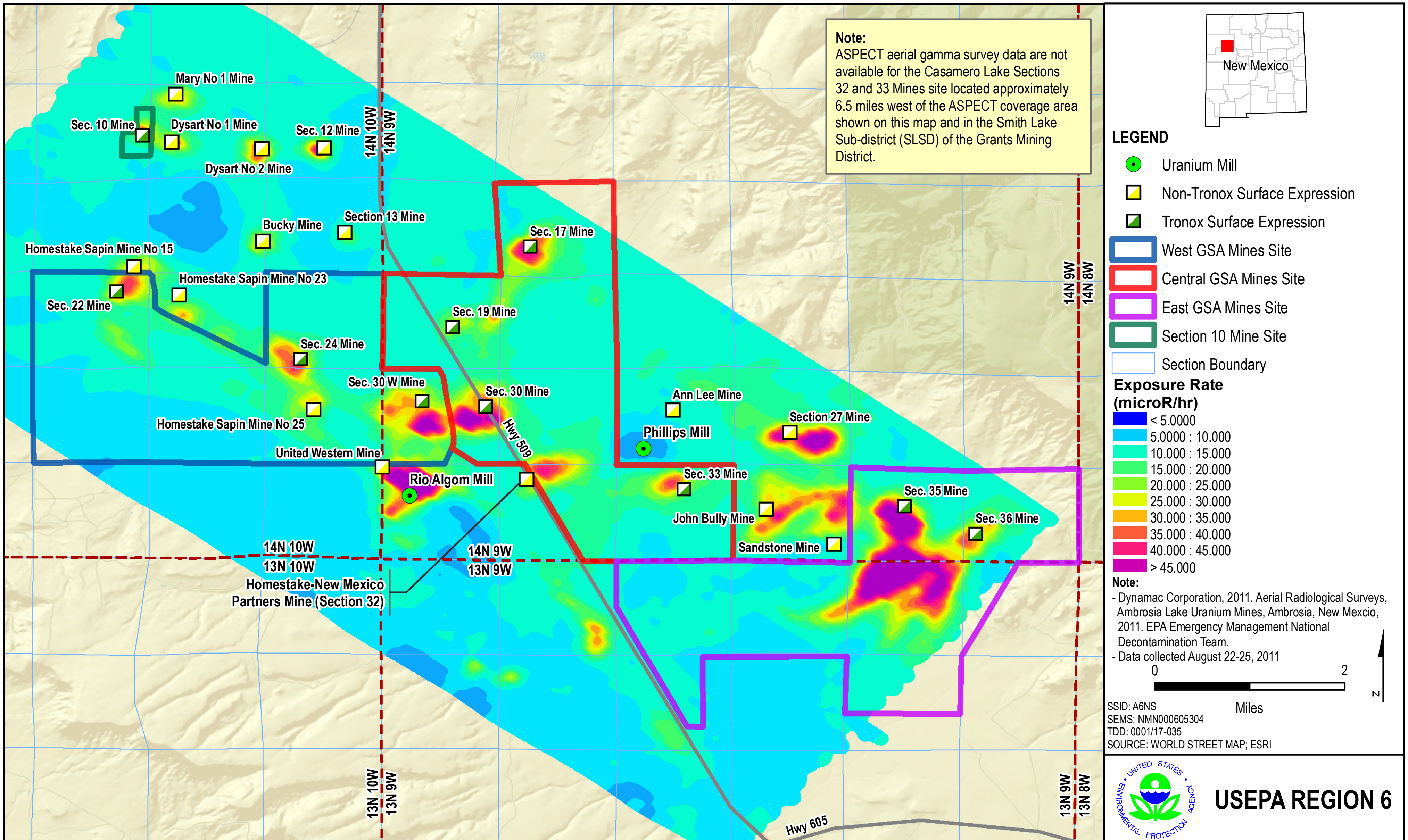
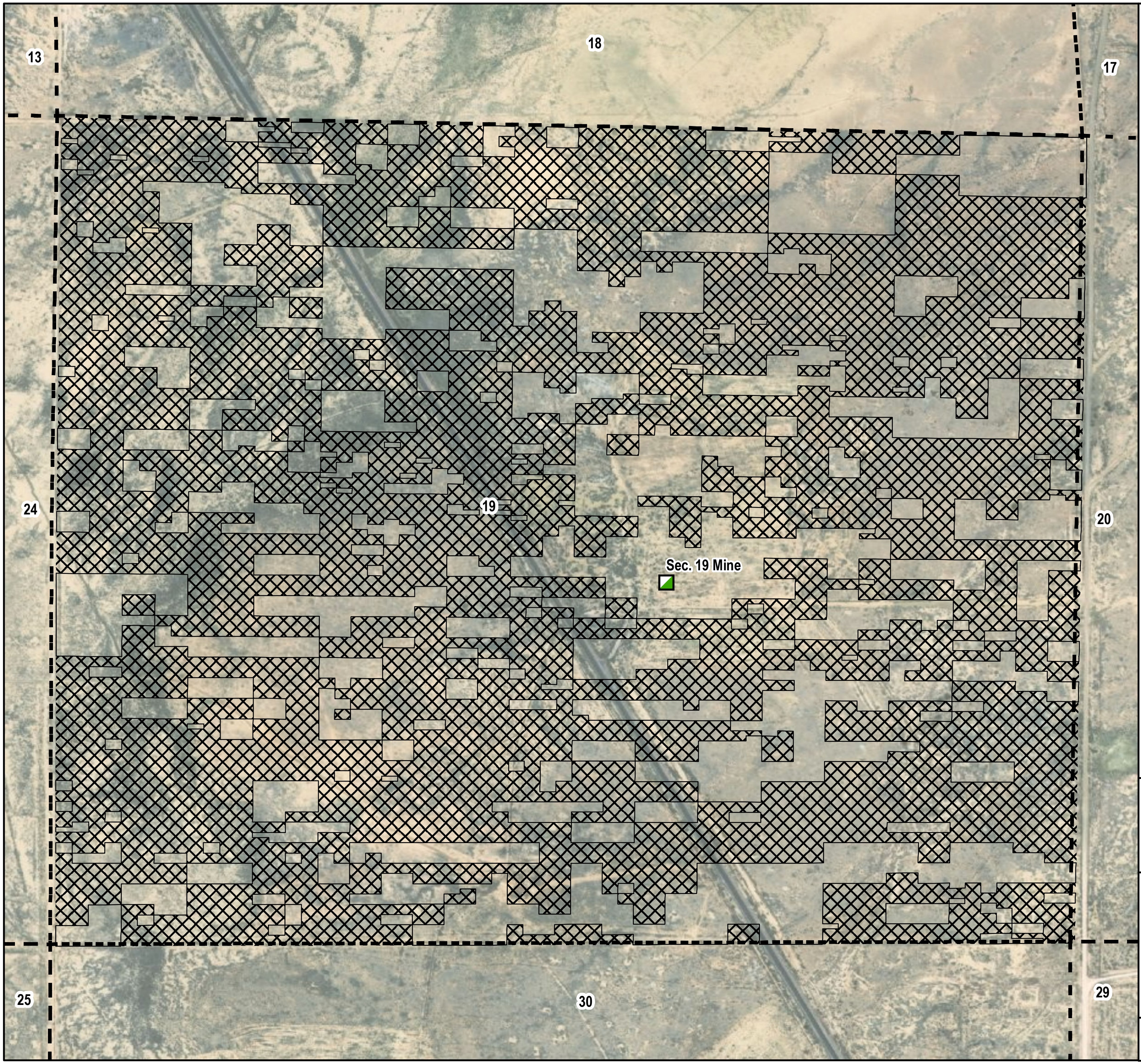
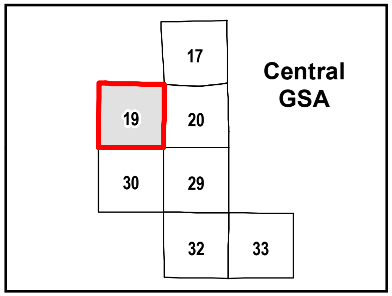


FIGURE 1-9
ASPECT AERIAL GAMMA SURVEY MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-9 - ASPECT Aerial Gamma Survey Map.mxd 11:17:11 AM 9/23/2020 GRANTSGIS





LEGEND

- No Access
- Section Boundary
- Tronox Surface Expression

NOTE:
Ownership Status data layer was interpolated from documentation provided by RAML.

N

0 1,300
Feet

SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: WORLD IMAGERY; ESRI

USEPA REGION 6

FIGURE 1-10
SECTION 19 ACCESS MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-10 - Section 19 Access Map.mxd 11:38:41 AM 9/24/2020 GRANTSGIS

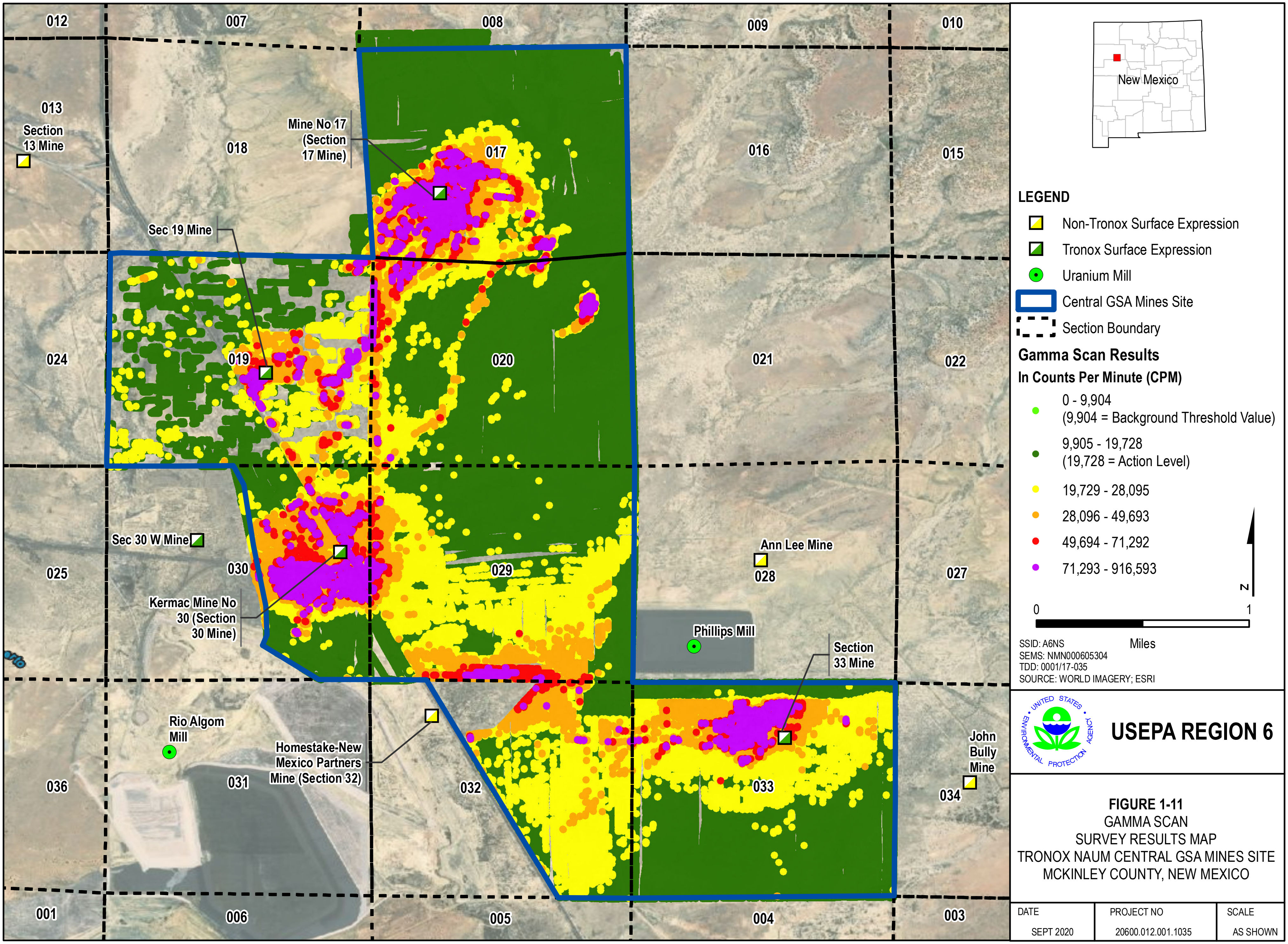


FIGURE 1-11
GAMMA SCAN
SURVEY RESULTS MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

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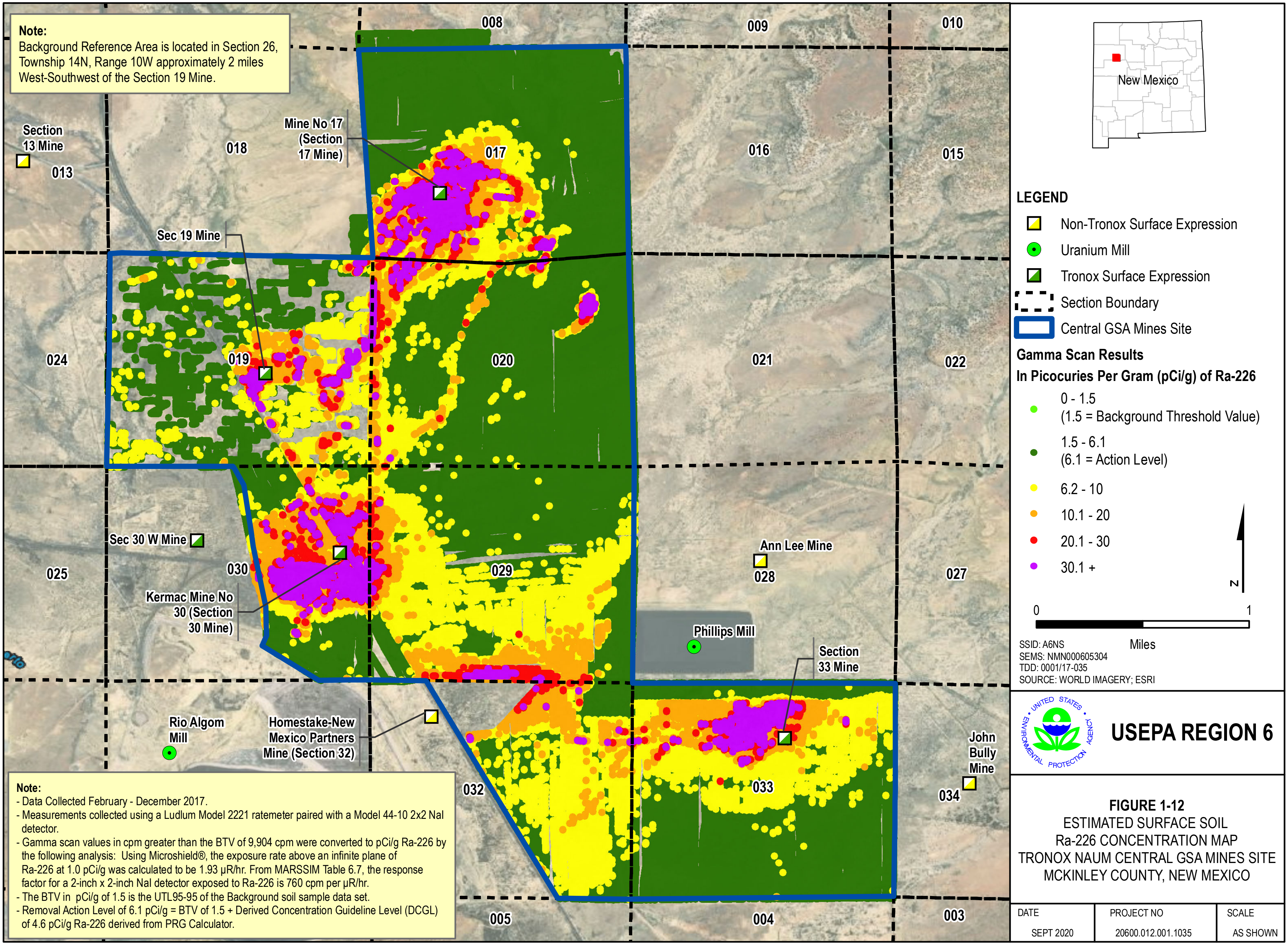

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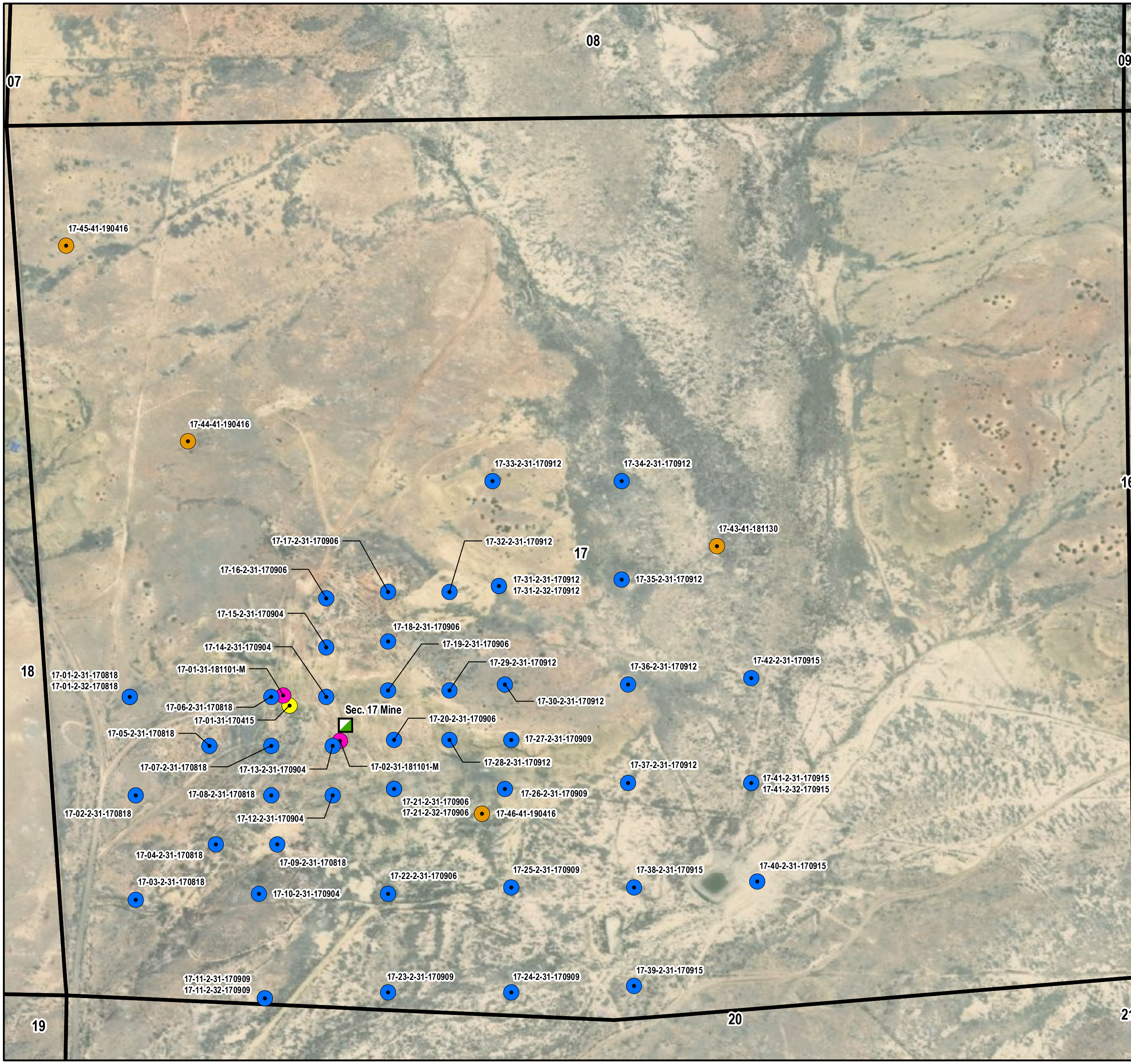
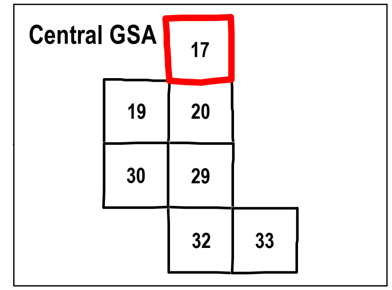




LEGEND

- Tronox Surface Expression
- Section Boundary

Sample Type

- Subsurface (12"-24") Grab Soil Sample Location
- Surface Grab Soil Sample Analyzed for TAL Metals
- Surface (0"-6") Composite Soil Sample Location
- Surface (0"-6") Grab Soil Sample Location

N

0 1,000

Feet

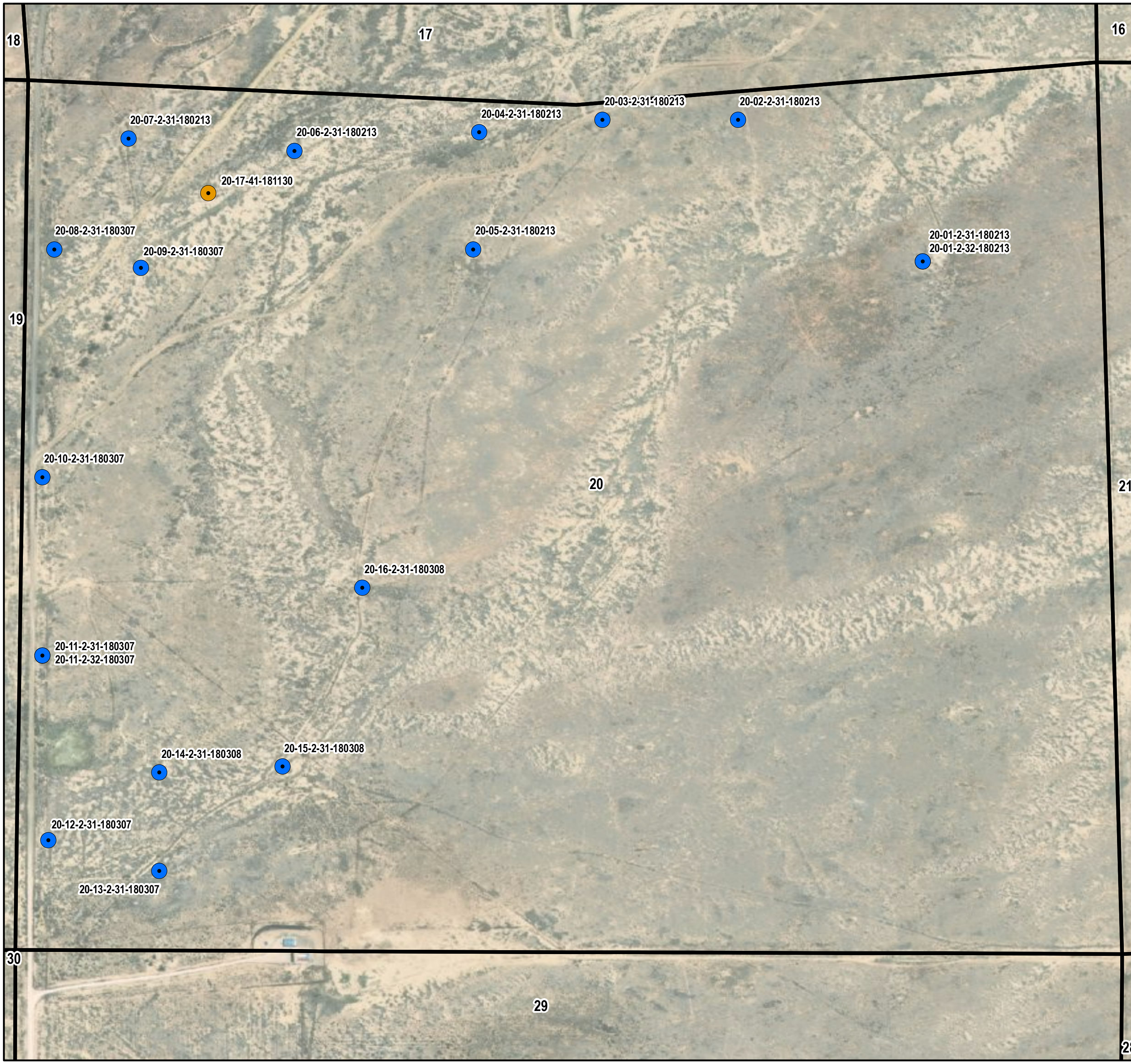
SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: WORLD IMAGERY; ESRI

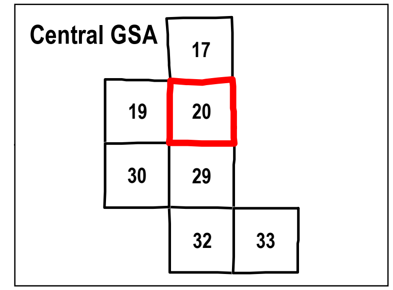
USEPA REGION 6

FIGURE 1-13
SECTION 17 SOIL SAMPLE LOCATION MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-13 - Section 17 Soil Sample Location Map.mxd 12:12:23 PM 9/23/2020 GRANTSGIS





LEGEND

Section Boundary

Sample Type

Subsurface (12”-24”) Grab Soil Sample Location

Surface (0"-6") Composite Soil Sample Location

N

0 1,000

Feet

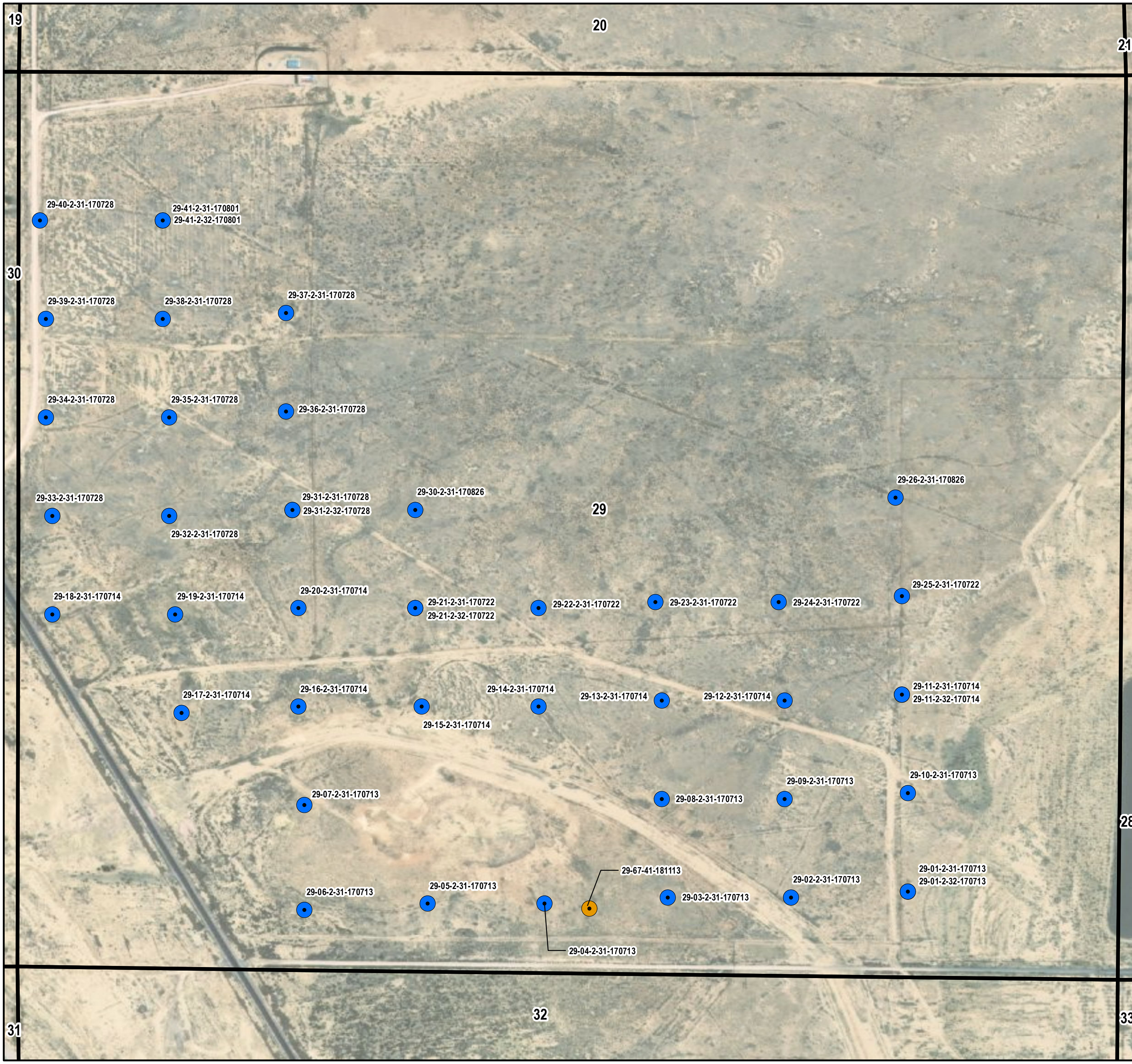
SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: WORLD IMAGERY; ESRI

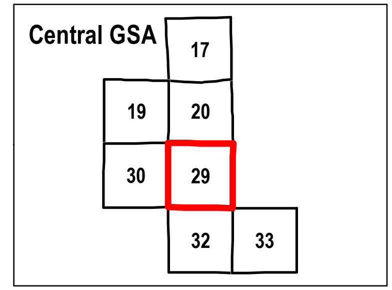
USEPA REGION 6

FIGURE 1-14
SECTION 20 SOIL SAMPLE LOCATION MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-14 - Section 20 Soil Sample Location Map.mxd 12:29:46 PM 9/23/2020 GRANTSGIS





LEGEND

Section Boundary

Sample Type

Subsurface (12"-24") Grab Soil Sample Location

Surface (0"-6") Composite Soil Sample Location

N

0 1,000

Feet

SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE:WORLD IMAGERY; ESRI

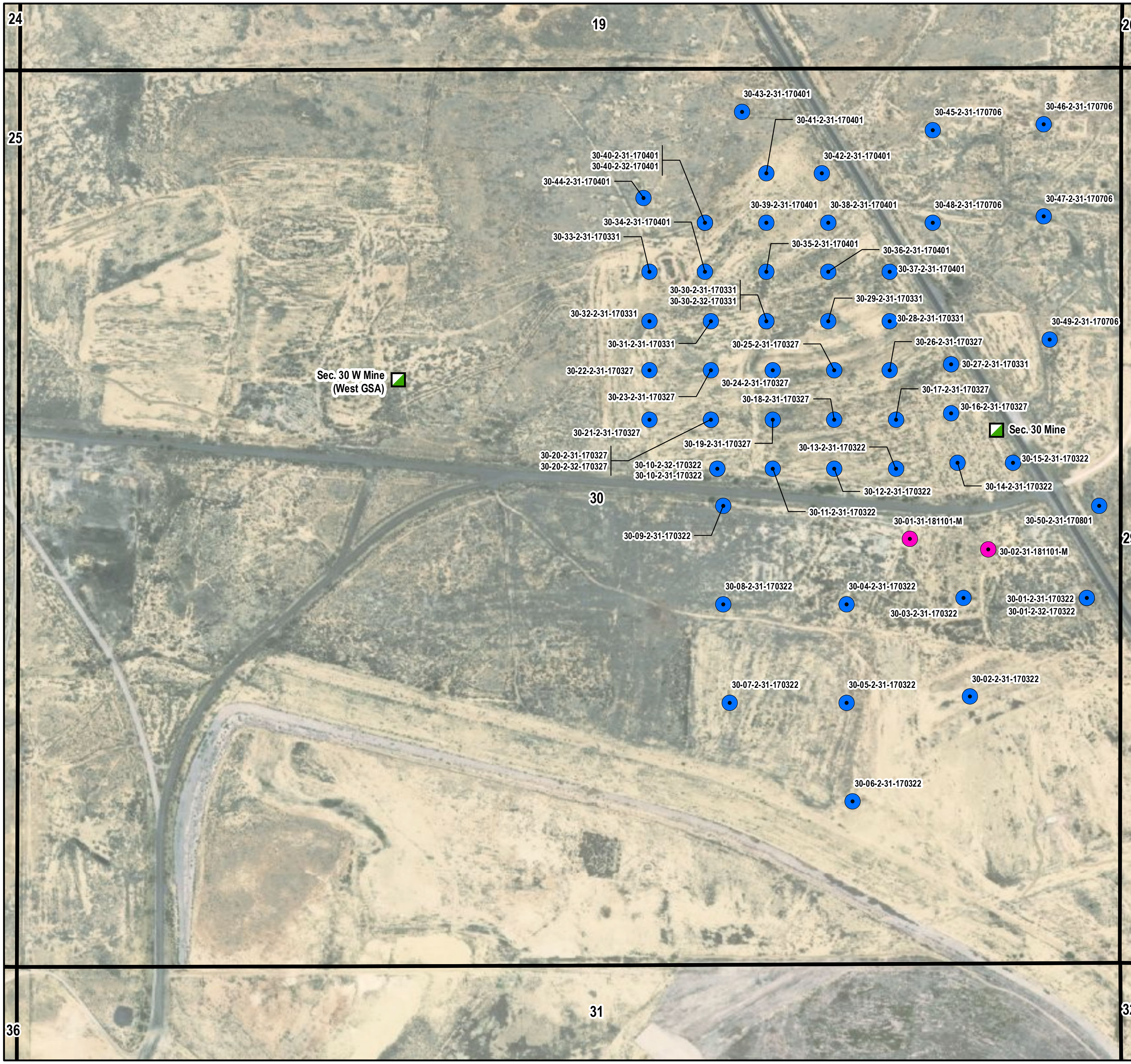
USEPA REGION 6

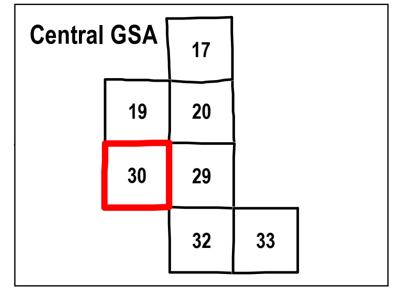
FIGURE 1-15

SECTION 29 SOIL SAMPLES LOCATION MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-15 - Section 29 Soil Sample Location Map.mxd 12:47:17 PM 9/23/2020 GRANTSGIS





LEGEND

Tronox Surface Expression

Section Boundary

Sample Type

Subsurface (12"-24") Grab Soil Sample Location

Surface Grab Soil Sample Analyzed for TAL Metals

N

0 1,000

Feet

SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: WORLD IMAGERY; ESRI

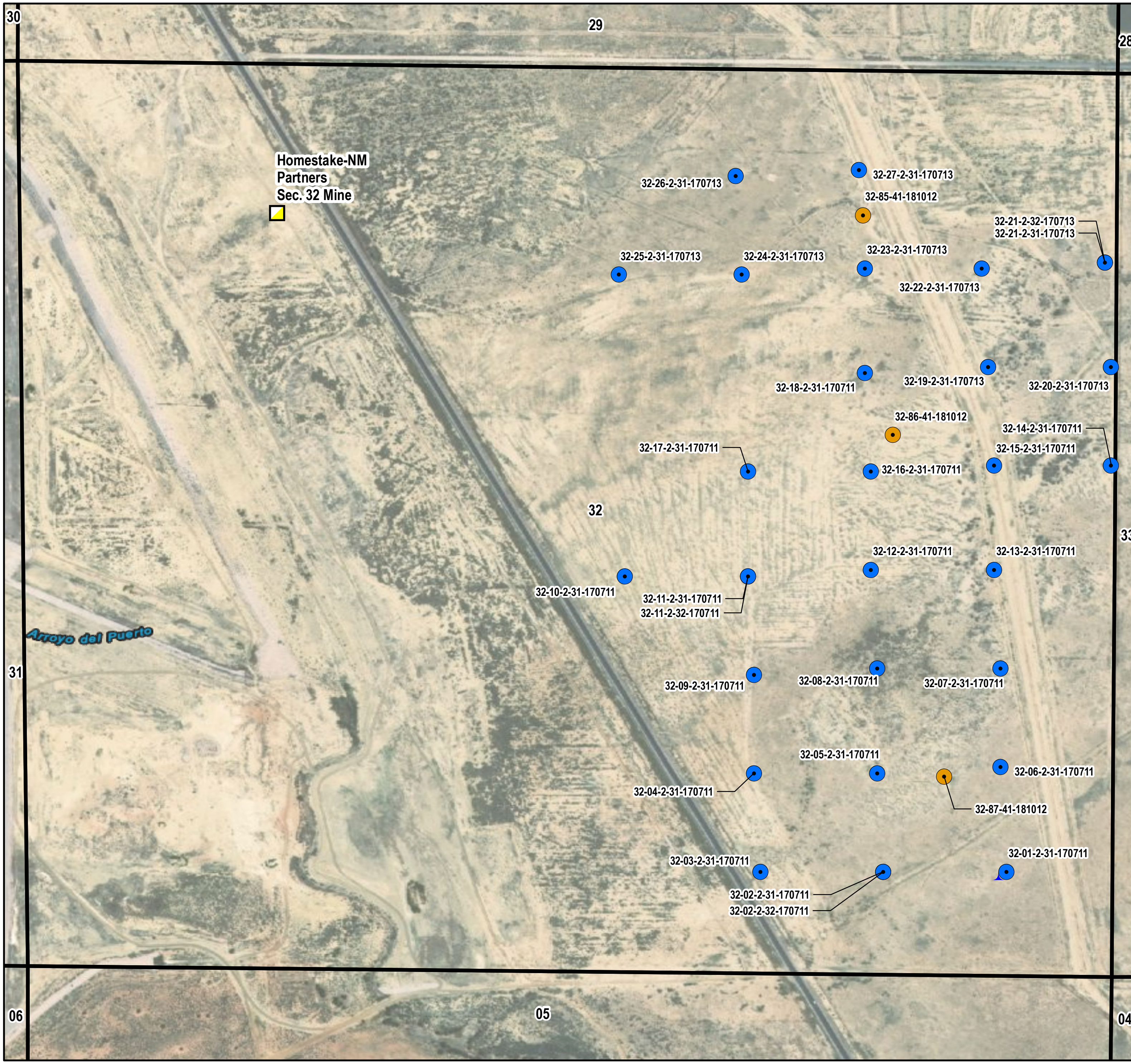
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

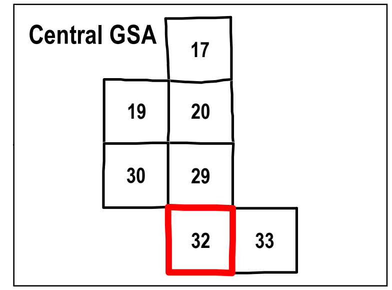
USEPA REGION 6

FIGURE 1-16
SECTION 30 SOIL SAMPLE LOCATION MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-16 - Section 30 Soil Sample Location Map.mxd 12:54:36 PM 9/23/2020 GRANTSGIS





LEGEND

Non-Tronox Surface Expression

Section Boundary

Sample Type

Subsurface (12"-24") Grab Soil Sample Location

Surface (0"-6") Composite Soil Sample Location

N

0 1,000

Feet

SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: ESRI ONLINE IMAGERY

USEPA REGION 6

FIGURE 1-17
SECTION 32 SOIL SAMPLE LOCATION MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

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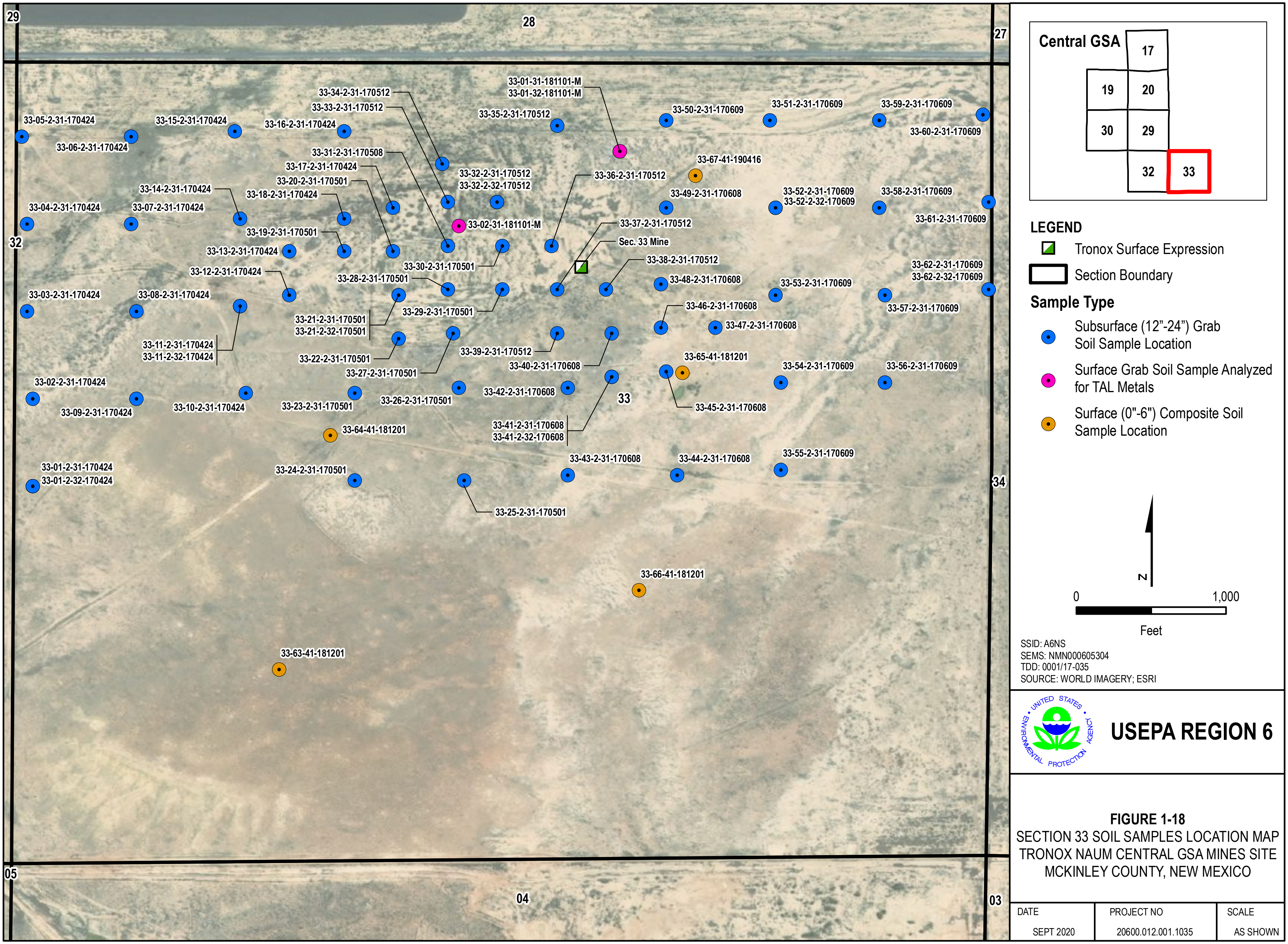


USEPA REGION 6

FIGURE 1-18
SECTION 33 SOIL SAMPLES LOCATION MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-18 - Section 33 Soil Sample Location Map.mxd 1:05:56 PM 9/23/2020 GRANTSGIS

Central GSA

	17	
19	20	
30	29	
	32	33

LEGEND

- Tronox Surface Expression
- Section Boundary

Sample Type

- Surface Grab Soil Sample Analyzed for TAL Metals
- Surface (0"-6") Composite Soil Sample Location

N

0 1,000

Feet

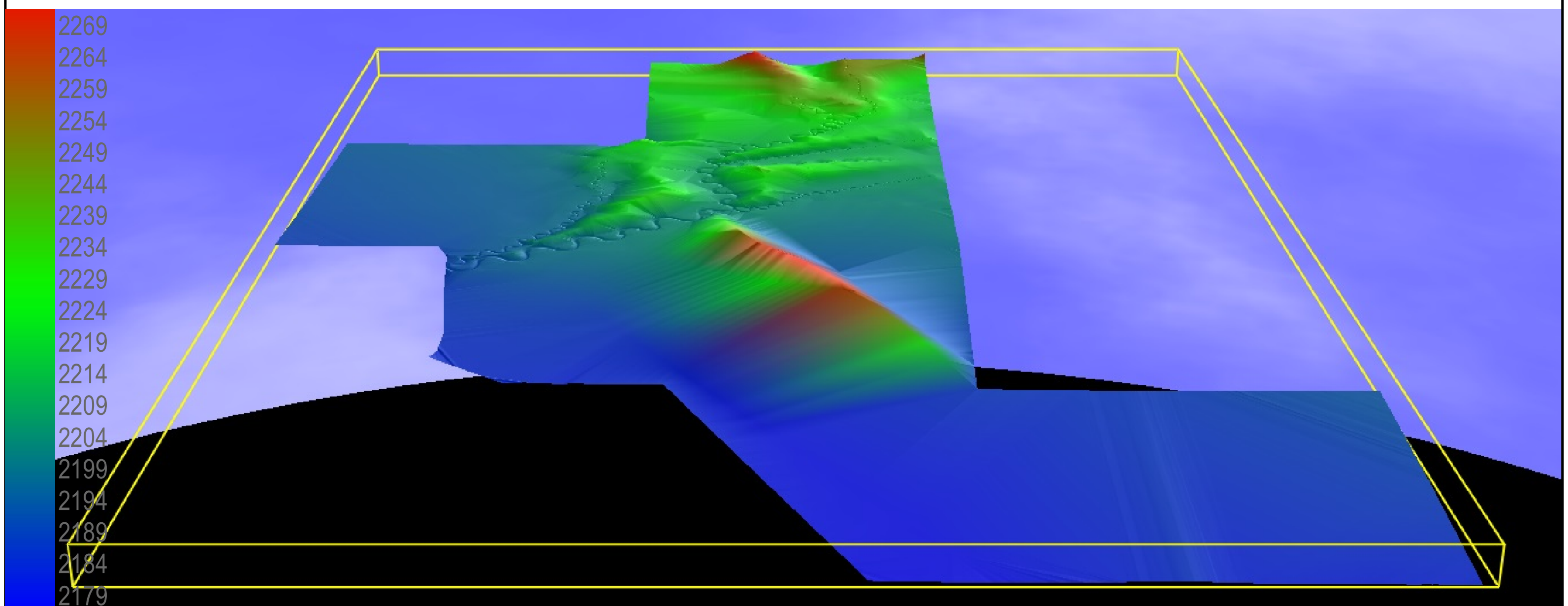
SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: WORLD IMAGERY; ESRI

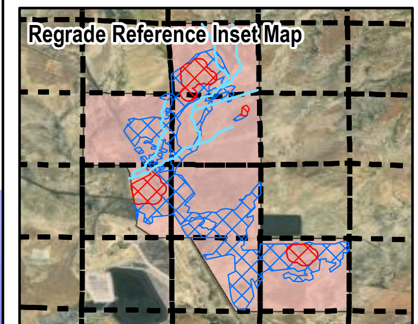
USEPA REGION 6

FIGURE 1-19
SECTION 19 SOIL SAMPLE LOCATION MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-19 - Section 19 Soil Sample Location Map.mxd 1:15:06 PM 9/23/2020 GRANTSGIS





LEGEND

- Approximate Channel Location
- 1 ft. Removal Zone
- 2 ft. Removal Zone
- Approximate Regrade Area
- Section Boundary

SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: CARLSON NATURAL REGRADE WITH GEOFLUV

NOTES
- Elevation in meters.
- This figure depicts a post-removal regrade model if either removal action alternative # 2 (Excavation and Off-Site Disposal of Contaminated Soils at a Licensed, Low-Level Radioactive Waste Facility) or alternative #4 (Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Incised [Below-Ground], ALSD Regional Repository) becomes the accepted alternative. If alternative #3 (Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Aboveground, On-Site Repository) becomes the accepted removal alternative, a repository as designed preliminarily in Appendix K will be incorporated into a regrade model.

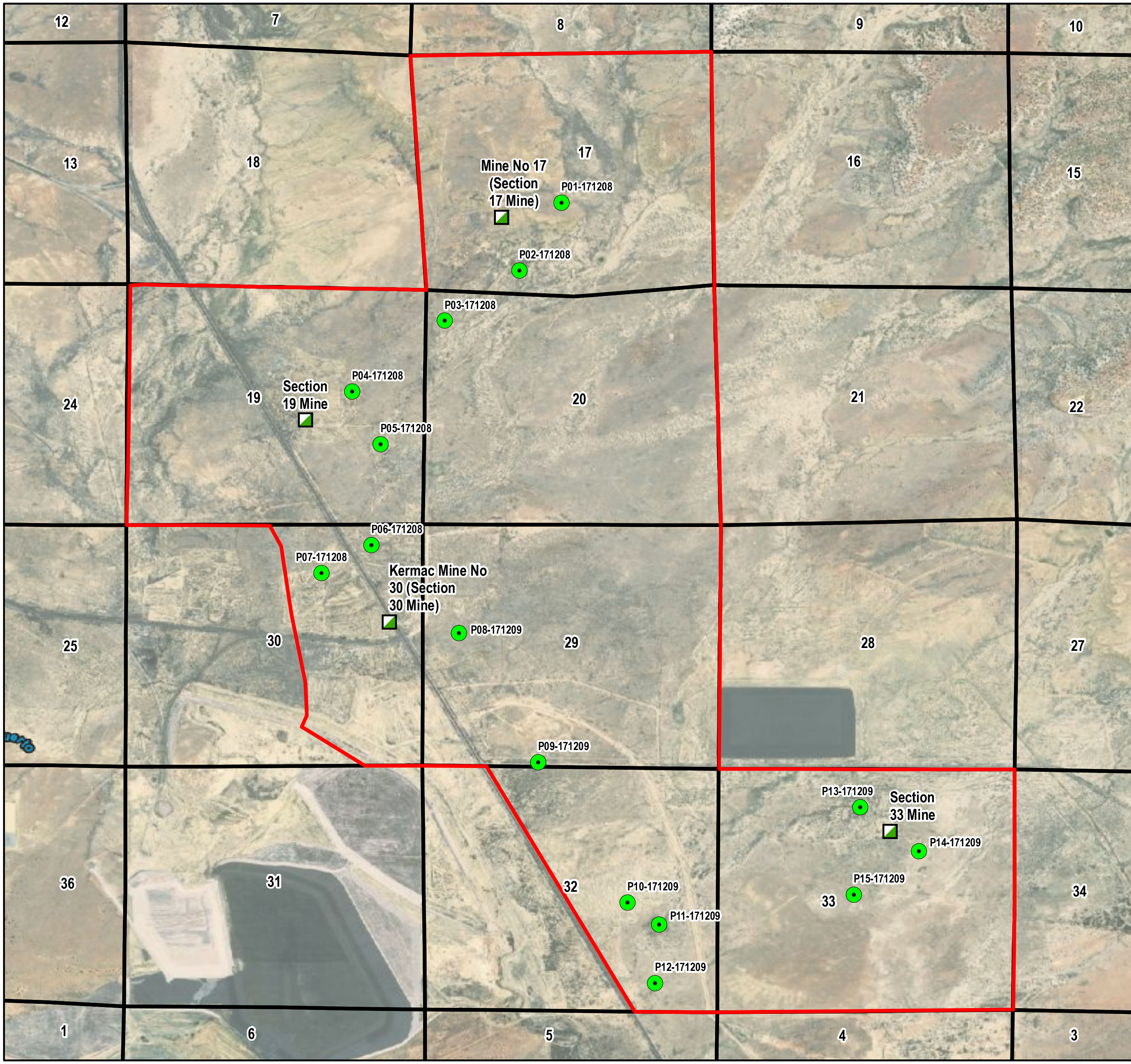
N

USEPA REGION 6

FIGURE 1-20
REGRADE MODEL OF
CENTRAL GSA MINES SITE
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-20 - Regrade Model of Central GSA Mines Site.mxd 11:46:39 AM 9/23/2020 GRANTSGIS



LEGEND

- Tronox Surface Expression
- Soil/Vegetation Sample Analyzed for Fe, Zn, Cu, Mn, Mo, U, V, Se
- Central GSA Mines Site
- Section Boundary

Note:
1. Iron (Fe), Zinc (Zn), Copper (Cu), Manganese (Mn), Molybdenum (Mo), Uranium (U), Vanadium (V), and Selenium (Se).

N

0 1

Miles

SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: WORLD IMAGERY; ESRI

USEPA REGION 6

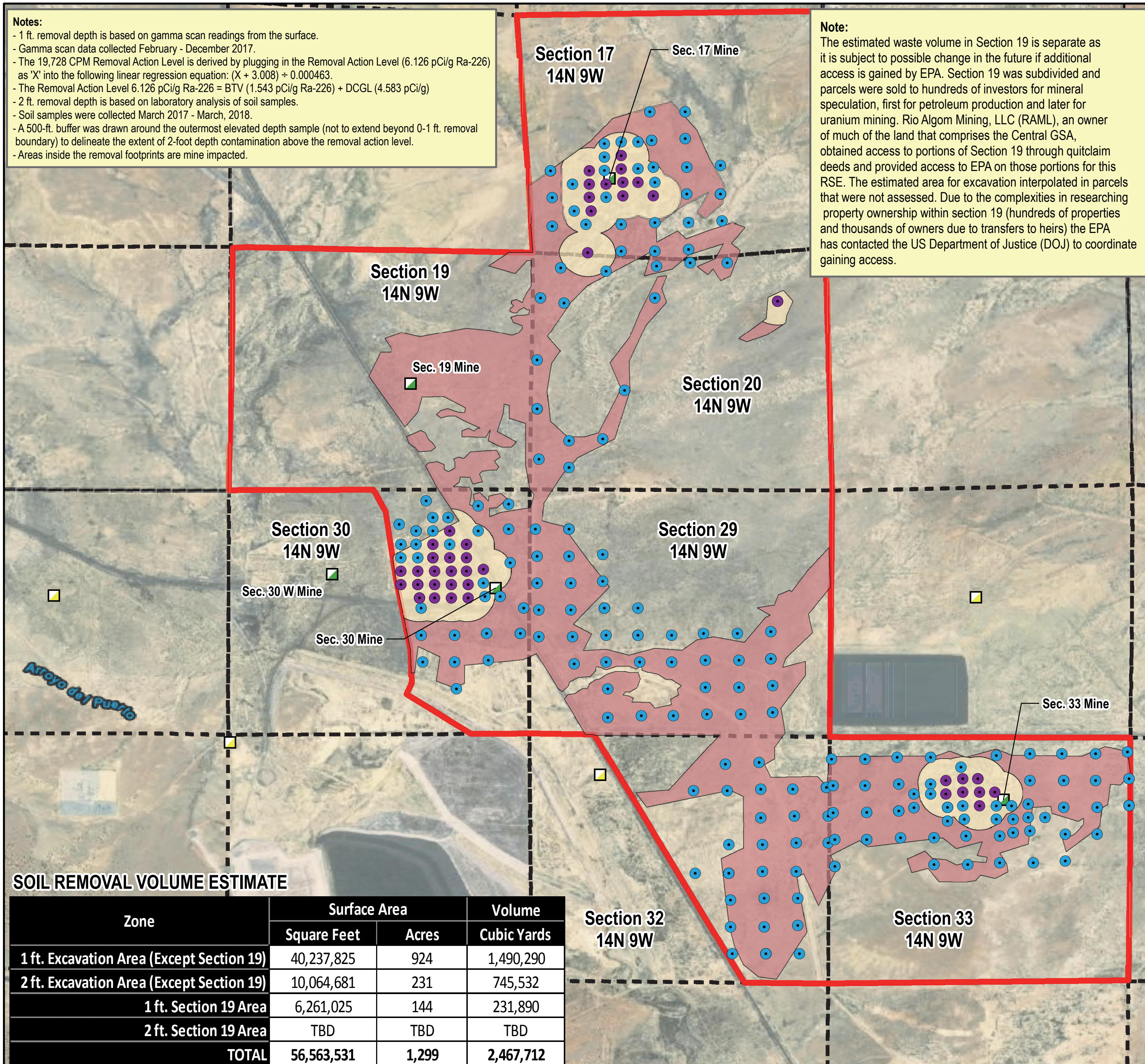
FIGURE 1-21
SOIL AND VEGETATION
SAMPLE LOCATION MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 1-21 - Soil and Vegetation Sample Location Map1.mxd 1:21:45 PM 9/23/2020 GRANTSGIS

Notes:
- 1 ft. removal depth is based on gamma scan readings from the surface.
- Gamma scan data collected February - December 2017.
- The 19,728 CPM Removal Action Level is derived by plugging in the Removal Action Level (6.126 pCi/g Ra-226) as 'X' into the following linear regression equation: (X + 3.008) ÷ 0.000463.
- The Removal Action Level 6.126 pCi/g Ra-226 = BTV (1.543 pCi/g Ra-226) + DCGL (4.583 pCi/g)
- 2 ft. removal depth is based on laboratory analysis of soil samples.
- Soil samples were collected March 2017 - March, 2018.
- A 500-ft. buffer was drawn around the outermost elevated depth sample (not to extend beyond 0-1 ft. removal boundary) to delineate the extent of 2-foot depth contamination above the removal action level.
- Areas inside the removal footprints are mine impacted.

Note:
The estimated waste volume in Section 19 is separate as it is subject to possible change in the future if additional access is gained by EPA. Section 19 was subdivided and parcels were sold to hundreds of investors for mineral speculation, first for petroleum production and later for uranium mining. Rio Algom Mining, LLC (RAML), an owner of much of the land that comprises the Central GSA, obtained access to portions of Section 19 through quitclaim deeds and provided access to EPA on those portions for this RSE. The estimated area for excavation interpolated in parcels that were not assessed. Due to the complexities in researching property ownership within section 19 (hundreds of properties and thousands of owners due to transfers to heirs) the EPA has contacted the US Department of Justice (DOJ) to coordinate gaining access.



SOIL REMOVAL VOLUME ESTIMATE

Zone	Surface Area		Volume
	Square Feet	Acres	Cubic Yards
1 ft. Excavation Area (Except Section 19)	40,237,825	924	1,490,290
2 ft. Excavation Area (Except Section 19)	10,064,681	231	745,532
1 ft. Section 19 Area	6,261,025	144	231,890
2 ft. Section 19 Area	TBD	TBD	TBD
TOTAL	**56,563,531**	**1,299**	**2,467,712**

Legend

- Non-Tronox Surface Expression
- Tronox Surface Expression
- Central GSA Mines Site
- Section Boudary

Soil Sample (2 ft. depth)

Concentration (pCi/g Ra-226)

- ≤ 6.1
- > 6.1 (Action Level)
- 0-1 ft. (19,728 CPM Action Level)
- 0-2 ft. (6.1 pCi/g of Ra-226 Action Level)

N

0 2,500 5,000

Feet

SSID: A6NS
SEMS: NMN000605304
TDD: 0001/17-035
SOURCE: ESRI ONLINE IMAGERY

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FIGURE 2-1
SOIL REMOVAL ESTIMATE MAP
TRONOX NAUM CENTRAL GSA MINES SITE
MCKINLEY COUNTY, NEW MEXICO

DATE	PROJECT NO	SCALE
SEPT 2020	20600.012.001.1035	AS SHOWN

FILE: Z:\TRONOX-CENTRAL-GSA_GIS\mxd\Misc\EECA\Figure 2-1 - Soil Removal Estimate Map.mxd 3:10:23 PM 9/23/2020 GRANTSGIS

TABLES

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Table 1-1
Background Reference Area Summary of Field and Laboratory Measurements
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Sample ID	[1]Ludlum 2"x2" NaI One-Minute Stationary Measurement (counts per minute [cpm])	Laboratory Gamma Spectroscopy Result Radium-226 (picocuries per gram [pCi/g])
26BKGD-01-61-160303	9,513	1.14
26BKGD-02-61-160303	9,774	0.894
26BKGD-03-61-160303	9,307	1.05
26BKGD-04-61-160303	9,486	1.18
26BKGD-05-61-160303	9,447	0.984
26BKGD-06-61-160303	9,403	1.02
26BKGD-07-61-160303	9,622	1.30
26BKGD-08-61-160303	9,163	1.06
26BKGD-09-61-160303	9,280	1.15
26BKGD-10-61-160303	9,673	1.32
26BKGD-11-61-160303	9,614	1.09
26BKGD-12-61-160303	9,159	1.19
26BKGD-13-61-160303	9,232	0.850
26BKGD-14-61-160303	9,556	1.27
26BKGD-15-61-160303	9,607	1.35
26BKGD-16-61-160303	9,024	0.838
26BKGD-17-61-160303	9,228	0.960
26BKGD-18-61-160303	9,569	1.35
26BKGD-19-61-160303	9,461	1.06
26BKGD-20-61-160303	9,413	0.978
Mean	***9,427***	***1.12***
Standard Deviation	***199***	***0.179***
Coefficient of Variance	***0.02***	***0.16***

[1]One-minute stationary gamma measurements were collected with a Ludlum Model 2221 Rate Meter attached to a Model 44-10 Sodium Iodide (NaI) 2-inch by 2-inch Scintillator Probe.

Table 1-2
Surface Soil Samples - Gamma Spectroscopy Results
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Sample ID[1,2]	Latitude	Longitude	Collection Method	Sample Type	Radium 226 (picocuries per gram [pCi/g]) Field Laboratory Multichannel Analyzer (MCA)[3]	Radium 226 (picocuries per gram [pCi/g]) Off-site Laboratory[4,5]	Figure Depicting Sample Location
17-01-31-170415	35.439658	-107.818199	Grab	Field Sample	n/a	156	1-13
17-43-41-181130	35.44225	-107.811258	Composite	Field Sample	n/a	4.45	1-19
17-44-41-190416	35.44395	-107.819854	Composite	Field Sample	n/a	5.02	1-13
17-45-41-190416	35.447127	-107.821833	Composite	Field Sample	n/a	4.24	1-18
17-46-41-190416	35.437902	-107.815071	Composite	Field Sample	n/a	3.92	1-18
19-01-41-181130	35.424843	-107.825308	Composite	Field Sample	n/a	6.64	1-19
19-02-41-181130	35.430127	-107.824624	Composite	Field Sample	n/a	5.92	1-18
20-17-41-181130	35.433111	-107.818905	Composite	Field Sample	n/a	9.05	1-18
29-67-41-181113	35.40722	-107.812771	Composite	Field Sample	n/a	10.66	1-15
32-85-41-181012	35.403765	-107.808332	Composite	Field Sample	n/a	9.46	1-14
32-86-41-181012	35.400195	-107.807845	Composite	Field Sample	n/a	9.11	1-17
32-87-41-181012	35.394649	-107.807009	Composite	Field Sample	n/a	11.59	1-17
33-63-41-181201	35.394942	-107.799385	Composite	Field Sample	n/a	12.67	1-17
33-64-41-181201	35.399231	-107.798452	Composite	Field Sample	n/a	1.41	1-13
33-65-41-181201	35.400375	-107.792001	Composite	Field Sample	n/a	1.72	1-13
33-66-41-181201	35.396393	-107.792798	Composite	Field Sample	n/a	9.51	1-13
33-67-41-190416	35.403988	-107.791766	Composite	Field Sample	n/a	23.2	1-18

1 All samples collected from 0-6 inches below ground surface.

2 First two digits of the sample number indicate the section from which they were collected.

3 n/a denotes that the sample was not analyzed with the on-site MCA.

4 Samples analyzed for Bismuth-214. Samples were held before analysis so that Bismuth-214 was in equilibrium with Radium-226.

5 Sample results above the 6.4 pCi/g Removal Action Level (RAL) are shaded in gray.

Table 1-3
Subsurface Soil Samples - Gamma Spectroscopy Results
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Sample ID$_{1,2}$	Latitude	Longitude	Collection Method	Sample Type	Radium 226 (picocuries per gram [pCi/g])		Figure Depicting Sample Location
					Field Laboratory Multichannel Analyzer (MCA)$_{3,4,5}$	Off-site Laboratory$_{3,4,5,6}$	
17-01-2-31-170818	35.4398	-107.8208	Grab	Field Sample	1.8	n/a	1-13
17-01-2-32-170818	35.4398	-107.8208	Grab	Field Duplicate	1.6	n/a	1-13
17-02-2-31-170818	35.4382	-107.8207	Grab	Field Sample	2	n/a	1-13
17-03-2-31-170818	35.4365	-107.8207	Grab	Field Sample	1.9	n/a	1-13
17-04-2-31-170818	35.4374	-107.8194	Grab	Field Sample	1.5	n/a	1-13
17-05-2-31-170818	35.4390	-107.8195	Grab	Field Sample	2.4	n/a	1-13
17-06-2-31-170818	35.4398	-107.8185	Grab	Field Sample	45.2	n/a	1-13
17-07-2-31-170818	35.4390	-107.8185	Grab	Field Sample	45.6	n/a	1-13
17-08-2-31-170818	35.4382	-107.8185	Grab	Field Sample	177.7	n/a	1-13
17-09-2-31-170818	35.4374	-107.8184	Grab	Field Sample	8.2	8.05	1-13
17-10-2-31-170904	35.4366	-107.8187	Grab	Field Sample	1.9	n/a	1-13
17-11-2-31-170909	35.4349	-107.8186	Grab	Field Sample	8.7	10.1	1-13
17-12-2-31-170904	35.4382	-107.8175	Grab	Field Sample	2.6	n/a	1-13
17-13-2-31-170904	35.4390	-107.8175	Grab	Field Sample	24.5	n/a	1-13
17-14-2-31-170904	35.4398	-107.8176	Grab	Field Sample	4.8	3.07	1-13
17-15-2-31-170904	35.4406	-107.8176	Grab	Field Sample	1.6	n/a	1-13
17-16-2-31-170906	35.4414	-107.8176	Grab	Field Sample	2.4	n/a	1-13
17-17-2-31-170906	35.4415	-107.8166	Grab	Field Sample	2.5	n/a	1-13
17-18-2-31-170906	35.4407	-107.8166	Grab	Field Sample	29.5	n/a	1-13
17-19-2-31-170906	35.4399	-107.8166	Grab	Field Sample	9.8	11.5	1-13
17-20-2-31-170906	35.4391	-107.8165	Grab	Field Sample	23.2	n/a	1-13
17-21-2-31-170906	35.4383	-107.8165	Grab	Field Sample	19	n/a	1-13
17-22-2-31-170906	35.4366	-107.8166	Grab	Field Sample	2.2	n/a	1-13
17-23-2-31-170909	35.4350	-107.8166	Grab	Field Sample	2.2	n/a	1-13
17-24-2-31-170909	35.4350	-107.8146	Grab	Field Sample	2.9	n/a	1-13
17-25-2-31-170909	35.4367	-107.8146	Grab	Field Sample	2.2	n/a	1-13
17-26-2-31-170909	35.4383	-107.8147	Grab	Field Sample	41.6	n/a	1-13
17-27-2-31-170909	35.4391	-107.8146	Grab	Field Sample	1.6	n/a	1-13
17-28-2-31-170912	35.4391	-107.8156	Grab	Field Sample	81.3	n/a	1-13
17-29-2-31-170912	35.4399	-107.8156	Grab	Field Sample	2.7	n/a	1-13
17-30-2-31-170912	35.4400	-107.8147	Grab	Field Sample	1.4	n/a	1-13
17-31-2-31-170912	35.4416	-107.8148	Grab	Field Sample	1.6	n/a	1-13
17-31-2-32-170912	35.4416	-107.8148	Grab	Field Duplicate	1.4	n/a	1-13
17-32-2-31-170912	35.4415	-107.8156	Grab	Field Sample	2.7	3.35	1-13
17-33-2-31-170912	35.4433	-107.8149	Grab	Field Sample	4.6	n/a	1-13
17-34-2-31-170912	35.4433	-107.8128	Grab	Field Sample	3.1	n/a	1-13
17-35-2-31-170912	35.4417	-107.8128	Grab	Field Sample	3.2	n/a	1-13
17-36-2-31-170912	35.4400	-107.8127	Grab	Field Sample	3	n/a	1-13
17-37-2-31-170912	35.4384	-107.8127	Grab	Field Sample	2.6	n/a	1-13
17-38-2-31-170915	35.4367	-107.8126	Grab	Field Sample	2.6	n/a	1-13
17-39-2-31-170915	35.4351	-107.8126	Grab	Field Sample	3.5	n/a	1-13
17-40-2-31-170915	35.4368	-107.8106	Grab	Field Sample	2.9	2.24	1-13
17-41-2-31-170915	35.4384	-107.8107	Grab	Field Sample	3.2	n/a	1-13
17-41-2-32-170915	35.4384	-107.8107	Grab	Field Duplicate	3	n/a	1-13

Table 1-3 (continued)
Subsurface Soil Samples - Gamma Spectroscopy Results
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Sample ID$_{1,2}$	Latitude	Longitude	Collection Method	Sample Type	Radium 226 (picocuries per gram [pCi/g]) Field Laboratory Multichannel Analyzer (MCA)$_{3,4,5}$	Radium 226 (picocuries per gram [pCi/g]) Off-site Laboratory$_{3,4,5,6}$	Figure Depicting Sample Location
17-42-2-31-170915	35.4401	-107.8107	Grab	Field Sample	2.4	n/a	1-13
20-01-2-31-180213	35.4320	-107.8073	Grab	Field Sample	5.2	3.9	1-14
20-01-2-32-180213	35.4320	-107.8073	Grab	Field Duplicate	7.8	7.12	1-14
20-02-2-31-180213	35.4343	-107.8103	Grab	Field Sample	2.1	n/a	1-14
20-03-2-31-180213	35.4343	-107.8125	Grab	Field Sample	2.5	n/a	1-14
20-04-2-31-180213	35.4341	-107.8145	Grab	Field Sample	3.5	n/a	1-14
20-05-2-31-180213	35.4322	-107.8146	Grab	Field Sample	2.5	n/a	1-14
20-06-2-31-180213	35.4338	-107.8175	Grab	Field Sample	3.7	n/a	1-14
20-07-2-31-180213	35.4340	-107.8202	Grab	Field Sample	2.4	n/a	1-14
20-08-2-31-180307	35.4322	-107.8214	Grab	Field Sample	4.2	2.34	1-14
20-09-2-31-180307	35.4319	-107.8200	Grab	Field Sample	3.3	n/a	1-14
20-10-2-31-180307	35.4285	-107.8216	Grab	Field Sample	1.9	n/a	1-14
20-11-2-31-180307	35.4256	-107.8216	Grab	Field Sample	2.1	0.9	1-14
20-11-2-32-180307	35.4256	-107.8216	Grab	Field Duplicate	2.5	n/a	1-14
20-12-2-31-180307	35.4226	-107.8215	Grab	Field Sample	3.9	n/a	1-14
20-13-2-31-180307	35.4221	-107.8197	Grab	Field Sample	2.1	n/a	1-14
20-14-2-31-180308	35.4237	-107.8197	Grab	Field Sample	3.1	n/a	1-14
20-15-2-31-180308	35.4238	-107.8177	Grab	Field Sample	3.4	n/a	1-14
20-16-2-31-180308	35.4267	-107.8164	Grab	Field Sample	1.8	n/a	1-14
29-01-2-31-170713	35.4075	-107.8076	Grab	Field Sample	2.3	n/a	1-15
29-01-2-32-170713	35.4075	-107.8076	Grab	Field Duplicate	2.2	n/a	1-15
29-02-2-31-170713	35.4074	-107.8095	Grab	Field Sample	2.9	1.47	1-15
29-03-2-31-170713	35.4074	-107.8115	Grab	Field Sample	1.5	n/a	1-15
29-04-2-31-170713	35.4073	-107.8135	Grab	Field Sample	1.7	n/a	1-15
29-05-2-31-170713	35.4073	-107.8154	Grab	Field Sample	2.2	n/a	1-15
29-06-2-31-170713	35.4072	-107.8174	Grab	Field Sample	1.8	n/a	1-15
29-07-2-31-170713	35.4089	-107.8174	Grab	Field Sample	1.5	n/a	1-15
29-08-2-31-170713	35.4090	-107.8116	Grab	Field Sample	1.4	n/a	1-15
29-09-2-31-170713	35.4090	-107.8096	Grab	Field Sample	2.5	n/a	1-15
29-10-2-31-170713	35.4091	-107.8076	Grab	Field Sample	2.1	n/a	1-15
29-11-2-31-170714	35.4107	-107.8077	Grab	Field Sample	2.4	n/a	1-15
29-11-2-32-170714	35.4107	-107.8077	Grab	Field Duplicate	2.3	n/a	1-15
29-12-2-31-170714	35.4106	-107.8096	Grab	Field Sample	1.5	n/a	1-15
29-13-2-31-170714	35.4106	-107.8116	Grab	Field Sample	1.6	n/a	1-15
29-14-2-31-170714	35.4105	-107.8136	Grab	Field Sample	2	n/a	1-15
29-15-2-31-170714	35.4105	-107.8155	Grab	Field Sample	2.7	n/a	1-15
29-16-2-31-170714	35.4105	-107.8175	Grab	Field Sample	2.5	n/a	1-15
29-17-2-31-170714	35.4104	-107.8194	Grab	Field Sample	1.8	n/a	1-15
29-18-2-31-170714	35.4120	-107.8215	Grab	Field Sample	3.1	1.17	1-15
29-19-2-31-170714	35.4120	-107.8195	Grab	Field Sample	3	1.51	1-15
29-20-2-31-170714	35.4121	-107.8175	Grab	Field Sample	1.9	n/a	1-15
29-21-2-31-170722	35.4121	-107.8156	Grab	Field Sample	1.5	n/a	1-15
29-21-2-32-170722	35.4121	-107.8156	Grab	Field Duplicate	1.6	n/a	1-15
29-22-2-31-170722	35.4121	-107.8136	Grab	Field Sample	1.6	n/a	1-15

Table 1-3 (continued)
Subsurface Soil Samples - Gamma Spectroscopy Results
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Sample ID[1,2]	Latitude	Longitude	Collection Method	Sample Type	Radium 226 (picocuries per gram [pCi/g])		Figure Depicting Sample Location
					Field Laboratory Multichannel Analyzer (MCA)[3,4,5]	Off-site Laboratory[3,4,5,6]	
29-23-2-31-170722	35.4122	-107.8117	Grab	Field Sample	1.8	n/a	1-15
29-24-2-31-170722	35.4122	-107.8097	Grab	Field Sample	2.1	n/a	1-15
29-25-2-31-170722	35.4123	-107.8077	Grab	Field Sample	2.7	n/a	1-15
29-30-2-31-170826	35.4137	-107.8156	Grab	Field Sample	2.7	n/a	1-15
29-31-2-31-170728	35.4137	-107.8176	Grab	Field Sample	1.7	n/a	1-15
29-31-2-32-170728	35.4137	-107.8176	Grab	Field Duplicate	1.6	n/a	1-15
29-32-2-31-170728	35.4136	-107.8196	Grab	Field Sample	1.5	n/a	1-15
29-33-2-31-170728	35.4136	-107.8215	Grab	Field Sample	2.5	n/a	1-15
29-34-2-31-170728	35.4152	-107.8216	Grab	Field Sample	2.7	n/a	1-15
29-35-2-31-170728	35.4152	-107.8196	Grab	Field Sample	1.9	n/a	1-15
29-36-2-31-170728	35.4153	-107.8177	Grab	Field Sample	2.9	1.22	1-15
29-37-2-31-170728	35.4169	-107.8177	Grab	Field Sample	1.5	n/a	1-15
29-38-2-31-170728	35.4168	-107.8197	Grab	Field Sample	1.9	n/a	1-15
29-39-2-31-170728	35.4168	-107.8216	Grab	Field Sample	3.7	1.83	1-15
29-40-2-31-170728	35.4184	-107.8217	Grab	Field Sample	1.6	n/a	1-15
29-41-2-31-170801	35.4184	-107.8197	Grab	Field Sample	1.6	n/a	1-15
29-41-2-32-170801	35.4184	-107.8197	Grab	Field Duplicate	2	n/a	1-15
30-01-2-31-170322	35.4122	-107.8226	Grab	Field Sample	2.8	n/a	1-16
30-01-2-32-170322	35.4122	-107.8226	Grab	Field Duplicate	1.9	n/a	1-16
30-02-2-31-170322	35.4106	-107.8245	Grab	Field Sample	3.7	n/a	1-16
30-03-2-31-170322	35.4122	-107.8246	Grab	Field Sample	2.4	n/a	1-16
30-04-2-31-170322	35.4121	-107.8265	Grab	Field Sample	2.3	n/a	1-16
30-05-2-31-170322	35.4105	-107.8265	Grab	Field Sample	1.6	n/a	1-16
30-06-2-31-170322	35.4089	-107.8264	Grab	Field Sample	3.1	n/a	1-16
30-07-2-31-170322	35.4105	-107.8284	Grab	Field Sample	2.2	n/a	1-16
30-08-2-31-170322	35.4121	-107.8285	Grab	Field Sample	2.6	n/a	1-16
30-09-2-31-170322	35.4137	-107.8285	Grab	Field Sample	2.8	n/a	1-16
30-10-2-31-170322	35.4143	-107.8286	Grab	Field Sample	28.3	n/a	1-16
30-10-2-32-170322	35.4143	-107.8286	Grab	Field Duplicate	23.1	n/a	1-16
30-11-2-31-170322	35.4143	-107.8277	Grab	Field Sample	7.8	5.61	1-16
30-12-2-31-170322	35.4143	-107.8267	Grab	Field Sample	12.8	11.6	1-16
30-13-2-31-170322	35.4143	-107.8257	Grab	Field Sample	319	n/a	1-16
30-14-2-31-170322	35.4144	-107.8247	Grab	Field Sample	3.6	n/a	1-16
30-15-2-31-170322	35.4144	-107.8238	Grab	Field Sample	2.9	n/a	1-16
30-16-2-31-170327	35.4152	-107.8248	Grab	Field Sample	2.3	n/a	1-16
30-17-2-31-170327	35.4151	-107.8257	Grab	Field Sample	27.2	n/a	1-16
30-18-2-31-170327	35.4151	-107.8267	Grab	Field Sample	94.9	n/a	1-16
30-19-2-31-170327	35.4151	-107.8277	Grab	Field Sample	159.8	n/a	1-16
30-20-2-31-170327	35.4151	-107.8287	Grab	Field Sample	5.4	3.53	1-16
30-20-2-32-170327	35.4151	-107.8287	Grab	Field Duplicate	7.4	n/a	1-16
30-21-2-31-170327	35.4151	-107.8297	Grab	Field Sample	7	6.47	1-16
30-22-2-31-170327	35.4159	-107.8297	Grab	Field Sample	19.3	n/a	1-16
30-23-2-31-170327	35.4159	-107.8287	Grab	Field Sample	46.3	n/a	1-16
30-24-2-31-170327	35.4159	-107.8277	Grab	Field Sample	90.7	n/a	1-16

Table 1-3 (continued)
Subsurface Soil Samples - Gamma Spectroscopy Results
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Sample ID[1,2]	Latitude	Longitude	Collection Method	Sample Type	Radium 226 (picocuries per gram [pCi/g])		Figure Depicting Sample Location
					Field Laboratory Multichannel Analyzer (MCA)[3,4,5]	Off-site Laboratory[3,4,5,6]	
30-25-2-31-170327	35.4159	-107.8267	Grab	Field Sample	38.5	n/a	1-16
30-26-2-31-170327	35.4159	-107.8258	Grab	Field Sample	149.1	n/a	
30-27-2-31-170331	35.4160	-107.8248	Grab	Field Sample	123.8	n/a	1-16
30-28-2-31-170331	35.4167	-107.8258	Grab	Field Sample	94.9	n/a	1-16
30-29-2-31-170331	35.4167	-107.8268	Grab	Field Sample	39.3	n/a	1-16
30-30-2-31-170331	35.4167	-107.8278	Grab	Field Sample	8.9	7.01	1-16
30-30-2-32-170331	35.4167	-107.8278	Grab	Field Duplicate	12.8	n/a	1-16
30-31-2-31-170331	35.4167	-107.8287	Grab	Field Sample	2.8	n/a	1-16
30-32-2-31-170331	35.4167	-107.8297	Grab	Field Sample	5.1	4.67	1-16
30-33-2-31-170331	35.4175	-107.8297	Grab	Field Sample	3.4	n/a	1-16
30-34-2-31-170401	35.4175	-107.8288	Grab	Field Sample	2.9	n/a	1-16
30-35-2-31-170401	35.4175	-107.8278	Grab	Field Sample	8.9	n/a	1-16
30-36-2-31-170401	35.4175	-107.8268	Grab	Field Sample	1.7	n/a	1-16
30-37-2-31-170401	35.4175	-107.8258	Grab	Field Sample	18.3	n/a	1-16
30-38-2-31-170401	35.4183	-107.8268	Grab	Field Sample	31.5	n/a	1-16
30-39-2-31-170401	35.4183	-107.8278	Grab	Field Sample	1.7	n/a	1-16
30-40-2-31-170401	35.4183	-107.8288	Grab	Field Sample	2.1	n/a	1-16
30-40-2-32-170401	35.4183	-107.8288	Grab	Field Duplicate	2.3	n/a	1-16
30-41-2-31-170401	35.4191	-107.8278	Grab	Field Sample	1.4	n/a	1-16
30-42-2-31-170401	35.4191	-107.8269	Grab	Field Sample	3.9	n/a	1-16
30-43-2-31-170401	35.4201	-107.8282	Grab	Field Sample	2.2	n/a	1-16
30-44-2-31-170401	35.4187	-107.8298	Grab	Field Sample	1.9	n/a	1-16
30-45-2-31-170706	35.4198	-107.8251	Grab	Field Sample	2.3	n/a	1-16
30-46-2-31-170706	35.4199	-107.8233	Grab	Field Sample	2.5	n/a	1-16
30-47-2-31-170706	35.4184	-107.8233	Grab	Field Sample	3.6	n/a	1-16
30-48-2-31-170706	35.4183	-107.8251	Grab	Field Sample	2.1	n/a	1-16
30-49-2-31-170706	35.4164	-107.8232	Grab	Field Sample	2.2	n/a	1-16
30-50-2-31-170801	35.4137	-107.8224	Grab	Field Sample	1.8	n/a	1-16
32-01-2-31-170711	35.3931	-107.8060	Grab	Field Sample	2	n/a	1-17
32-02-2-31-170711	35.3931	-107.8080	Grab	Field Sample	2.2	n/a	1-17
32-02-2-32-170711	35.3931	-107.8080	Grab	Field Duplicate	2.2	n/a	1-17
32-03-2-31-170711	35.3931	-107.8100	Grab	Field Sample	3.4	1.34	1-17
32-04-2-31-170711	35.3947	-107.8101	Grab	Field Sample	2.3	n/a	1-17
32-05-2-31-170711	35.3947	-107.8081	Grab	Field Sample	1.9	n/a	1-17
32-06-2-31-170711	35.3948	-107.8061	Grab	Field Sample	2.7	n/a	1-17
32-07-2-31-170711	35.3964	-107.8061	Grab	Field Sample	3.1	n/a	1-17
32-08-2-31-170711	35.3964	-107.8081	Grab	Field Sample	3.1	n/a	1-17
32-09-2-31-170711	35.3963	-107.8101	Grab	Field Sample	2.5	n/a	1-17
32-10-2-31-170711	35.3979	-107.8122	Grab	Field Sample	4.1	2.08	1-17
32-11-2-31-170711	35.3979	-107.8102	Grab	Field Sample	4.1	n/a	1-17
32-11-2-32-170711	35.3979	-107.8102	Grab	Field Duplicate	4.6	n/a	1-17
32-12-2-31-170711	35.3980	-107.8082	Grab	Field Sample	2.9	n/a	1-17
32-13-2-31-170711	35.3980	-107.8062	Grab	Field Sample	3.6	n/a	1-17
32-14-2-31-170711	35.3997	-107.8043	Grab	Field Sample	4	n/a	1-17

Subsurface Soil Samples - Gamma Spectroscopy Results
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Sample ID[1,2]	Latitude	Longitude	Collection Method	Sample Type	Radium 226 (picocuries per gram [pCi/g]) Field Laboratory Multichannel Analyzer (MCA)[3,4,5]	Radium 226 (picocuries per gram [pCi/g]) Off-site Laboratory[3,4,5,6]	Figure Depicting Sample Location
32-15-2-31-170711	35.3997	-107.8062	Grab	Field Sample	3.9	n/a	1-17
32-16-2-31-170711	35.3996	-107.8082	Grab	Field Sample	4.1	1.61	1-17
32-17-2-31-170711	35.3996	-107.8102	Grab	Field Sample	4.1	n/a	1-17
32-18-2-31-170711	35.4012	-107.8083	Grab	Field Sample	2.3	n/a	1-17
32-19-2-31-170713	35.4013	-107.8063	Grab	Field Sample	3.1	n/a	1-17
32-20-2-31-170713	35.4013	-107.8043	Grab	Field Sample	2.4	n/a	1-17
32-21-2-31-170713	35.4030	-107.8044	Grab	Field Sample	2.2	n/a	1-17
32-21-2-32-170713	35.4030	-107.8044	Grab	Field Duplicate	2.1	n/a	1-17
32-22-2-31-170713	35.4029	-107.8064	Grab	Field Sample	3.8	n/a	1-17
32-23-2-31-170713	35.4029	-107.8083	Grab	Field Sample	3.6	1.35	1-17
32-24-2-31-170713	35.4028	-107.8103	Grab	Field Sample	1.6	n/a	1-17
32-25-2-31-170713	35.4028	-107.8123	Grab	Field Sample	2.8	n/a	1-17
32-26-2-31-170713	35.4044	-107.8104	Grab	Field Sample	2.1	n/a	1-17
32-27-2-31-170713	35.4045	-107.8084	Grab	Field Sample	2.1	n/a	1-17
33-01-2-31-170424	35.3983	-107.8039	Grab	Field Sample	2.4	n/a	1-18
33-01-2-32-170424	35.3983	-107.8039	Grab	Field Duplicate	2.5	n/a	1-18
33-02-2-31-170424	35.3999	-107.8039	Grab	Field Sample	3.6	n/a	1-18
33-03-2-31-170424	35.4015	-107.8040	Grab	Field Sample	2.6	n/a	1-18
33-04-2-31-170424	35.4031	-107.8040	Grab	Field Sample	2.8	n/a	1-18
33-05-2-31-170424	35.4047	-107.8041	Grab	Field Sample	2.8	n/a	1-18
33-06-2-31-170424	35.4047	-107.8021	Grab	Field Sample	2.2	n/a	1-18
33-07-2-31-170424	35.4031	-107.8021	Grab	Field Sample	2.3	n/a	1-18
33-08-2-31-170424	35.4015	-107.8020	Grab	Field Sample	4.4	2.41	1-18
33-09-2-31-170424	35.3999	-107.8020	Grab	Field Sample	2	n/a	1-18
33-10-2-31-170424	35.4000	-107.8000	Grab	Field Sample	1.8	n/a	1-18
33-11-2-31-170424	35.4016	-107.8001	Grab	Field Sample	1.9	n/a	1-18
33-11-2-32-170424	35.4016	-107.8001	Grab	Field Duplicate	2.2	n/a	1-18
33-12-2-31-170424	35.4018	-107.7992	Grab	Field Sample	2.5	n/a	1-18
33-13-2-31-170424	35.4026	-107.7992	Grab	Field Sample	2.2	n/a	1-18
33-14-2-31-170424	35.4032	-107.8001	Grab	Field Sample	2.5	n/a	1-18
33-15-2-31-170424	35.4048	-107.8002	Grab	Field Sample	4.3	1.62	1-18
33-16-2-31-170424	35.4048	-107.7982	Grab	Field Sample	2.1	n/a	1-18
33-17-2-31-170424	35.4034	-107.7973	Grab	Field Sample	34.8	n/a	1-18
33-18-2-31-170424	35.4032	-107.7982	Grab	Field Sample	2.8	n/a	1-18
33-19-2-31-170501	35.4026	-107.7982	Grab	Field Sample	3	n/a	1-18
33-20-2-31-170501	35.4026	-107.7973	Grab	Field Sample	88.3	n/a	1-18
33-21-2-31-170501	35.4018	-107.7972	Grab	Field Sample	3.3	n/a	1-18
33-21-2-32-170501	35.4018	-107.7972	Grab	Field Duplicate	3.7	n/a	1-18
33-22-2-31-170501	35.4010	-107.7972	Grab	Field Sample	2.2	n/a	1-18
33-23-2-31-170501	35.4000	-107.7980	Grab	Field Sample	2.3	n/a	1-18
33-24-2-31-170501	35.3984	-107.7980	Grab	Field Sample	3.3	n/a	1-18
33-25-2-31-170501	35.3984	-107.7960	Grab	Field Sample	2.8	n/a	1-18
33-26-2-31-170501	35.4001	-107.7961	Grab	Field Sample	2.2	n/a	1-18
33-27-2-31-170501	35.4011	-107.7962	Grab	Field Sample	2.9	n/a	1-18

Table 1-3 (continued)
Subsurface Soil Samples - Gamma Spectroscopy Results
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Sample ID[1,2]	Latitude	Longitude	Collection Method	Sample Type	Radium 226 (picocuries per gram [pCi/g])		Figure Depicting Sample Location
					Field Laboratory Multichannel Analyzer (MCA)[3,4,5]	Off-site Laboratory[3,4,5,6]	
33-28-2-31-170501	35.4019	-107.7963	Grab	Field Sample	5.5	1.38	1-18
33-29-2-31-170501	35.4019	-107.7953	Grab	Field Sample	87.9	n/a	1-18
33-30-2-31-170501	35.4027	-107.7953	Grab	Field Sample	25.4	n/a	1-18
33-31-2-31-170508	35.4027	-107.7963	Grab	Field Sample	69.7	n/a	1-18
33-32-2-31-170512	35.4035	-107.7954	Grab	Field Sample	3.9	n/a	1-18
33-32-2-32-170512	35.4035	-107.7954	Grab	Field Duplicate	11.7	9.77	1-18
33-33-2-31-170512	35.4035	-107.7963	Grab	Field Sample	134.6	n/a	1-18
33-34-2-31-170512	35.4042	-107.7964	Grab	Field Sample	2.3	n/a	1-18
33-35-2-31-170512	35.4049	-107.7943	Grab	Field Sample	2.4	n/a	1-18
33-36-2-31-170512	35.4027	-107.7944	Grab	Field Sample	17.5	15.8	1-18
33-37-2-31-170512	35.4019	-107.7943	Grab	Field Sample	3.9	2.53	1-18
33-38-2-31-170512	35.4019	-107.7934	Grab	Field Sample	1.8	n/a	1-18
33-39-2-31-170512	35.4011	-107.7943	Grab	Field Sample	2.2	n/a	1-18
33-40-2-31-170608	35.4011	-107.7933	Grab	Field Sample	2.2	n/a	1-18
33-41-2-31-170608	35.4003	-107.7933	Grab	Field Sample	2.3	n/a	1-18
33-41-2-32-170608	35.4003	-107.7933	Grab	Field Duplicate	3	n/a	1-18
33-42-2-31-170608	35.4001	-107.7941	Grab	Field Sample	2.5	n/a	1-18
33-43-2-31-170608	35.3985	-107.7941	Grab	Field Sample	3.4	n/a	1-18
33-44-2-31-170608	35.3985	-107.7921	Grab	Field Sample	1.8	n/a	1-18
33-45-2-31-170608	35.4004	-107.7923	Grab	Field Sample	3.5	n/a	1-18
33-46-2-31-170608	35.4012	-107.7924	Grab	Field Sample	3.4	n/a	1-18
33-47-2-31-170608	35.4012	-107.7914	Grab	Field Sample	2.3	n/a	1-18
33-48-2-31-170608	35.4020	-107.7924	Grab	Field Sample	2.1	1.01	1-18
33-49-2-31-170608	35.4034	-107.7923	Grab	Field Sample	2.8	n/a	1-18
33-50-2-31-170609	35.4050	-107.7923	Grab	Field Sample	3	n/a	1-18
33-51-2-31-170609	35.4050	-107.7904	Grab	Field Sample	3.4	n/a	1-18
33-52-2-31-170609	35.4034	-107.7903	Grab	Field Sample	2.8	n/a	1-18
33-52-2-32-170609	35.4034	-107.7903	Grab	Field Duplicate	2.9	n/a	1-18
33-53-2-31-170609	35.4018	-107.7903	Grab	Field Sample	1.9	n/a	1-18
33-54-2-31-170609	35.4002	-107.7902	Grab	Field Sample	2.3	n/a	1-18
33-55-2-31-170609	35.3986	-107.7902	Grab	Field Sample	2.2	n/a	1-18
33-56-2-31-170609	35.4002	-107.7883	Grab	Field Sample	2.1	n/a	1-18
33-57-2-31-170609	35.4018	-107.7883	Grab	Field Sample	3.8	n/a	1-18
33-58-2-31-170609	35.4034	-107.7884	Grab	Field Sample	2.7	n/a	1-18
33-59-2-31-170609	35.4050	-107.7884	Grab	Field Sample	2.3	n/a	1-18
33-60-2-31-170609	35.4051	-107.7865	Grab	Field Sample	2.2	n/a	1-18
33-61-2-31-170609	35.4035	-107.7864	Grab	Field Sample	3.6	n/a	1-18
33-62-2-31-170609	35.4019	-107.7864	Grab	Field Sample	2.8	n/a	1-18
33-62-2-32-170609	35.4019	-107.7864	Grab	Field Duplicate	3	n/a	1-18

1 All samples collected from 12-24 inches below ground surface.

2 First two digits of the sample number indicate the section from which they were collected.

3 Samples analyzed for Bismuth-214. Samples were held before analysis so that Bismuth-214 was in equilibrium with Radium-226.

Table 1-3 (continued)
Subsurface Soil Samples - Gamma Spectroscopy Results
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Sample ID[1,2]	Latitude	Longitude	Collection Method	Sample Type	Radium 226 (picocuries per gram [pCi/g])		Figure Depicting Sample Location
					Field Laboratory Multichannel Analyzer (MCA)[3,4,5]	Off-site Laboratory[3,4,5,6]	

[4] Sample results above the 6.1 pCi/g Removal Action Level (RAL) are shaded in gray.

[5] Samples measured above the 6.1 pCi/g Ra-226 Action Level on the MCA, but less than 6.1 pCi/g Ra-226 at the off-site laboratory, were not considered to be above the Action Level for the purposes of estimating the volume of contaminated soil.

[6] n/a denotes that the sample was not sent for offsite laboratory analysis.

Table 1-4
Surface Soil Samples - TAL Metals Results
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Analyte[1]	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Magnesium	Manganese	Nickel	Potassium	Silver	Sodium	Thallium	Mercury	Selenium	Vanadium	Zinc	Uranium	Figure Depicting Sample Location
Sample Number[2]																									
17-01-31-181101-M	14000	ND	6.1	71	0.74	ND	32000	9.3	6	11	18000	9.9	3500	220	17	2200	ND	250	ND	0.033	ND	52	54	ND	1-13
17-02-31-181101-M	15000	ND	4.3	98	0.69	ND	15000	9.1	4.4	7.9	15000	4.9	3000	140	11	2700	ND	180	ND	0.014	ND	32	37	ND	1-13
19-01-31-181101-M	11000	ND	6.8	81	0.73	ND	17000	5.4	3.5	4.5	13000	9	3200	190	5.5	3100	ND	210	ND	0.025	6.8	98	32	77	1-19
19-02-31-181101-M	15000	ND	9.8	87	0.84	ND	23000	8.4	5.9	8.4	17000	8.5	4900	200	10	4800	ND	250	ND	0.027	ND	65	48	ND	1-19
30-01-31-181101-M	12000	ND	5.1	82	0.62	ND	24000	6.5	4.2	4.4	13000	3.2	4700	140	7	3200	ND	190	ND	0.012	ND	20	30	ND	1-16
30-02-31-181101-M	11000	ND	5.2	72	0.65	ND	13000	6.9	4.5	4.5	13000	3.9	4300	150	7.6	2600	ND	200	ND	0.012	ND	19	34	ND	1-16
33-01-31-181101-M	10000	ND	7.5	56	0.67	ND	7800	6	3.1	5.3	12000	9.5	2800	180	5.8	3200	ND	180	ND	0.02	7	62	25	24	1-18
33-01-32-181101-M	8900	ND	7.9	53	0.63	ND	8100	4.9	3.9	4.9	12000	13	2600	170	6	2900	ND	160	ND	0.018	ND	63	32	23	1-18
33-02-31-181101-M	8200	ND	4.5	65	0.56	ND	14000	5	4.4	4.4	12000	4.4	4000	140	7.1	2200	ND	360	ND	0.015	ND	18	30	ND	1-18

Notes:

1 Analytes are from the Targeted Analyte List plus Uranium

2 First two digits of the sample number are the section from which the sample was collected.

3 ND indicates that the analyte was not detected.

Table 3-1
Chemical-Specific ARARs and TBC Information
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Media	Requirement	Requirement Synopsis	Status and Rationale
Hazardous Wastes	FEDERAL **Resource Conservation and Recovery Act (RCRA) of 1976, as amended –**42 USC 6901 *et seq*.; 40 CFR 261 Subpart C	Provides for "cradle-to-grave" regulation of hazardous wastes. Per 42 USC 6903(27), RCRA does not regulate "source, special nuclear, or byproduct material" as defined in the Atomic Energy Act. Per 40 CFR 261.4(b)(7), wastes derived from the extraction, beneficiation and processing of ores are not hazardous wastes. U.S. EPA does not anticipate encountering RCRA hazardous wastes during this removal action. However, if hazardous wastes (e.g., buried drums containing solvents) are discovered, toxicity characteristic leaching procedure (TCLP) limits would be ARARs for characterizing hazardous waste.	Substantive requirements may be applicable if wastes that are subject to the Act are encountered.
Hazardous Materials	FEDERAL **Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA), as amended –** And regulations at 40 CFR Part 192, Subparts A-E	Protect the public and the environment from uranium mill tailings. Some requirements (e.g., 40 CFR 192.02, 192.12, 192.32) may be ARARs.	TBC
Other	FEDERAL **Code of Federal Regulations (CFR), Title 10, Part 20** Nuclear Regulatory Commission (NRC) Regulations – Standards for Protection Against Radiation; Subpart D – Radiation Dose Limits	Establishes standards for protection against ionizing radiation resulting from activities conducted under licenses issued by the NRC.	Substantive requirements may be applicable or relevant and appropriate if source, byproduct or special nuclear material is encountered.
Other	FEDERAL **EPA Directive on Protective Cleanup Levels for Radioactive Contamination at CERCLA sites.** OSWER Directive 9200.4-18	Provides guidance for cleanup levels for CERCLA sites with radioactive contamination. Cleanup of radionuclides are governed by risk established in the NCP when ARARS are not available or sufficiently protective.	TBC.

Table 3-1 (Continued)
Chemical-Specific ARARs and TBC Information
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Media	Requirement	Requirement Synopsis	Status and Rationale
Other	FEDERAL **EPA Directive on Conducting Risk Assessments for Radioactive Contamination at CERCLA sites.** OSWER Directive 9285.6-20	Provides guidance in a Q&A format, giving answers to several commonly asked questions regarding risk assessments at radioactively contaminated CERCLA sites.	TBC.
Hazardous Waste	STATE **20.4 New Mexico Administrative Code (NMAC) –** Hazardous Waste Management	Establishes criteria for the classification of hazardous waste and for the treatment, storage, and disposal of hazardous waste. The state Act incorporates most Federal RCRA regulations, including the definition of solid waste, which excludes “source, byproduct or special nuclear material.” New Mexico’s definition of hazardous waste also excludes wastes from the extraction, beneficiation, and processing of ores and minerals. Although hazardous waste is not expected, the requirement to characterize waste to determine whether it is hazardous is an ARAR.	Substantive requirements may be applicable or relevant and appropriate if wastes that are subject to the Act are encountered.

Table 3-1 (Continued)
Chemical-Specific ARARs and TBC Information
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Media	Requirement	Requirement Synopsis	Status and Rationale
Soil	STATE **Joint Guidance for the Cleanup and Reclamation of Existing Uranium Mining Operations in New Mexico** (New Mining and Minerals Division and the New Mexico Environment Department; March 2016)	Provides general guidance for cleanup and reclamation of existing uranium mine sites. Prepared by the New Mexico Mining and Minerals Division and the New Mexico Environment Department.	TBC – The numeric criteria listed in the guidance are not promulgated numeric standards but are recommended to satisfy NMAC 19.10 (New Mexico Mining Commission action-specific requirements). (1) The concentration of Ra-226 in land averaged over any area of 100 square meters (“m^2”) shall not exceed the background level by more than (a) 5 pCi/g, averaged over the first 15 cm of soil below the surface, and (b) 15 pCi/g, averaged over 15 cm thick layers of soil more than 15 cm below the surface. (2) Site post-reclamation radiation level (“PRRL”) for gamma radiation should not exceed the site-specific value of gamma radiation that correlates to 5 pCi/g Ra-226 above background at the 95th percentile value. (3) For sites at which contaminated material exceeding the target radium activity level discussed above is emplaced in an on-site repository, cover material for the repository must achieve radon flux equal or less than 20 pCi/m^2/s.
Water	STATE **20.6.2 NMAC –** New Mexico Water Quality Ground and Surface Water Protections	Establishes water quality standards and regulations to prevent or abate water pollution from discharges.	Substantive requirements may be relevant and appropriate to surface runoff on tribal trust land, and may be applicable to surface runoff on non-tribal lands.

Table 3-1 (Continued)
Chemical-Specific ARARs and TBC Information
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Media	Requirement	Requirement Synopsis	Status and Rationale
Water	STATE **20.6.4 NMAC –** New Mexico Standards for Interstate and Intrastate Surface Waters	Establishes water quality standards that consist of the designated use or uses of surface waters, water quality criteria necessary to protect the use or uses, and an anti-degradation policy.	Substantive requirements may be relevant and appropriate to surface runoff on tribal lands, and may be applicable to surface runoff on non-tribal lands.
Other	STATE **20.3.4 NMAC –** Standards for Protection Against Radiation	Establishes standards for protection against ionizing radiation resulting from activities conducted pursuant to licenses or registrations issued by the Department.	Substantive requirements may be relevant and appropriate.

Notes:
ARAR = applicable or relevant and appropriate requirements
CERCLA = Comprehensive Environmental Response Compensation and Liability Act
NCP = National Oil and Hazardous Substances Pollution Contingency Plan
pCi/g = pico Curies per gram
CFR = Code of Federal Regulations
NPL = National Priorities List
OSWER = Office of Solid Waste and Emergency Response
TBC = To Be Considered

Table 3-2
Location-Specific ARARs and TBC Information
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Media	Requirement	Requirement Synopsis	Status and Rationale
Cultural Resources	FEDERAL **The Native American Graves Protection And Repatriation Act – **25 United States Code (USC) Section 3001 *et seq* and its regulations Title 43 CFR Part 10.	Protects Native American graves from desecration through the removal and trafficking of human remains and cultural items including funerary and sacred objects.	Substantive requirements applicable if Native American burials or cultural items are identified within area to be disturbed.
Cultural Resources	FEDERAL **National Historic Preservation Act –** 16 USC 470 *et seq*; 36 CFR Part 800	Provides for the protection of sites with historic places and structures.	Substantive requirements applicable if eligible resources identified within area to be disturbed.
Cultural Resources	FEDERAL **Archeological Resources Protection** **Act of 1979 –** 16 USC Sections 470aa-mm; 43 CFR Part 7	Prohibits removal of or damage to archaeological resources unless by permit or exception.	Substantive requirements applicable if eligible resources are identified within area to be disturbed.
Cultural Resources	FEDERAL **American Indian Religious Freedom** **Act –** 42 USC Section 1996 *et seq*.	Protects religious, ceremonial, and burial sites, and the free practice of religions by Native American groups.	Substantive requirements applicable if Native American sacred sites are identified within area to be disturbed.
Wildlife	FEDERAL **Endangered Species Act –** 16 USC Sections 1531-1544, Title 50 CFR Parts 17 and 402	Regulates the protection of threatened and endangered species or critical habitat of such species.	Substantive requirements applicable if protected species are identified within area to be disturbed.
Cultural Resources	STATE **New Mexico Cultural Properties Act** – New Mexico Statutes Annotated (NMSA) 1978 Sections 18-6-1 through 18-6-27	Requires the identification of cultural resources, assessment of impact on those resources that may be caused by the proposed remedy, and consultation with the State Historic Preservation Officer.	Substantive requirements applicable to response actions on non-tribal lands in New Mexico.

Notes:
ARAR = applicable or relevant and appropriate requirements
TBC = To Be Considered

Table 3-3
Action-Specific ARARs and TBC Information
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Media/ Activity	Requirement	Requirement Synopsis	Status and Rationale
Solid Wastes	FEDERAL **Resource Conservation and Recovery Act (RCRA) of 1976, as amended –** 42 USC 6901 *et seq*.	Regulates disposal of solid waste. Per 42 USC 6903(27), RCRA does not regulate "source, special nuclear, or byproduct material" as defined in the Atomic Energy Act, but may apply to other wastes, including ores containing uranium in concentrations less than 500 ppm.	Substantive requirements may be applicable to wastes that are subject to the Act.
Solid Waste	FEDERAL **Criteria for Classification of Solid Waste Disposal Facilities** – 40 CFR 257 and 258	Establishes criteria for use in determining which solid waste disposal facilities and practices pose a reasonable probability of adverse effects on health or the environment and, thereby, constitute prohibited open dumps.	Substantive requirements relevant and appropriate for siting disposal repositories.
Hazardous Materials	FEDERAL **Federal Hazardous Materials Transportation Law (formerly Hazardous Materials Transportation Act) –** 49 CFR Parts 171, 172, 173, 174	Provides protection against the risks to life, property, and the environment that are inherent in transportation of hazardous materials in commerce.	Substantive requirements applicable to transportation of materials subject to the Act, including radionuclides.
Water	FEDERAL **EPA Guidance for Developing Best Management Practices for Storm Water –** Publication EPA/832/R-92006	Guidance for developing stormwater BMPs for industrial facilities.	TBC.
Water	FEDERAL **Clean Water Act (CWA) –** Section 402, National Pollutant Discharge Elimination System (NPDES) Stormwater discharges (40 CFR parts 122, 125).	On-site and off-site discharges from site are required to meet the substantive CWA requirements, including discharge limitations, monitoring and best management practices.	Substantive requirements may be applicable.
Water	FEDERAL **CWA –** Section 404, dredged or fill material, 33 CFR Parts 320-330, 40 CFR 230.	Regulates discharge of dredge or fill material into waters of the U.S.	Substantive requirements may be applicable to activities impacting waters of the U.S.

Table 3-3 (Continued)
Action-Specific ARARs and TBC Information
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Media/ Activity	Requirement	Requirement Synopsis	Status and Rationale
Air	STATE **20.2 NMAC –** Air Quality	Establishes ambient air quality standards, performance standards for specific sources of air pollutants, and specifies monitoring methods.	Substantive requirements may be relevant and appropriate to sources during removal action.
Mining	STATE **19.10 NMAC –** Regulation of Non-Coal Mining	Establishes requirements for mine reclamation and close-out plans. The New Mexico Ming Act (NMMA), administered under NMMC Regulations, contemplates returning an area affected by mining activity to pre-mining conditions. The regulations apply to all currently-operating mines as well as to mines that operated for a minimum of two years between January 1, 1970 and June 18, 1993. Defines "reclamation" as the employment of measures to mitigate disturbance and stabilize the permit area so as to "minimize future impact" on the environment and to protect air and water quality [Section 69-36-3(K); 19.10.1.7(R)(1)]. Section 69-36-7.H.2 of the NMMA requires the "protection of human health and safety, the environment, wildlife and domestic animals." Also, sections 19.10.3.304.D.7.b, 19.10.5.507.B(2), 19.10.5.508.B and 19.10.6.603.C NMAC of the NMMC regulations have similar requirements. Section 69-36-11(B)(3) requires that existing sites be reclaimed so as to re-establish a self-sustaining ecosystem.	Substantive requirements are relevant and appropriate.
Wildlife	STATE **New Mexico Wildlife Conservation Act** – NMSA 178 Sections 17-2-37 thru 17-2-46	Provides for the protection of threatened and endangered species.	Substantive requirements may be applicable if protected species are identified within area to be disturbed.

Table 3-3 (Continued)
Action-Specific ARARs and TBC Information
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Media/ Activity	Requirement	Requirement Synopsis	Status and Rationale
Plants	STATE **New Mexico Endangered Plant Species Act –** NMSA 1978, Section 75-6-1	Provides for the regulation and protection of threatened and endangered plant species. Endangered plant species means any plant species whose prospects of survival within the state are in jeopardy or are likely within the foreseeable future.	Substantive requirements may be applicable if protected species are identified within area to be disturbed.
Plants	STATE **New Mexico Endangered Plants Regulations** – Section 19.21 New Mexico Administrative Code (NMAC)	Establishes requirements for the protection of threatened and endangered flora and fauna.	Substantive requirements applicable if such species are identified within area to be disturbed.
Plants	STATE **New Mexico Noxious Weed Control Act** – NMSA 1978, Sections 76-7-1 through 76-7-30	Addresses the management and control of noxious weeds because of their negative impact on the economy or the environment.	Relevant and appropriate requirement if noxious weed plant species that are not indigenous to New Mexico are found at the Site or within areas to be disturbed.

Notes:
ARAR = applicable or relevant and appropriate requirements
CFR = Code of Federal Regulations
CWA = Clean Water Act
EPA = U.S. Environmental Protection Agency
NMAC = New Mexico Administrative Code
NMSA = New Mexico Statutes Annotated
TBC = To Be Considered

Table 3-4
Off-Site Transportation and Disposal Cost Estimates
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Disposal Facility	Location	One-way Distance (miles)[1]	Transportation Costs ($/ton)[2,3]	Disposal/ Processing Costs ($/ton)[3,4]	Total Costs ($/ton)[3,5]
Clean Harbors	Deer Trail, CO	545	$62.40	$75.00	**$137.40**
US Ecology	Beatty, NV	605	--	--	$210.00
	Grand View, ID	830	--	--	$295.00

Notes:

1) The haul distance is measured from the site to the disposal facility.
2) Transportation costs assume 335 highway-rated trucks per day carrying approximately 26 tons each (20 cubic yard capacity). Includes one-time mobilization fee of approximately $1,290 per truck.
3) Budgetary quotes for disposal were received from US Ecology and Clean Harbors in December 2019.
4) The Clean Harbors disposal fee of $75 per ton was used as the basis of the EE/CA cost estimate. Transportation costs to the facility were built up based on Note 2 (approximately $70/ton).
5) US Ecology total costs include transportation, processing and disposal costs.

Table 4-1
Summary of Analysis of Alternatives
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Removal Alternative	Evaluation Criteria					
	Protection of Human Health and the Environment	**Compliance with ARARs**	**Short-Term Effectiveness**	**Long-Term Effectiveness and Permanence**	**Implementability**	**Cost Effectiveness**
Alternative1: No Further Action	Low – No additional protection provided.	Not Applicable	Low – No action.	Low – Does not provide any effectiveness or permanence.	Low – No action.	Low – No action.
Alternative 2: Excavation and Off-Site Disposal of Radiologically Contaminated Soils at a Licensed, Low-Level Radioactive Waste Facility	High – Protection provided by waste being placed in an off-site, engineered, and regulated landfill facility.	High – Complies with ARARs.	Medium – Disturbance of the entire waste area during excavation. Effective once waste is removed from the Site.	High – No on-site waste to manage. Off-site waste is managed at a permitted landfill facility.	Medium – Readily implementable. Administratively and technically feasible. Difficult to schedule large amount of required off-site trucking.	Low
Alternative 3: Excavation, Consolidation, and Long-term Management of Radiologically Contaminated Soils at an Aboveground On-Site Repository	High – Protection provided by waste being placed in an on-site, engineered repository. Maintenance of cap will be required.	High – Complies with ARARs.	High – Disturbance of the entire waste area during excavation; however, all transport of wastes is on-site. Less greenhouse emissions than Alternative 4.	Medium – Waste is managed in an engineered repository. Maintenance of the cover is required.	Medium – Readily implementable and. technically feasible; however, medium administrative feasibility due to New Mexico state guideline of *incised* (below-ground) repository.	Medium
Alternative 4: Excavation, Consolidation, and Long-term Management of Radiologically Contaminated Soils at an Incised (Below-Ground), ALSD Regional Repository	High – Protection provided by waste being placed in an on-site, engineered repository. Maintenance of cap will be required.	High – Complies with ARARs.	High – Disturbance of the entire waste area during excavation; however transport of wastes is predominantly on-site.	Medium – Waste is managed in an engineered repository. Maintenance of the cover is required.	High – Readily implementable. Administratively and technically feasible.	Medium

Table 4-2
Estimated Risk of Fatalities and Greenhouse Gas Emissions Due to Off-Site Trucking
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

	Truckloads of Waste	Miles Round Trip to Transport Waste	Truckloads of Fill	Miles Round Trip to Transport Fill	Total Miles	Estimated Fatalities due to Off-Site Trucking[1]	Estimated Greenhouse Gas Emissions due to Off-Site Trucking[2] (metric tons CO_2e)
Alternative 1, No Further Action	0	0	0	0	0	0	0
Alternative 2, Excavation and Off-Site Processing and Disposal of Contaminated Soils at Licensed, Low-Level Radioactive Waste Facility (Clean Harbors, Deer Trail, CO)	148,100	1,110	0	0	164,391,000	3	291,794
Alternative 3, Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Above-Ground, On-Site Repository	27,871	6	580	6	170,704	0	303
Alternative 4, Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Incised (Above-Ground) ALSD Regional Repository	148,100	18	0	0	2,665,800	0	4,732

Notes:
CO_2e= Carbon Dioxide Equivalent

1. A rate of **1.55** fatalities per 100 million large truck miles traveled was calculated as shown below using data (2014 - 2018) from the National Center for Statistics and Analysis. (2020, March). Large trucks: 2018 data. (Traffic Safety Facts. Report No. DOT HS 812 891). Washington, DC: National Highway Traffic Safety Administration (https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812891).

	People Killed in Crashes Involving Large Trucks	Large-Truck Miles Traveled (millions)	Fatality Rate per 100 Million Large-Truck-Miles Traveled	
2014	3,908	279,132	1.40	
2015	4,095	279,844	1.46	
2016	4,678	287,895	1.62	
2017	4,905	297,593	1.65	
2018	4,951	304,864	1.62	
Average from 2014 - 2018			**1.55**	fatalities per 100 million miles traveled

2. Metric tons of CO2e per large truck mile traveled was calculated as shown below using data and methods from the EPA GHG Equivalencies Calculator - Calculations and References (https://www.epa.gov/energy/ghg-equivalencies-calculator-calculations-and-references). Carbon dioxide emissions per gallon of diesel fuel was obtained from the US Energy Information Administration Frequently Asked Questions (http://www.eia.gov/tools/faqs/faq.cfm?id=307&t=11).
Mileage for Combination Trucks (Classification Types 8-13) was obtained from the FHWA Highway Statistics Table VM-1 based on 2012 and 2013 data (https://www.fhwa.dot.gov/policyinformation/statistics/2013/vm1.cfm).

$$\frac{22.38 \text{ lb CO2/gallon diesel fuel}}{2{,}205 \text{ lb CO2/metric ton CO2}} \times \frac{1 \text{ CO2e}}{0.986 \text{ CO2}} \times \frac{1}{5.8 \text{ miles/gallon}} = \frac{0.001775 \text{ metric tons CO2e}}{\text{miles traveled}}$$

APPENDICES

APPENDIX A

NATURAL RESOURCES EVALUATION REPORT

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NATURAL RESOURCES EVALUATION

Tronox Navajo Abandoned Uranium Mine
Central Geographic Sub Area Mines
McKinley County, New Mexico

Prepared for:

US Environmental Protection Agency Region 6
Through
Weston Solutions, Inc.

Prepared by:

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January 2018

TABLE OF CONTENTS

LIST OF TABLES

ACRONYMS AND ABBREVIATIONS

AMSL	Above Mean Sea Level
APE	Area of Potential Effect
AUE	Animal Unit Equivalent
AUM	Abandoned Uranium Mine
AUM	Animal Unit Month
BLM	Bureau of Land Management
BMP	Best Management Practice
CMEH	Carrizo Mountain Environmental and Herbarium
FFO	Farmington Field Office
GSA	Geographic Sub Area
MBTA	Migratory Bird Treaty Act
NM	New Mexico
NMPM	New Mexico Principal Meridian
SSS	Special Status Species
SMS	Special Management Species
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey

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1. INTRODUCTION

1.1. Project Background

Under the guidance of the United Stated Environmental Protection Agency (USEPA) Region 6, Weston Solutions, Inc. (Weston) is conducting assessments of four abandoned uranium mine sites near San Mateo, New Mexico. The assessment area includes the Tronox Navajo Abandoned Uranium Mine Central Geographic Sub Area Mines (Central GSA) located on approximately 100 square miles within McKinley County, New Mexico (see Attachment A for area maps). The assessment area is within the Ambrosia Lake Sub-District which is a mining district that was heavily mined for uranium in the past.

The purpose of Weston's assessment is to determine the ecological and human health impact from radiological wastes generated through mining activities. In support of this assessment, Weston contracted Carrizo Mountain Environmental & Herbarium, Inc. (CMEH) to conduct a Natural Resources Evaluation for lands associated with the USEPA's Central GSA project area ("survey area" henceforth).

The following is a Natural Resources Evaluation documenting the baseline ecological conditions in the survey area, including but not limited to:

- Description of habitat and vegetation
- Assessment of the presence of threatened and endangered species and habitats thereof
- Identification of wildlife and cattle grazing value to the existing vegetation
- A summary of sensitive habitats or vegetation observed
- A summary of invasive species and noxious weeds
- A summary of local and migratory wildlife expected to utilize the habitats
- Description of basic soil chemistry
- Assessment of watershed impacts

1.2. Project Location

The 1,322 acre Tronox NAUM Central GSA project area (survey area) is located approximately 17 miles north of Grants, New Mexico (NM) along NM State Highway 509 at an elevation range of approximately 6,940 to 7,180 feet AMSL. Approximately 1,268 acres of the survey area is located on private lands and the remaining 54 acres is on public lands managed by the Bureau of Land Management – Farmington Field Office (BLM-FFO). The project area is within Sections 17, 19, 20, 29, 30, 32, and 33, Township 14 North, Range 9 West, New Mexico Principal Meridian (NMPM) in McKinley County, NM. Project area maps are provided in Appendix A.

1.3. Methods

1.3.1. Off-site Methods

For the purpose of this evaluation, the area of potential effect (APE) includes the 1,322 acre Tronox NAUM Central GSA survey area and adjacent habitat within a 0.25 mile perimeter for certain sensitive species such as raptors (see Tables 6, 7 and 8 for specific habitat requirements). Prior to conducting fieldwork, CMEH conducted a desktop review of existing literature regarding the survey area ecology including Federal, State and BLM-listed species with potential to occur within the APE (USFWS 2017a, NMDGF 2017, BLM 2011a, BLM 2011b, BLM 2011c, and BLM 2012), species protected under the Migratory Bird Treaty Act (MBTA) with potential to occur in the APE, soil survey data (NCRS 2006), and area watershed information including potential wetlands and U.S. Army Corps of Engineers (USACE) jurisdictional waterways (USFWS 2008).

1.3.2. On-site Survey Methods

On-site surveys of the APE were conducted October 20th through October 25th, 2017 by CMEH personnel. Specific methods for each type of assessments are described below.

Natural Resource Evaluation

The on-site survey consisted of pedestrian transects 100 feet in width throughout the APE. The surveyors identified and described environmental conditions including animal and plant species composition, general soil characteristics and geology, potential wetlands, ephemeral drainages, and habitat potential for Federal, State, BLM and/or MBTA-listed species. The surrounding areas within 0.25 mile of the project area boundary were visually inspected with binoculars for nests, raptors, or past signs of raptor use. All plant and wildlife species observed in the APE were recorded (Appendix C), and digital photos were taken (Appendix B). Field biologists with considerable experience identifying local flora and fauna species lead survey crews.

Rangeland Evaluation

Common methodologies to determine vegetation cover types, overall total percent vegetation cover, and rangeland conditions over a period of several months, seasons or years vary depending on the specific goals of the analysis and vegetation community. A specific technique may work for two or more cover types, however, the same technique may be inadequate on another plant community type. The range biologist determined transects based on on-site field conditions in order to meet each specific cover type encountered out on the range.

For the rangeland evaluation of the survey area, a series of 64 transects, each 30 feet in length and 2 feet wide, were established throughout the APE. Each transect was given an identification number and the slope, orientation, vegetation community, soil Munsell reading, soil texture, vegetation diversity, and shrub density were recorded. A photo was also taken from each end of the transect looking toward the transect median.

Shrub Density - Shrub density was determine by counting all individual shrubs located within the area extending one foot out from the centerline on both sides of the 30 foot line transect. Additionally, surveyors recorded the height of the tallest and shortest individual from each shrub species within the transects in order to determine height range and vertical cover.

Cover - A measuring tape was placed along each 30 foot transect and the transect was divided into six equal sections representing 0 – 5 feet, 5 – 10 feet, 10 – 15 feet, 15 – 20 feet, 20 – 25 feet, and 25 – 30 feet. A pin flag marked the start and end of each section. Within each section, surveyors recorded all trees, shrubs, sub-shrubs, cacti, grasses and herbaceous forbs as well as their cover (in inches) present along the measuring tape. Within each section the litter cover (plant debris, dead branches, etc.) and rock cover were also estimated.

Production and Stocking Rate - A one-square-foot frame was placed in a random location along each of the transects. All of the current year's growth located within the frame was clipped to ground level (including plants whose stems originate within the frame including all aboveground parts that extend beyond the frame boundary but excluding all plants whose stems originate outside of the frame). Old dry leaves were discarded. Shrubs were clipped where there was new growth from the current year. The clipped vegetation was then placed in a plastic bag and labeled with the date, species, and transect ID. After all locations were collected all samples were weighted (grams) and recorded.

Soil and Vegetation Sampling

On December 8th and 9th, 2017, Weston collected both vegetation and soil samples from 15 separate locations throughout the APE. The number of samples was established by reviewing onsite soil diversity, and using the industry standard of approximately one sample per 60 acres. Sampling locations were chosen to provide equal representation of soil makeup throughout the APE taking into account the physical composition of the soil, topography and vegetation communities.

Soil – Technicians collected soil samples using the techniques and preservation provided in the Quality Assurance Surveillance Plan (QASP) soil sampling section in general accordance with EPA/Environmental Response Team standard operating procedures. Soils were collected from a depth at which the radiological analysis is below the removal action level. Samples were collected utilizing dedicated plastic scoops to reduce the potential for cross-contamination between intervals and locations. The samples were then placed into quart-size or larger plastic bags, and then homogenized. Foreign material such as vegetation, large rocks and pebbles, etc. were removed from the samples and placed back on the property.

Vegetation – A standard one square meter quadrat was placed, subjectively, at each of the 15 sample locations and all vegetative material available to wildlife and domesticated animals within the quadrat (minimum of 20 grams) was clipped and collected (woody material greater than ½ centimeter and vegetation below 3 inches above ground surface was excluded). The clipped vegetation was placed within a paper bag to prevent mold and decomposition and bags were loosely folded at the top, secured using tape and labeled according to the procedures outlined in the soil sampling portion of the QASP.

Sample analysis was by performed by IAS Laboratories. Analysis of the samples was done using a method of metals extraction that mimics the uptake potential from bovine or equine digestive uptake from the plants. Results from the sample analysis are summarized in Tables 2, 3 and 4.

2. NATURAL RESOURCE EVALUATION

2.1. Environmental Setting

The APE is located in west central New Mexico within the USEPA designated Arizona/New Mexico Plateau Level III Ecoregion. The Arizona/New Mexico Plateau occurs primarily in Arizona, Colorado, and New Mexico, with a small portion in Nevada. This ecoregion is approximately 45,870,500 acres, and the elevation ranges from 2,165 to 11,949 feet AMSL. The ecoregion's landscapes include low mountains, hills, mesas, foothills, irregular plains, alkaline basins, some sand dunes, and wetlands. This ecoregion is a large transitional region between the semiarid grasslands to the east, the drier shrublands and woodlands to the north, and the lower, hotter, less vegetated areas to the west and south (Griffith et al. 2006). More specifically the APE lies within the Ambrosia Lake Sub-District (ALSD), a landscape of contrasting scenery, diversified geologic setting, moderately varying elevation gradient, and extreme temperature fluctuations.

The APE is situated within an open valley which slopes gently southward, surrounded by a network of disjunct mesas and plateaus located approximately 2 to 6 miles away. Existing surface disturbances within the APE include numerous areas used for past mining activities, NM State Road 509 which runs through and adjacent to the APE, and several maintained and unmaintained dirt and two-track roads used to access private land throughout the APE.

2.2. Geology

The ALSD is situated on a broad valley between two mesas. To the south, is a narrowing valley that turns into Poison Canyon. To the far west, protrudes a mesa above the lower benches and valley. To the north and northeast, is a northwest oriented mesa that forms extensive sandstone cliffs with a lower monoclinal ridge just below the mesa top. Several miles to the east and southeast, is Mount Taylor and the basalt flow cap rock of the mesas.

Ambrosia Lake valley is bounded by two faults that trend south to north--San Mateo Fault to the south-southeast and Ambrosia Fault to the north-northwest. Much further north is the southern end of Chaco Slope which is part of the southern San Juan Basin. Mount Taylor's volcanic center is located numerous miles to the southeast.

Rock units exposed in the ALSD, range in age from the Pliocene Epoch, to older basal rocks of the Triassic Period. In the low lying Ambrosia Lake valley, rocks exposed are from the Cretaceous Age. Ledge forming sandstones on the east side are Gallup Sandstone--a coastal, beach deposited sandstone. On the west side of the valley are exposures of Dakota Sandstone--another coastal, beach deposited sandstone. Gallup Sandstone and Dakota Sandstone represent transgressive-regressive sequence, coastal deposition. The valley contains weathered Burro Canyon Member Dakota Sandstone, and Mancos Shale. Older rock units of Jurassic Age to Triassic Age occur to the south and southwest. Large regions of the lower foothills and mesa benches of Mount Taylor are capped by Late Pliocene Epoch basalt flows that cap sedimentary rock units.

Stratigraphic rock units represented include in descending order: Mesa Verde Group and Cretaceous Age Mancos Shale, which overlie both Gallup Sandstone and Dakota Sandstone of Lower Cretaceous Period which overlies the Morrison Formation of Upper Jurassic Period. The Morrison Formation in descending order include Brushy Basin and Saltwash Members. The Morrison Formation overlies the San Rafael Group of Middle to Upper Jurassic Period. San Rafael Group Members in descending order include Todilto Limestone, Recaptured Member of Bluff Sandstone, and Bluff Sandstone. San Rafael Group overlies the Glen Canyon Group of Upper Triassic Period--one includes lower Wingate Sandstone. The older, basal unit is Chinle Formation of Upper Triassic Period. Regionally, Chinle Formation is represented by four members in descending order: Church Rock, Owl Rock, Petrified Forest, and Shinarump Conglomerate Members.

2.3. Hydrology/Wetlands

The APE is located within the San Mateo Creek Watershed (HUC10 #1302020703). According to U.S. Fish and Wildlife Service (USFWS) National Wetlands Inventory (USFWS 2008) 10 potential wetland areas and two ephemeral drainages that may be considered "USACE jurisdictional waters" are located within the APE. Numerous, smaller washes occur within the APE and generally run northeast to southwest and drain into the larger, ephemeral Arroyo del Puerto but only in response to large storm events. The Rio San Jose, located approximately 12 miles southwest of the APE, is the nearest perennial water source. There are no known or observed seeps, springs, or riparian areas within the APE.

During the biological survey, no wetland obligate species (USACE 2016) were observed within any of the 10 potential wetland areas.

2.4. Soils

2.4.1. Soil Types

According to the U.S. Department of Agriculture's Natural Resources Conservation Service (NRCS) Web Soil Survey, soils within the APE are 56.1-percent Penistaja-Tintero complex, 1 to 10 percent slopes; 24.6-percent Sparank-San Mateo-Zia complex, 0 to 3 percent slopes; 9.4-percent Uranium mined lands; 6.3-percent Hagerwest-Bond fine sandy loams, 1 to 8 percent slopes, and 3.6-percent Berryhill-Casamero clays, 2 to 10 percent slopes. The different characteristics of these soil types are listed in the tables below and a map of the soil types within the APE can be found in Appendix A.

Table 1a. Characteristics of the Soil Types Present within the Tronox NAUM Central GSA Project Area

Soil Characteristic	Soil Type				
	Penistaja	Tintero	Sparank	San Mateo	Zia
Surface Layer	Brown fine sandy loam	Strong brown fine sandy loam	Brown clay loam	Light yellowish brown loam	Brown fine sandy loam
Slope	0-10%	0-10%	0-4%	0-5%	0-25%
Surface Runoff	Low	Low to medium	Low to high	Low to medium	Very low
Typical Use	Livestock grazing	Rangeland and urban development	Rangeland	Livestock grazing	Irrigated cropland, livestock grazing, wildlife habitat, limited fuelwood and fencepost production.
Moisture Regime	Ustic aridic	Ustic aridic	Ustic aridic	Ustic aridic	Ustic aridic
Drainage Class	Well drained	Somewhat excessively drained	Well drained	Well drained	Well drained and somewhat excessively drained
Permeability	Moderate	Moderately rapid	Very slow	Moderately slow	Moderate or moderately rapid
Parent Material	Alluvium, fan alluvium, slope alluvium and eolian material derived from sandstone and shale	Eolian material and alluvium, fan alluvium, and slope alluvium derived from sandstone	Alluvium, fan alluvium, and stream alluvium derived from sandstone and shale	Alluvium, fan alluvium and stream alluvium from mixed sources	Alluvium, fan alluvium, and stream alluvium and eolian material from sandstone

Soil Characteristic	Soil Type			
	Hagerwest	Bond	Berryhill	Casamero
Surface Layer	Light brown fine sandy loam	Brown sandy loam	Light olive brown silty clay	Light olive brown clay
Slope	0-5%	0-50%	2-8%	2-10%
Surface Runoff	Negligible on slopes < 1 percent and low to medium on 1 to 5 percent slopes	Medium	Medium to very high	High and very high
Typical Use	Rangeland and wildlife habitat	Livestock grazing	Rangeland	Rangeland
Moisture Regime	Ustic aridic	Ustic aridic	Ustic aridic	Ustic aridic
Drainage Class	Well drained	Well drained	Well drained	Well drained
Permeability	Moderate over very slowly permeable bedrock	Moderate or moderately slow	Very slow	Very slow
Parent Material	Eolian material, slope alluvium and alluvium.	Alluvium, slope alluvium, and eolian deposits from sandstone	Alluvium and slope alluvium derived from gypsiferous Mancos shale	Alluvium and slope alluvium over residuum derived from gypsiferous Mancos shale

2.4.2. *Existing Soil Condition and Basic Soil Chemistry*

Soil is a major source of nutrients needed by plants for growth, and these nutrients derived from soils are commonly grouped into two different categories, macronutrients and micronutrients. Macronutrients are those required in relatively large amounts for normal plant growth and include nitrogen, phosphorus, potassium, calcium, magnesium and sulfur. Micronutrients, however, only exist in small amounts in ordinary soils but are also known, or suspected to be essential, for normal plant growth and typically include iron, manganese, zinc, copper, boron, molybdenum, chlorine, and sodium. The deficiency or overabundance of one or more of these nutrients can affect soil condition and, in turn, the overall health not only to the local plant populations but area fauna as well due to plants being the source of many key nutrients for browsing animals necessary for normal growth, reproduction, and immune response. In order to create an initial summary of existing soil conditions within the APE, Weston collected both vegetation and soil samples from 15 separate locations throughout the APE. Samples were collected to help determine the current vegetative nutrient values of various micronutrients including iron, zinc, copper, manganese, and molybdenum. The plant analysis included overall presence (parts per million - ppm) of several essential micronutrients and a summary of the results can be found below in Table 2, and a map of the micronutrient distribution among and between the 15 sampling locations within the APE can be found in Appendix A.5.

Table 2. Typical Plant Content of Various Soil-derived Essential Micronutrients and Their Concentrations Found within the APE.

Element	Known critical values[1,2]				Within APE	
	Range of Concentrations (ppm)	Average Concentrations (ppm)	Deficiency Threshold (ppm)		Range of Concentrations (ppm)	Average Concentrations (ppm)
Iron	50-1,000	100	50		129 - 1,193.4	506.1
Zinc	10-100	20	15		0.03 - 358.4	32.1
Copper	2-20	6	3		4.44 - 11.21	6.9
Manganese	20-200	50	15		2.8 - 196.7	33.9
Molybdenum	0.05-10	0.1	0.10		3 - 27.4	12.9

References: [1] Mahler 2004, [2] Jones 1997

The vegetation samples were also collected to help determine plant uptake of trace metals which would, in turn, be available to grazing animals utilizing the APE. Selenium is an essential trace metal that plays an important role in biochemical and physiological functions in plants and animals; however, uptake of this metal in excess may result in toxic effects. Uranium and vanadium are non-essential trace metals considered as soil pollutants due to their acute and chronic toxic effect on plants grown on such soils; additionally, uranium and vanadium are potentially hazardous to grazing animals utilizing the APE. The plant analysis included overall presence (parts per million - ppm) of several trace metals and a summary of the results can be found below in Table 3 and a map of the trace metal distribution among and between the 15 sampling locations within the APE can be found in Appendix A.6.

Table 3. Typical Plant Content of Various Soil-derived Trace Metals and Their Concentrations Found within the APE.

Element	Known critical values[1,2]			Within APE	
	Range of Concentrations (ppm)	**Average Concentrations (ppm)**	**Hazard Threshold (ppm)**	**Range of Concentrations (ppm)**	**Average Concentrations above <0.10 (ppm)**
Uranium	N/A	0.01	>50	<0.10 – 3.9[a]	*(All <0.10 except for one)*
Vanadium	0.1-1.0	0.5	5-10	<0.10 – 3.21[b]	1.50 (N=8)
Selenium	0.05-2.0	0.02	5-30	<0.10 – 38.08[c]	10.67 (N=8)

[a] 14 of 15 samples <0.10, [b] 7 of 15 samples <0.10, [c] 7 of 15 samples <0.10
References: [1] Mahler 2004, [2] Jones 1997

Additional indicators of soil health include parameters such as water holding capacity (WHC) and carbon nitrogen ratios (C:N). The carbon nitrogen ratio is a measurement of the availability of two of the most important nutrients for microorganisms in the soil. Carbon is used as an energy source and nitrogen is a requirement for building proteins and enzymes. Soils with C:N ratios near 24:1 can support the highest levels of biological activity. If the C:N ratio is too high then nitrogen limits the growth of the organisms and they will compete with plants for any available source of N. If the ratio is too low then the carbon is restricting the growth of micro-organisms and their beneficial activities of nutrient cycling and release are limited. Other benefits from a healthy soil also depend on a balanced C:N ratio. These benefits include factors such as higher organic matter content and improved soil structural stability, both of which increase the soil's water holding capacity, or the maximum amount of plant available water a soil can provide. The WHC is an indicator of a soil's ability to retain water and make it sufficiently available for plant use. WHC is affected by soil texture, presence and abundance of rock fragments, and soil depth and layers and increases with increasingly fine textured soil, from sands to loams and silt loams. Coarse textured soils have lower field capacity since they are high in large pores subject to free drainage. Fine textured soils have a greater occurrence of small pores that hold water against free drainage, resulting in a comparatively higher field capacity.

In addition to the vegetation sample analysis conducted by Weston, soil samples were collected from the same 15 sites and analyzed to determine the amount of total carbon and total nitrogen available at each site in order to determine the overall C:N ratios. The WHC for each site was measured as well. A summary of the laboratory results including the range and average for all 15 sites is outlined in Table 4 and a map of the C:N and WHC distribution among and between the 15 sampling locations within the APE can be found in Appendix A.7.

Table 4. Summary of Total Carbon and Nitrogen, C:N and Water Holding Capacity for the APE

Summary from 15 samples	Total Carbon %	Total Nitrogen %	C:N	Water Holding Capacity – 0 Bar %
Range	0.16 – 2.28	0.07 – 0.32	2:1 – 10:1	16.84 – 36.09
Average	0.90	0.16	5.4:1	26.9

Further discussion on the results from vegetation and soil sampling for micronutrient content, trace metals, C:N ratio and water holding capacity are included Section 3.2.2. Soil Condition.

2.5. Flora

2.5.1. Vegetation communities

Vegetation communities found within the Arizona/New Mexico Plateau ecoregion include shrublands and grasslands. Higher elevations may support Piñon-Juniper woodlands. The APE is comprised of six different plant community types outlined below in order of occurrence.

Grassland-Shrub Community - Grassland-Shrub community has equal coverage of grasses and shrubs. Shrubs include: broom snakeweed (*Gutierrezia sarothrae*), Bigelow's rabbitbrush (*Chrysothamnus nauseosus* var. *bigelovii*), winterfat (*Ceratoides lanata*) and four wing saltbush (*Atriplex canescens*). Grasses include: galleta (*Hilaria jamesii*), bluegrama (*Bouteloua gracilis*), purple threeawn (*Aristida purpurea*), Indian ricegrass (*Oryzopsis hymenoides*). Herbaceous forbs include: plains spring parsley (*Cymopterus acaulis* var. *fendleri*), silvery townsendia (*Townsendia incana*), common globemallow (*Sphaeralcea coccinea*), plains cryptanth (*Cryptantha crassisepala*), small flowered milkvetch (*Astragalus nuttallianus*), western stickseed (*Lappula occidentalis*), Anderson's larkspur (*Delphinium andersonii* var. *scaposum*), and nodding buckwheat (*Eriogonum cernuum*). Soils are silty to siltysand.

Grasslands Community - Shrubland community are dominated by grasses. Shrubs include: broom snakeweed (*Gutierrezia sarothrae*), and winterfat (*Ceratoides lanata*). Grasses include: galleta (*Hilaria jamesii*), bluegrama (*Bouteloua gracilis*), purple threeawn (*Aristida purpurea*), Indian ricegrass (*Oryzopsis hymenoides*), and pullup muhly (*Muhlenbergia filiformis*). Herbaceous forbs include: plains spring parsley (*Cymopterus acaulis* var. *fendleri*), plains cryptanth (*Cryptantha crassisepala*), western stickseed (*Lappula occidentalis*), Anderson's larkspur (*Delphinium andersonii* var. *scaposum*), and nodding buckwheat (*Eriogonum cernuum*). Soils are silty to siltysand. This community type occurs in large patches.

Shrubland Community - Shrubland community are dominated by shrubs. Shrubs include: rubber rabbitbrush (*Chrysothamnus nauseosus*), broom snakeweed (*Gutierrezia sarothrae*), Bigelow's rabbitbrush (*Chrysothamnus nauseosus* var. *bigelovii*), winterfat (*Ceratoides lanata*) and four wing saltbush (*Atriplex canescens*). Grasses include: galleta (*Hilaria jamesii*), bluegrama (*Bouteloua gracilis*), purple threeawn (*Aristida purpurea*), and Indian ricegrass (*Oryzopsis hymenoides*). Herbaceous forbs include: plains spring parsley (*Cymopterus acaulis* var. *fendleri*), plains cryptanth (*Cryptantha crassisepala*), small flowered milkvetch (*Astragalus nuttallianus*), western stickseed (*Lappula occidentalis*), Anderson's larkspur (*Delphinium andersonii* var. *scaposum*), and nodding buckwheat (*Eriogonum cernuum*). Soils are silty to siltysand. A large amount of acreage is covered by Shrublands.

Southwest Arroyo Shrubland Community - Arroyo shrubland communities is characterized by a mixture of shrubs that includes: rubber rabbitbrush (*Chrysothamnus nauseosus*), big sagebrush (*Artemisia tridentata*), and snakeweed (*Gutierrezia sarothrae*). Other shrub associates include: Louisiana lousewort (*Artemisia ludoviciana*). Non-native shrubs saltcedar (*Tamarix chinensis*) and Russian olive (*Elaeagnus angustifolia*) are slowly taking over these community types. Both shrubs are highly aggressive, once established they easily overtake and invade native plant communities. Associate grasses include: desert saltgrass (*Distichlis spicata*), and cheatgrass (*Bromus tectorum*). Soils are typically sandy. This vegetation cover type occurs along ephemeral stream courses.

Grassland Swale Community - Grassland Swales are dominated by alkali sacaton (*Sporobolus airoides*) mixed with New Mexico saltbush (*Atriplex obovata*), shadscale (*Atriplex confertifolia*), greasewood (*Sarcobatus vermiculatus*), and plains prickly pear (*Opuntia polyacantha*). Associate grasses include:

galleta (*Hilaria jamesii*). Herbaceous forbs include: annual townsendia (*Townsendia annua*), common globemallow (*Sphaeralcea coccinea*), corrugate phacelia (*Phacelia crenulata* var. *corrugata*), Russian thistle (*Salsola tragus*), small flowered milkvetch (*Astragalus nuttallianus*), plains cryptanth (*Cryptantha crassisepala*), pinnate tansymustard (*Descurainia pinnata*), and tumble weed (*Salsola tragus*). Alluvial deposited soils are silty to siltysand. This vegetation cover occurs in lowland playas, low gradient alluvial fans and gentle sloped flood plains.

Juniper Savannah Community - Plant community with sparsely scattered one seed juniper (*Juniperus monosperma*). Associate shrubs include: big sagebrush viscid rabbitbrush (*Chrysothamnus viscidiflorus*), broom snakeweed (*Gutierrezia sarothrae*), slender buckwheat (*Eriogonum microthecum*), and broadleaf yucca (*Yucca baccata*). Grasses include: galleta (*Hilaria jamesii*), bluegrama (*Bouteloua gracilis*), Torrey's muhly (*Muhlenbergia torreyi*), and pullup muhly (*Muhlenbergia filiformis*). Herbaceous forbs include: (*Lappula occidentalis*), hoary aster (*Machaeranthera canescens*), Clokey's gilia (*Gilia clokeyi*), Fendler's milkspurge (*Euphorbia fendleri*), and nodding buckwheat (*Eriogonum cernuum*). Soils are clay to siltysand. This cover type occurs on small knolls and high regions to the northern block.

The APE also contains previously disturbed areas including existing and established roads, numerous two-track and unmaintained roads, previous staging areas used for mining activities, and other areas where the vegetation was notably disturbed.

2.5.2. Noxious Weeds and Invasive Species

Noxious weeds are plants that have no economic value, often agricultural pests with no nutritious value for most animals. Noxious weeds are predominately non-native plants, they may also include several native plants that exhibit weed like patterns of aggressive growth or possessing some form of plant toxicity. Noxious weeds and invasive species are frequently found in areas that have been disturbed by surface activities. The re-establishment of plant communities in arid regions occurs over a longer time period than in wetter regions, which may create an increased potential for the establishment and distribution of invasive species. Invasive plant species typically develop high population densities and tend to exclude most other plant species, thereby reducing species diversity and potentially resulting in long-term effects. Some noxious and invasive weeds can change soil chemistry and some are highly toxic to livestock. Management of noxious weeds and invasive plant species is mandated under several pieces of legislation, including the Lacey Act, as amended (16 USC 3371-3378); the Federal Noxious Weed Act of 1974, as amended (7 USC 2801 et seq.); the New Mexico Noxious Weed Management Act of 1998; and Executive Order (EO) 13112 regarding Invasive Species. Under EO 13112, federal agencies are ordered not to authorize or carry out actions that would cause or promote the introduction of invasive species.

The U.S. Department of Agriculture (USDA) has designated certain plants as federally listed noxious weeds (NRCS 2010). The New Mexico Department of Agriculture (NMDA) has designated certain plants as state-listed noxious weeds (NMDA 2016). NMDA categorize the listed noxious weeds into Class A, B or C species. Class A species are currently not present in New Mexico, or have limited distribution. Preventing new infestations of these species and eradicating existing infestations is the highest priority. Class B Species are limited to portions of the state. In areas with severe infestations, management should be designed to contain the infestation and stop any further spread. Class C species are wide-spread in the state. Management decisions for these species should be determined at the local level, based on feasibility of control and level of infestation. NMDA has also identified species that fall under a “Watch List”. Watch List species are species of concern in the state. These species have the potential to become problematic. Table 5 includes noxious weeds or invasive plant species observed during the on-site survey within the APE and their listed weed status.

Russian thistle (*Salsola australis*) was also noted in sporadic patches throughout the APE, particularly in areas of existing disturbance. Although Russian thistle is not included on the USDA, NMDA, or BLM-FFO invasive, non-native plant species lists, it is known to out-compete desirable, native vegetation (Whitson et al. 1992).

Table 5: Noxious Weeds or Invasive Species Observed Within the Tronox NAUM Central GSA Project Area

Species	Status	Habitat	Remarks
Whorled milkweed (*Asclepias subverticillata*)	USDA - NMDA -	A native species that takes advantage of disturbed sites associated with roadsides, farmlands, irrigation ditch banks, and other disturbed areas next to undisturbed rangelands they inhabit.	Poisonous to livestock, especially sheep. Often found in baled alfalfa.
Field bindweed (*Convolvulus arvensis*)	USDA - NMDA -	Agricultural areas, cultivated fields, roadsides, irrigation ditch margins, river floodplains, well site locations, pipeline right-of-ways, road sides, and other disturbed sites.	A low growing, vine like plant that climbs fences, or shrubs. Deep roots enable its survival. Very difficult to eradicate, often in alfalfa fields.
Russian olive (*Elaeagnus angustifolia*)	USDA - NMDA Class C	Originally cultivated as shade trees, for wind breaks along fields, and later for erosion control. Now widely established along rivers, streams, other water ways.	An aggressive noxious weed that has become naturalized along rivers, streams, and other water ways. They have also infected springs, seeps and other moist areas in the southwest.
Halogeton (*Halogeton glomeratus*)	USDA - NMDA Class B	Alkaline soils in salt desert scrub, mixed desert shrub communities, particularly on weathered shale outcrops.	A toxic plant containing high concentration of oxalic acid salts. Sheep are most susceptible, followed by cattle. Poisoning occur late fall to early winter, when no other forage is available.
Saltcedar (*Tamarix chinensis*)	USDA - NMDA Class C	Planted for erosion control, now widely established along rivers, streams, other water ways, ponds, stock ponds.	A very aggressive noxious weed that has expand its range without control, this shrub has now become naturalized along rivers, streams, other water ways including critical springs, seeps and other moist areas in the southwest.

2.6. Fauna

Wildlife or evidence of wildlife observed within the APE during the on-site survey are summarized below and in Appendix C. USFWS-listed species can be found in Section 2.4.

2.6.1. Birds

Numerous raptor species including red-tailed hawk (*Buteo jamaicensis*), ferruginous hawk (*Buteo regalis*), Northern harrier (*Circus cyaneus*), and merlin (*Falco columbarius*) were observed foraging in the APE and perched along area power poles and fence posts. Additional avian species that were either seen or heard within the APE include: scaled quail (*Callipepla squamata*), Western meadowlark (*Sturnella neglecta*), loggerhead shrike (*Lanius ludovicianus*), mountain bluebird (*Sialia currucoides*), Western bluebird (*Sialia Mexicana*), mountain chickadee (*Poecile gambeli*), horned lark (*Eremophila alpestris*), American pipit (*Anthus rubescens*), sagebrush sparrow (*Artemisiospiza nevadensis*), song sparrow (*Melospiza melodia*), white-crowned sparrow (*Zonotrichia leucophrys*), dark-eyed junco (*Junco hyemalis*), American goldfinch (*Spinus tristis*), house finch (*Haemorhous mexicanus*), sage thrasher (*Oreoscoptes montanus*), and green-winged teal (*Anas carolinensis*).

2.6.2. Mammals

Numerous burrows, both active and abandoned, occur throughout the APE. Burrows appear to belong to a variety of species including prairie dog (*Cynomys* sp.), kangaroo rat (*Dipodomys sp.),* banner-tailed kangaroo rat (*Dipodomys spectabilis*), and pocket gopher (*Thomomys bottae*). Many burrows appeared open and in good condition; however, no individuals of any of the burrowing species were seen during the survey. It should be noted that surveys occurred during the fall when many of these species would not be very active. Other observations of mammals within the APE included Bobcat (*Lynx rufus*) and coyote (*Canis latrans*) tracks and scat.

2.7. Threatened, Endangered, and Sensitive Species Evaluation

The federal Endangered Species Act (ESA) of 1973, 16 U.S.C. §1531 et seq., requires all federal departments and agencies to conserve threatened, endangered, and critical and sensitive species and the habitats on which they depend, and to consult with the USFWS on all actions authorized, funded, or carried out by each agency to ensure that the action will not likely jeopardize the continued existence of any threatened and endangered species or adversely modify critical habitat (USFWS 1998). This section describes the potential for federal ESA-listed endangered, threatened, candidate, or otherwise designated sensitive flora and fauna to occur in the APE. The action area with regard to the ESA is defined as any area that may be directly or indirectly impacted by proposed activities (50 CFR §402.02).

2.7.1. Species from the USFWS IPaC Species List

Table 6 includes ESA-listed plant and animal species with potential to occur in the APE based on the unofficial USFWS IPaC Species List for the area. CMEH biologists evaluated habitat suitability within and surrounding the APE for the species listed in Table 2.

Table 6: USFWS Species List for the Tronox NAUM Central GSA Project Area

Species	Status	Occurrence Within Region	Habitat	Potential to Occur within Action Area
BIRDS				
Southwestern Willow Flycatcher (*Empidonax traillii extimus*)	Endangered with Designated Critical Habitat	Summer/breeding range.[2]	Breeds in dense riparian habitat.[2]	**No potential.** Action area does not provide suitable habitat for species to occur. Lack of riparian habitat a limiting factor.
Mexican spotted owl (*Strix occidentalis lucida*)	Threatened with Designated Critical Habitat	Year-round range.[1]	Mixed conifer forests. Typically where unlogged, uneven-aged, closed-canopy forests occur in steep canyons.[1]	**No potential.** Action area does not provide suitable habitat for species to occur. Lack of mixed conifer forests and steep canyons a limiting factor. Nearest suitable habitat is found approx. xx miles to the west within the Cibola National Forest.
Western Yellow-Billed Cuckoo (*Coccyzus americanus*)	Threatened	Possible rare summer/breeding occurrences.[2]	In the southwestern U.S., associated with riparian woodlands dominated by cottonwood or willow trees. In New Mexico, native or exotic species may be used.[2]	**No potential.** Action area does not provide suitable habitat for species to occur. Lack of riparian habitat a limiting factor.

Species	Status	Occurrence Within Region	Habitat	Potential to Occur within Action Area
FISHES				
Zuni Bluehead Sucker (*Catostomus discobolus yarrowi*)	Endangered	Native to headwater streams of the Little Colorado River in east-central AZ and west-central NM; current range in NM is limited to the upper Río Nutria drainage.[2]	Low-velocity pools and pool-runs with seasonally dense perilithic and periphytic algae, particularly shady, cobble/boulder/bedrock substrates in streams with frequent runs and pools.[2]	**No potential.** Action area does not provide suitable habitat for species to occur. The Rio San Jose, located approximately 12 miles southwest of the APE, is the nearest perennial water source. However, ESA-listed fish species are not known to occur in Rio San Jose, nor is it considered critical habitat of any ESA-listed species.
PLANTS				
Zuni fleabane (*Erigeron rhizomatus*)	Threatened	Zuni and Chuska Mountains, and Datil and Sawtooth ranges in New Mexico.[3]	Found on fine textured clay hillsides of mid to high elevation between 7000 and 8300ft. It is known from clays derived from the Chinle Formation in the Zuni and Chuska Mountains, and to similar clays of the Baca Formation in the Datil and Sawtooth ranges in New Mexico.[3]	**No potential.** Action area does not provide suitable habitat for species to occur.

Sources: [1]USFWS; [2]NatureServe Explorer, [3] IUCN Red List

2.7.2. State of New Mexico and Bureau of Land Management Sensitive Species

The Bureau of Land Management (BLM) manages certain species which are not federally listed as threatened or endangered in order to prevent or reduce the need to list them as threatened or endangered in the future. BLM Sensitive Species include BLM Special Status Species (SSS) and BLM-FFO Special Management Species (SMS).

New Mexico BLM State Directors have developed a list of BLM Sensitive Species for the State of New Mexico (BLM 2011b, BLM 2011c, 2011d, BLM 2012). In accordance with BLM Manual 6840, the BLM-FFO has prepared a list of BLM-FFO SMS to focus species management efforts toward maintaining habitats under a multiple-use mandate (BLM 2008a, BLM 2008b). BLM-FFO SMS include some BLM Sensitive Species and other species for which the BLM-FFO has determined special management is appropriate (BLM 2008b, BLM 2011a). The authority for this policy and guidance is established by the ESA; Title II of the Sikes Act, as amended (16 USC 670a-670o, 74 Stat. 1052); FLPMA; and Department of Interior Manual 235.1.1A.

In addition, the State of New Mexico maintains a list of species for the state designated as Endangered Threatened or Species of Concern (NMDGF 2017). The table below provides an evaluation of the potential for BLM Special Status Species (SSS and SMS) and/or State of New Mexico listed Endangered (E), Threatened (T), or Species of Concern (SOC) to occur in the APE. Potential presence determination is based on an evaluation of the APE habitat and the known habitat requirements of the species. Species addressed previously will not be reiterated here.

Table 7: Bureau of Land Management and State of New Mexico Sensitive Species with Potential to Occur within the Tronox NAUM Central GSA Project Area

Species Name	Conservation Status	Habitat Associations	Potential to Occur in the Action Area
BIRDS			
American peregrine falcon (*Falco peregrinus anatum*)	BLM SMS State NM T	Open country near lakes or rivers with rocky cliffs and canyons. Tall city bridges and buildings also inhabited. [2,3]	**No potential**. Action area does not provides suitable habitat for species to occur. More suitable habitat found to the west within the Cibola National Forest.
Bald eagle (*Haliaeetus leucocephalus*)	BLM SEN SMS State NM T	Near lakes, rivers and cottonwood galleries. Nests near surface water in large trees. May forage terrestrially in winter. [2,3]	**No potential**. Action area does not provides suitable habitat for species to occur. Lack of large natural waterbodies limiting factor.
Bendire's thrasher (*Toxostoma bendirei*)	BLM SEN State NM -	Typically inhabits sparse desert shrubland and open woodland with scattered shrubs. Breeds in scattered locations in central and western portions of NM; most common in southwest NM. [2,3]	**Potential**. Areas of open sagebrush within the action area may provide potential suitable habitat for species to occur.
Chestnut-collared Longspur (*Calcarius ornatus*)	BLM SEN State NM -	May occur in NM during the nonbreeding season in grasslands, deserts and plateaus dominated by low grasses and forbs, where most vegetation is <0.5 m high. May also occur during the nonbreeding season in fallow fields and mowed croplands and around water sources. [2,3]	**Potential**. Slightly rolling expanses of grassland with short, sparse vegetation within the action area may provide suitable habitat for species to occur.

Species Name	Conservation Status	Habitat Associations	Potential to Occur in the Action Area
Ferruginous hawk (*Buteo regalis*)	BLM SMS State NM -	Open areas containing broad expanses of prairie grassland or shrub-steppe vegetation. Landscapes with low to moderate agricultural coverage may be used for nesting and foraging, and agricultural fields may serve as important foraging areas. Within northwest NM, nesting often occurs on rock spires. May occasionally use transitional and edge areas between grassland and juniper savannah or pinyon-juniper woodland. [2,3]	**Potential**. Action area may contain habitat for foraging, and limited habitat for nesting. Lack of broad open grasslands and agricultural areas likely limiting factor. Species detected within APE.
Golden Eagle (*Aquila chrysaetos*)	BLM SMS State NM -	In the West, mostly open habitats in mountainous, canyon terrain. Nests primarily on cliffs and in large trees. [2,3]	**No potential**. Action area does not provides suitable habitat for species to occur. Lack of mountainous, canyon terrain likely limiting factor. More suitable habitat found to the west within the Cibola National Forest.
Gray vireo (*Vireo vicinior*)	BLM - State NM T	Open stands of piñon pine and Utah juniper (5,800 – 7,200 feet ASML) with a shrub component and mostly bare ground; antelope bitterbrush, mountain mahogany, Utah serviceberry and big sagebrush often present. Broad, flat or gently sloped canyons, in areas with rock outcroppings, or near ridge-tops.	**No potential**. Action area does not provides suitable habitat for species to occur. Lack of open stands of piñon pine and Utah juniper limiting factor
Least Tern (*Sternula antillarum*)	BLM - State NM E	Breeds mainly on riverine sandbars or salt flats.[2]	**No potential**. Action area does not provides suitable habitat for species to occur. Lack of riverine sandbars or salt flats limiting factor.

Species Name	Conservation Status	Habitat Associations	Potential to Occur in the Action Area
Mountain plover (*Charadrius montanus*)	BLM SMS State NM -	Typically nests in flat (<2% slope) to slightly rolling expanses of grassland, semi-desert, or badland, in an area with short, sparse vegetation, large bare areas (often >1/3 of total area), and that is typically disturbed (e.g. grazed); may also nest in plowed or fallow cultivation fields. Nest is a scrape in dirt often next to a grass clump or old cow manure pile. Migration habitat is similar to breeding habitat. [2,3]	**Potential**. Slightly rolling expanses of grassland with short, sparse vegetation and large bare areas within action area may provide suitable habitat for species to occur. Lack of badlands or agricultural area may be a limiting factor.
Pinyon jay (*Gymnorhinus cyanocephalus*)	BLM SEN State NM -	Foothills throughout NM wherever large blocks of pinyon-juniper woodland habitat occurs. [2,3]	**No potential**. Action area does not provides suitable habitat for species to occur. Lack of large blocks of woodland limiting factor.
Prairie falcon (*Falco mexicanus*)	BLM SMS State NM -	Arid, open country, grasslands or desert scrub, rangeland; nests on cliff ledges, trees, power structures. [2,3]	**Potential**. Action area may contain habitat for foraging, but limited habitat for nesting. Lack of steep cliff ledges and large trees for nesting likely limiting factor.
Western burrowing owl (*Athene cunicularia*)	BLM SEN State NM -	Dry, open, short-grass, treeless plains. Nests in abandoned burrows and is typically associated with prairie dog colonies. [2,3]	**Potential**. Open, short-grass areas within the action area may provide suitable habitat; however, no abandoned rodent and/or prairie dog burrows that would support burrowing owls and no signs of nesting were observed within the APE.
MAMMALS			
Cebolleta pocket gopher (*Thomomys bottae umbrinus paguatae*)	BLM SEN State NM T	Perennial riparian habitat with willows, cottonwood, alder and maple. Uplands include large sandstone cliffs with juniper, pinyon, and sage. In New Mexico populations have been found in a small area in Cibola County. [2]	**No potential**. Action area does not provide suitable habitat for species of occur. Lack of perennial riparian habitat or sandstone cliffs limiting factor.
Gunnison's prairie dog (*Cynomys gunnisoni*)	BLM SEN State NM -	Grasslands from low valleys to montane meadows. High mountain valleys and plateaus with open or slightly brushy country with scattered junipers and pines (6,000-12,000 feet AMSL). [2]	**Potential**. Suitable habitat is found within the action and project area. However no large networks of prairie dog burrows were observed within the APE.

Species Name	Conservation Status	Habitat Associations	Potential to Occur in the Action Area
Spotted bat (*Euderma maculatum*)	BLM SEN State NM T	A wide variety of habitats including in or near pine forests, pinyon-juniper woodland near sandstone cliffs areas and often near bodies of water in ponderosa or mixed-coniferous forest.[2]	**No potential**. Action area does not provide suitable habitat for species of occur.
Townsend's big-eared bat (*Corynorhinus townsendii*)	BLM SEN State NM -	In New Mexico, most commonly found in evergreen forests. Roosts and nursery colonies in caves and mine tunnels. [2]	**No potential**. Action area does not provide suitable habitat for species of occur. Lack of evergreen forest habitat and roosting locations likely limiting factor.
PLANTS			
Acoma Fleabane (*Erigeron acomanus*)	BLM SEN State NM SOC	Sandy slopes and benches beneath sandstone cliffs of the Entrada Sandstone Formation in pinyon-juniper woodland. (6,900 - 7,100 feet AMSL). In New Mexico, populations have been found in McKinley and Cibola counties. [2,4]	**No potential**. Action area does not provide suitable habitat in the form of Entrada Sandstone. Nearest population is northwest of Prewitt, NM.
Aztec gilia (*Aliciella formosa*)	BLM SMS SEN State NM E	Arid and sparsely vegetated Badland /Salt desert scrub communities in soils of the Nacimiento Formation (5,000-6,400 feet AMSL). [2,4]	**No potential**. Action area does not provide suitable habitat for species to occur. APE located south of known populations (BLM 2017).
Brack's hardwall cactus (*Sclerocactus cloveriae ssp. brackii*)	BLM SMS SEN State NM E	Sandy clay slopes of the Nacimiento Formation in sparse semi desert, pinyon-juniper grasslands and open arid areas of badland habitat (5,000-6,400 feet AMSL). [2,4]	**No potential**. Action area does not provide suitable habitat for species to occur. APE located south of known populations (BLM 2017).
Grama grass cactus (*Sclerocactus papyracanthus*)	BLM SEN State NM -	Grows in fine, sandy clay loams and red sandy soils of open flats on highly erodible sites within pinyon-juniper woodlands and in desert grasslands (5,000 - 7,200 feet AMSL). In New Mexico, populations have been found in southeast Rio Arriba County and McKinley County to Grant and Dona Ana counties. [2,4]	**No potential**. Action area does not provide suitable habitat, lack of red sandy soils and open desert grasslands likely a limiting factor. APE located north and northwest of known populations (NMRPTC 1999).

Species Name	Conservation Status	Habitat Associations	Potential to Occur in the Action Area
Mancos saltbrush (*Proatriplex pleiantha*)	BLM SEN State NM SOC	Desert badlands of Colorado Plateau on saline clay soils of the Mancos and Fruitland shale formations (5,000 - 5,500 feet AMSL). In New Mexico, populations have been found in San Juan County. [2,4]	**No potential**. Action area does not provide suitable habitat in the form of Mancos or Fruitland formations. APE located south of known populations (NMRPTC 1999).
Parish's alkali grass (*Puccinellia parishii*)	BLM SEN State NM E	Alkaline springs, seeps, and seasonally wet areas that occur at the heads of drainages or on gentle slopes (2,600 - 7,200 feet AMSL). In New Mexico, populations have been found in Catron, Cibola, Grant, Hidalgo, McKinley, Sandoval, and San Juan counties. [2,4]	**No potential**. Action area does not provide suitable habitat for species to occur. Lack of alkaline springs, seeps, and seasonally wet areas likely limiting factor.
San Juan Milkweed (*Asclepias Sanjuanensis*)	BLM SEN State NM SOC	Sandy loam soils, usually in disturbed sites, juniper savanna, and Great Basin desert scrub (5,000 -5,500 feet AMSL). In New Mexico, populations have been found in San Juan county. [2,4]	**No potential**. Action area does not provide suitable habitat in the form of sandy loam soils. APE located south of known populations (NMRPTC 1999).

[1]USFWS, 2016; [2]Nature Serve, 2012; [3]NMPIF, 2007; [4]NMRPTC, 1999

2.7.3. Migratory Bird Species

The Migratory Bird Treaty Act (MBTA) implements various treaties and conventions between the U.S. and Canada, Japan, Mexico and the former Soviet Union for the protection of migratory birds. Under the Act, taking, killing or possessing migratory birds is unlawful.

The bald eagle was delisted under the ESA on August 9, 2007. Both the bald eagle and golden eagle are still protected under the MBTA and Bald and Golden Eagle Protection Act (BGEPA). The BGEPA affords both eagles protection in addition to that provided by the MBTA, in particular, by making it unlawful to "disturb" eagles.

In preparation of the on-site survey information from the New Mexico Partners In Flight website (NMPIF 2007), the New Mexico PIF highest priority list of species of concern by vegetation type, the USFWS's Division of Migratory Bird Management website (USFWS 2017b), and the 2002 Birds of Conservation Concern Report for the Southern Rockies/Colorado Plateau Bird Conservation Region (BCR) No. 16 (Blakesley et al. 2010) were used to develop a list of high priority migratory bird species with potential to occur in the APE. Species addressed previously will not be reiterated here.

Table 8: Priority Birds of Conservation Concern with Potential to Occur in the Tronox NAUM Central GSA Project Area

Species Name	Habitat Associations	Potential to Occur in the Project Area
Black-throated sparrow (*Amphispiza bilineata*)	Xeric habitats dominated by open shrubs with areas of bare ground.	Suitable habitat is present within the action area for species to occur.
Brewer's sparrow (*Spizella breweri*)	Closely associated with sagebrush, preferring dense stands broken up with grassy areas.	Suitable habitat is present within the action area for species to occur.
Loggerhead shrike (*Lanius ludovicianus*)	Open country interspersed with improved pastures, grasslands, and hayfields. Nests in sagebrush areas, desert scrub, and woodland edges.	Suitable habitat is present within the action area for species to occur. **Species detected within APE.**
Mountain bluebird (*Sialia currucoides*)	Open piñon-juniper woodlands, mountain meadows, and sagebrush shrublands; requires larger trees and snags for cavity nesting.	Suitable habitat in the form of sagebrush shrublands present within the action area, however lack of larger trees and snags likely limiting factor for nesting. **Species detected within APE.**
Mourning dove (*Zenaida macroura*)	Open country, scattered trees, and woodland edges. Feeds on ground in grasslands and agricultural fields. Roost in woodlands in the winter. Nests in trees or on ground.	Suitable habitat is present within the action area for species to occur, however lack of trees likely limiting factor for nesting and winter roosting. **Species detected within APE.**
Sage sparrow (*Amphispiza belli*)	Large and contiguous areas of tall and dense sagebrush. Negatively associated with seral mosaics and patchy shrublands and abundance of greasewood.	Marginal habitat present within the action area for species to occur. **Species detected within APE.**
Sage thrasher (*Oreoscoptes montanus*)	Shrub-steppe dominated by big sagebrush.	Suitable habitat is present within the action area for species to occur.
Scaled quail (*Callipepla squamata*)	Brushy arroyos, cactus flats, sagebrush or mesquite plains, desert grasslands, Plains grasslands, and agricultural areas. Good breeding habitat has a diverse grass composition, with varied forbs and scattered shrubs.	Suitable habitat in the form of sagebrush plains and desert grasslands present within the action area. **Species detected within APE.**
Swainson's hawk (*Buteo swainsoni*)	A mixture of grassland, cropland, and shrub vegetation; nests on utility poles and in isolated trees in rangeland. Nest densities higher in agricultural areas.	Marginal habitat is present within the action area for species to occur.
Vesper sparrow (*Pooecetes gramineus*)	Dry montane meadows, grasslands, prairie, and sagebrush steppe with grass component; nests on ground at base of grass clumps.	Marginal habitat is present within the action area for species to occur.

2.8. Rangeland Evaluation

Rangeland evaluation is the process of determining the status of natural rangeland resources. Rangelands conditions are evaluated by a concept known as Biometry, meaning life measurements. Biometry entails the systematic measurement and study of living organisms, in this case plants, plant communities and how it relates to rangeland assessments, classification and management. Biometry combines numerous disciplines of science that includes botany, range science, biology, soil science, geomorphology and ecology. All the different disciplines of science are utilized to classify vegetation community types, to determine rangeland conditions and to make rangeland assessments based on existing field range conditions. The determinations are designed to derive quantifiable data that is use to interpret the overall health and conditions of forests, shrub lands, grasslands, wetlands, riparian areas, and other undisturbed plant communities.

The goal of the initial rangeland evaluation for the survey area was to determine the existing plant species composition, density, and palatability in order to determine current grazing and stocking rate potential. The data collected during the evaluation is intended to aid in potential, future rangeland inventories of the APE that would provide a more detailed analysis of area conditions in order to assist the proponent in establishing management goals, practices, and objectives for the APE and a monitoring program that would ensure those goals and objectives were met.

For the rangeland evaluation the six vegetation communities of the APE were re-grouped to represent the three most dominant rangeland vegetation communities: shrubland/grassland, arroyo shrubland and juniper savannah. The total area for each rangeland vegetation community was determined by delineating the communities within the APE using field notes from the on-site survey and ArcMap 10.1 aerial imagery, then calculating and summing the combined acreages for each community. Areas of disturbance (existing, established roads, previous staging areas used for mining activities, and other areas where the vegetation was notably disturbed, approximately 278 acres total) were excluded from the analysis. A map depicting the three rangeland vegetation communities is provided in Appendix A – Maps.

2.8.1. Grazing Vegetation Composition

Range plants are commonly classified according to their forage value. High forage value designates plants that are nutritious, palatable, and produce abundant forage. Medium forage value denotes a plant that will provide adequate nutrients if eaten; however, it is not preferred by animals or does not produce abundant forage. Low or poor forage value describes plants that simply do not provide adequate nutrients to the grazing animal. Additionally, most plants containing anti-quality compounds that reduce intake or poisonous plants containing toxins that cause illness or death in herbivores are classified as having "low" forage value. Furthermore, forage values of various plant species may also depend on whether the herbivore is classified as a grazer (typically cattle, sheep, and elk) or browser (goats, deer, and pronghorn) as specializations within the anatomy and digestive tracts of the two classifications allow them to better extract nutrients from their preferred forage class.

2.8.2. Cover

Cover is an important rangeland evaluation indicator as it provides information relating to area conditions such as erosion potential, the value of wildlife habitat, availability of forage, and trends in range condition. Average cover for each rangeland vegetation community was determined by summing the total cover of all forage within each rangeland vegetation community and dividing by the total number of transects within each community. Average percent cover for arroyo shrubland was 26.1 percent, shrubland/grassland was 22.6 percent, and juniper savannah was 13.4 percent.

2.8.3. Forage Production

Estimating forage production of an area is important tool in rangeland assessments because it directly correlates to how long a set number of livestock can utilize a given area. Also, a thorough understanding of area conditions is important as the climate (temperature and precipitation), soil (texture, depth, fertility) and current vegetation management strategies can all affect forage production. The total forage production for each rangeland vegetation community was determined by summing the weights of all vegetation within each rangeland vegetation community and dividing by the total area from which the samples were collected within each community. For forage production estimates, it was assumed that when herbivores forage on a plant 100 percent of the individual plant would be consumed except for a few shrub species in which it was assumed approximately 10 percent of the individual plant would be consumed. In the ladder case the weights of those shrub species were multiplied by 0.1 then summed with the remaining true weights of the other samples. Forage production values for each rangeland vegetation community can be found in Table 7.

2.8.4. Stocking Rate

Stocking rate is a statistical numeric value used to determine how many animals a specific land area will support. In order to determine stocking rate for each of the rangeland vegetation communities the total production of the transect areas was calculated. Animal Unit Month (AUM) was use to figure out rangeland capacity of grazing animals. The AUM is based on how much a 1,000 lb cow with calf will consume in a month. One (1) AUM is 800 lbs of dry forage consumed or about 80 percent of a 1,000 lb cow with calf combination. A numeric value of one (1) assigned to the cow with calf combination is a factor that all other grazing animals compare with. The conversion factor of different grazing animals called the Animal Unit Equivalent (AUE) varies from one animal class or type to another. For example: a mature sheep requires 20 percent of forage, compared to a 1,000 lb cow with calf, so 5 mature sheep AUM will be equivalent to 1000 lb cow with calf AUM.

The stocking rate for the three rangeland vegetation community types within the APE was determined by following the steps provided below:

- Total production (lbs/acre) = Total weight of available forage for each rangeland vegetation community dividing by the total acreage of each rangeland vegetation community.
- Total available forage (lbs/acre) = Total production multiplied by 0.5**

  ***(0.5 is used to indicate a general rule to graze only 50 percent and to leave 50 percent behind, however, this figure can be adjusted base on how intense you would like to graze that grazing unit).*
- Based on the animal class, determine pounds of forage consumed (or monthly intake, lbs/month). For example, and as discussed previously, a 1,000 lb animal consumes 80 percent of its total body weight or 800 lbs per month.
- Stocking rate (animals / month) = total available forage divided by the monthly intake.
- AUM (animals / month) = stocking rate divided by the AUE for the animal class.

- Number of animals to graze over an allotted time = AUM divided by the allotted time

Table 9 provides a summary of total production, available forage, and stocking rate potential for the three rangeland vegetation community types within the APE. Assumptions used in the calculations are noted below.

Table 9. Rangeland Assessment Values for each of the Rangeland vegetation communities found within the Tronox NAUM Central GSA Project Area.

Rangeland vegetation community	Total area of rangeland vegetation community (acres)	Total production (lbs/acre)	Total available forage[1] (lbs/acre)	Stocking rate[2] (animals / month)	AUM[3] (animals / month)
Shrubland/grassland	723	545	197,018	246	176
Arroyo shrubland	306	715	109,395	137	98
Juniper savannah	15	1,198	8,985	11	8

[1] Total Production x 0.5 (Graze only 50 percent and to leave 50 percent behind)
[2] Assumes 1,000lb animal consumes 80% of weight per month
[3] Stocking Rate x AUE for 1,200 lb cow with calf (AUE = 1.4)

3. DISCUSSION

The following section provides a brief summary of results presented in Chapter 2 as well as an assessment of current and potential impacts to each resources due to past, present, and future surface-disturbing activities within and immediately adjacent to the APE. Such activities could include, but are not limited to, the construction of roads, other facilities, and installation of trenches for utilities; road maintenance such as grading or ditch-cleaning; public recreational activities; vegetation manipulation and management activities; prescribed and natural fires; and livestock grazing.

3.1. Hydrology/Wetlands

CMEH determined that 10 potential wetland areas and two ephemeral drainages that may be considered “USACE jurisdictional waters” are located within the APE. No obligate wetland plant species were observed within any of the 10 potential wetland areas. USACE jurisdiction of the two waterways can be confirmed through an official Jurisdictional Determination (JD) request submitted to the USACE. There is no suitable habitat for ESA-listed fish in the nearest perennial water source, Rio San Jose, nor is it considered critical habitat of any ESA-listed species.

Current and potential impacts to surface waters within the APE may include stormwater runoff, accidental spill of chemicals both on and off site, and increased sedimentation due to past, present and future surface-disturbing activities within and immediately adjacent to the APE.

3.2. Soils

3.2.1. *Soil Type*

The soils found in the APE have been classified as having very low to very high surface runoff, are generally well drained, and exhibit very slow to moderately rapid permeability. Approximately 278 acres of soils within the APE (or 21-percent of the total APE acreage) are within areas of previous disturbance.

Current and potential impacts to soils within the APE due to past, present, and future surface disturbing activities within and immediately adjacent to the APE depend, in part, on seasonal variation in rainfall and snowmelt run-off, terrain, soil type, prevailing winds, and vegetative cover.

3.2.2. *Soil Condition*

In order to create a baseline record of overall soil condition within the APE, general soil mapping as well as vegetation and soil sample analysis were conducted. Both vegetation and soil samples were collected from 15 sites and analyzed to determine the following indicators: micronutrient availability and trace metal detection within area vegetation, and the carbon-nitrogen ratio and water holding capacity of area soils.

Micronutrient results from APE vegetation sampling of various soil-derived essential micronutrients within the APE by Weston shows a majority of the elements to be within the typical, known critical value range of concentrations with the exception of molybdenum whose average concentration within the APE (12.9 ppm) was slightly higher than the typical known critical value (range 0.05-10, average 0.1). None of the five micronutrients showed a deficiency according to the typical, known critical deficiency threshold values. No spatial trends were apparent from the micronutrient data.

Trace metal results from APE vegetation sampling also determined the presence of three soil-derived trace metals (uranium, vanadium, and selenium) within the APE and determined that the concentrations for a majority of the samples for all three elements were below the detectable threshold of 0.10 ppm. For those samples above 0.10 ppm the average concentrations for both vanadium and selenium within the APE (1.5 and 10.67, respectively, N=8 for both) were slightly higher to higher than the typical, known critical ranges (0.1-1.0 ppm for vanadium and 0.05-2.0 ppm for selenium). Only one sample was above the detectable threshold of 0.10 ppm for uranium and was reported at 3.9 ppm. None of the three trace metals showed a level at or above the known critical hazard threshold values. Spatially, the distribution of trace metal concentrations varied throughout the APE with the southern, and to a lesser degree, northern portion of the PPA exhibiting slightly higher selenium and vanadium concentrations than the central portion. The single detectable occurrence of uranium was found within the central portion of the PPA.

Carbon: Nitrogen results from APE soils shows a wide range of C:N ratios (2:1 – 10:1) and an overall average ratio of 5.4:1. In general, C:N ratios vary depending on the predominant soil type, but a value near 24:1 can support the highest levels of biological activity (NRCS 2004, Killham 1994). Therefore, results from the laboratory analysis indicate the average C:N ratio for the APE is lower than the typical, ideal ratio of 24:1 indicating an general overabundance of nitrogen. Spatially the distribution of C:N ratios were fairly similar throughout the APE with the southern portion of the PPA exhibiting slightly higher ratios.

Water holding capacity results from APE indicate a wide range of WHC (16.8 – 36.1 %) and an overall average of 26.9%. Recommendations for the optimal water-holding capacity of a substrate vary depending upon the vegetation type and growing conditions. However, a value between 50-70% is said to be the optimal water content for maximum respiration, but sometimes a value as low as 40% is stated (Linn & Doran 1984, Killham 1994).Therefore, results from the laboratory analysis indicate the existing WHC throughout the APE is lower than the common, optimal WHC content recommendations of 50-70%, with the average WHC of the APE being almost half that of the common recommendations. Spatially the distribution of WHC values were fairly similar throughout the APE.

3.3. Flora and Fauna

3.3.1. Flora

Six distinct, yet related vegetation communities are present within the APE. Current and potential impacts to flora within the APE include the direct removal of vegetation and/or suitable habitat for particular vegetation species to occur as well as the establishment of noxious weeds and invasive species due to past, present, and future surface disturbing activities within and immediately adjacent to the APE

3.3.1.1 Noxious Weeds and Invasive Species

Five noxious weeds and/or invasive species were observed within the APE. None of the five species are considered USDA-listed or NMDA Class A species. One NMDA Class B species (Halogeton) and two NMDA Class C species (Russian olive and Saltcedar) were observed within the APE: halogeton occurs within the lower and middle portions of the APE; saltcedar and Russian olive occur primarily within the narrow strips of arroyo shrub and within a few areas along roadsides within the APE.

3.3.2. Fauna

The APE contains potential wildlife habitat in the form of shrubland, grassland, arroyo shrubland, and to a lesser degree, juniper savannah vegetation communities. There is available, similar habitat in the surrounding areas as well. Current and potential impacts to fauna within the APE include the removal or degradation of habitat and/or audial and visual disturbances due to past, present, and future surface disturbing activities within and immediately adjacent to the APE. The intensity of the impacts depend upon the species, its life history, time of year and/or day and the type and level of human and vehicular activity occurring.

3.4. U.S. Fish and Wildlife Service Listed Species

CMEH conducted and informal consultation with the USFWS and received an Unofficial Species List for the APE. Qualified CMEH biologists evaluated habitat suitability within and surrounding the APE for these species and concluded there is no potential for USFWS-listed species to occur within the APE.

3.5. State of New Mexico and Bureau of Land Management Sensitive Species

Qualified CMEH biologists evaluated habitat suitability within and surrounding the APE for State of New Mexico and BLM Sensitive Species. Four (4) BLM Sensitive Species have potential to occur within the APE based on habitat suitability or actual record of observation and are discussed in further detail below.

3.5.1. Gunnison's Prairie Dog

Gunnison's prairie dogs are found in prairies, grasslands and shrublands in high mountain valleys and plateaus and typically live in colonies often smaller than those of other prairie dog species and may consist of fewer than 50-100 individuals. Colonies are comprised of densely aggregated burrows and in some areas with scattered, isolated burrows (NatureServe 2015). Gunnison's prairie dogs can be found in Colorado, New Mexico, Utah, and Arizona. In northwestern New Mexico, they are most abundant in the widespread short-grass plains of San Juan and Rio Arriba Counties within the BLM-FFO management area (Hawks Aloft, Inc. 2007). Gunnison's prairie dogs also play an important ecological role for a number of other key species in the BLM-FFO management area as prairie dog towns provide nesting habitat for burrowing owls, as well as, important foraging areas for raptors and other predator species.

Within the APE suitable habitat for Gunnison's prairie dogs was observed within areas of open or slightly brushy country and grasslands. However, no individuals or large scale prairie dog colonies were observed.

3.5.2. Ferruginous Hawk and Prairie Falcon

In New Mexico, ferruginous hawks typically breed across the northern two-thirds of the state, and may be found statewide during the winter months. Above-ground nesting is common in New Mexico, and occurs most frequently in isolated tree stands or rock outcrops. Power poles or other vertical structures, including artificial platforms, are also sometimes used. In the northwest part of the state, nesting often occurs on rock spires (NMPIF 2007).

Prairie falcons are sparsely distributed across New Mexico and can be found in appropriate habitat including arid plains and steppes at all elevations, wherever cliffs and bluffs present cliff ledges or crevices for nesting. They will occasionally nest in trees, power poles, buildings and steep sides of arroyos (NMPIF 2007).

CMEH biologists determined there was suitable foraging habitat for both species within the APE but no suitable nesting habitat. Both suitable foraging and nesting habitat was observed outside of the APE within the more densely forested Cibola National Forest approximately 11 miles to the west. During the on-site survey of the APE multiple raptors species were seen foraging in the area including ferruginous hawks. Due to the mobility of adult raptors and the lack of appropriate nesting sites, it is likely Ferruginous Hawks and Prairie Falcon utilize the APE for foraging but not for nesting.

3.5.3. Bendire's Thrasher

Bendire's thrasher typically inhabits sparse desert shrubland and degraded grassland vegetation. It may also occur in open woodland with scattered shrubs and avoids riparian areas and arroyos with dense shrub cover. Within New Mexico, the Bendire's thrasher breeds in scattered locations in the central and western portions of the state, being most common in the southwest portion of the state. New Mexico holds about 41 percent of the species population (NMPIF 2007).

CMEH biologists determined there was marginal habitat for Bendire's thrasher in the form of shrublands within the APE, however the APE is likely out of the species' typical breeding range. No individual Bendire's thrashers were seen or heard during the on-site survey. It should be noted that surveys occurred outside the breeding season for this species.

3.5.4. Chestnut-collared Longspur

The chestnut-collared longspur typically inhabits grassland, desert and plateau areas dominated by low grasses and forbs. Within New Mexico the chestnut-collared longspur winters over much of the state with highest concentrations residing in the central to southern portions. Furthermore, New Mexico appears to be responsible for a significant portion of the species' overall wintering range (NMPIF 2007).

CMEH biologists determined the APE contains suitable habitat for chestnut-collared longspurs in the form of grasslands and is also located in the typical wintering range for the species. No individual chestnut-collared longspurs were seen or heard during the on-site survey.

3.6. Migratory Birds

The APE contains approximately 1,322 acres of potential migratory bird nesting and foraging habitat in the form of shrubland, grassland, arroyo shrubland, and to a lesser degree, juniper savannah vegetation communities as well as 50 - 80 trees. Areas of shrubland and grassland were most prevalent in the APE and are the preferred habitat for a majority of the migratory bird species. Current and potential impacts to migratory birds within the APE include the removal or degradation of habitat and/or audial and visual disturbances due to past, present, and future surface disturbing activities within and immediately adjacent to the APE. The intensity of the impacts depend upon the species, its life history, time of year and/or day and the type and level of human and vehicular activity occurring

3.7. Rangeland Evaluation

The rangeland evaluation for the APE indicates:

- There are a number of high forage value grass, forb and shrub species available for both grazer and browser herbivore species.
- Five (5) species of noxious or invasive weeds were observed within the APE. The level of future grazing intensity may impact the establishment and spread of invasive species and noxious weeds in the APE. Furthermore, two of the species (whorled milkweed and halogeton) are potentially poisonous to livestock.

4. SUPPORTING INFORMATION

4.1. Report Preparers and Certification

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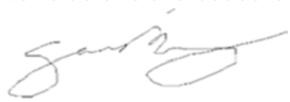
Durango, Colorado 81301
Lori Gregory - Biologist/Editor,
Sarah McCloskey - Biologist/Editor,
Arnold Clifford - Lead Field Biologist,
Jason St. Pierre - Field Biologist

Conclusions are based on actual field examination and are correct to the best of my knowledge.



18 January 2018

______________________________ ____________________

Sarah McCloskey Date

Biologist
Carrizo Mountain Environmental and Herbarium, Inc.
505.769.1407

4.2. References

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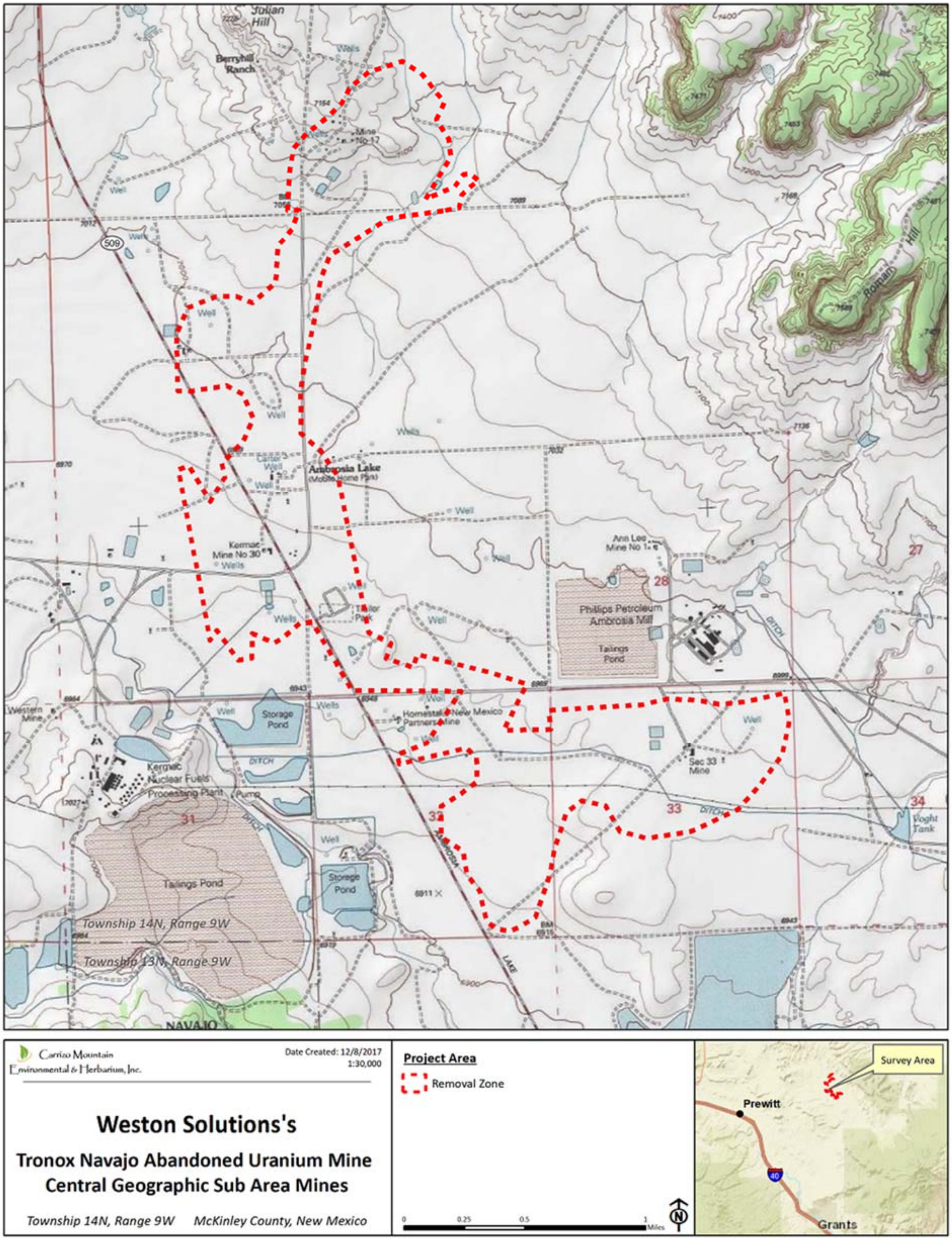
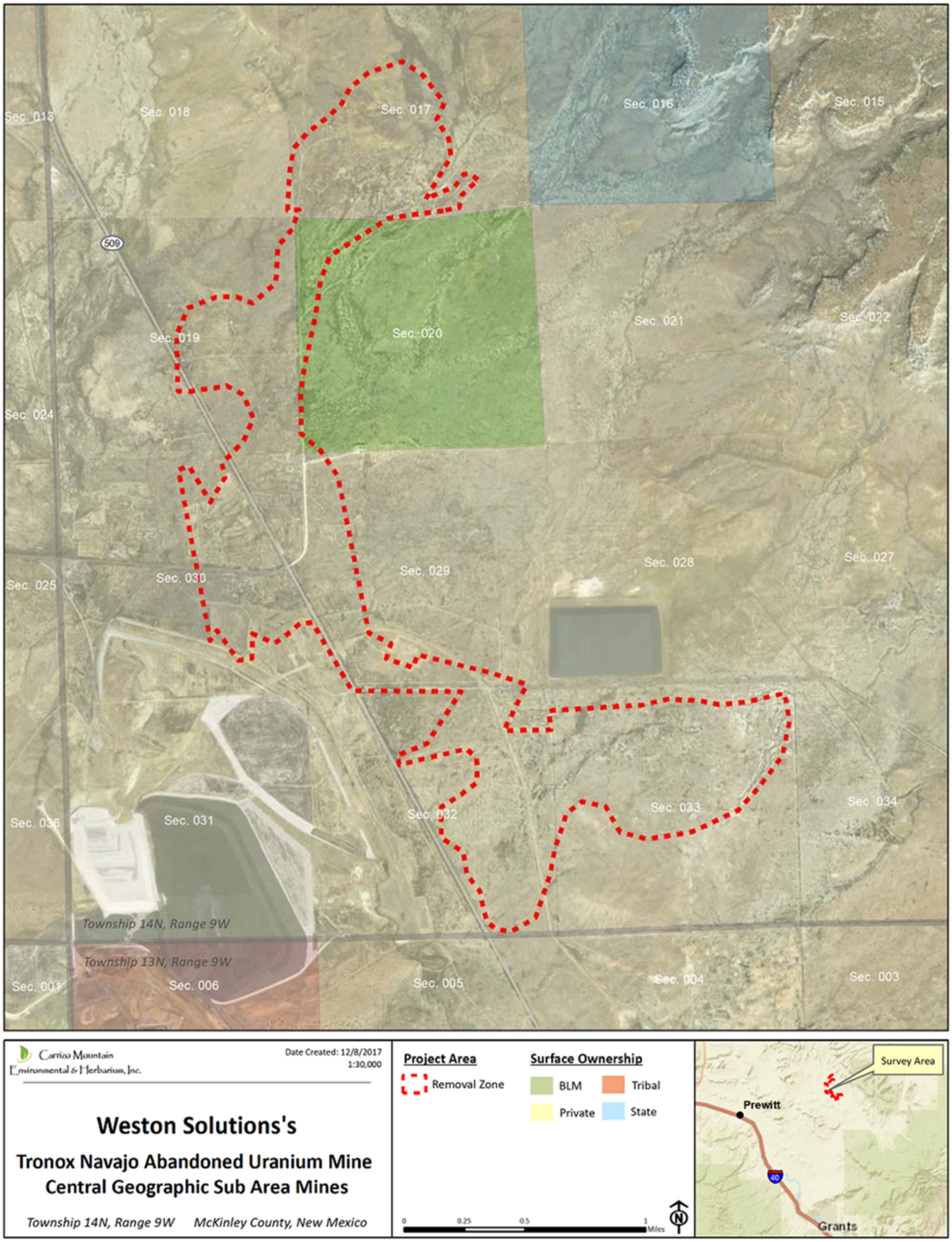
APPENDIX A. PROJECT AREA MAPS

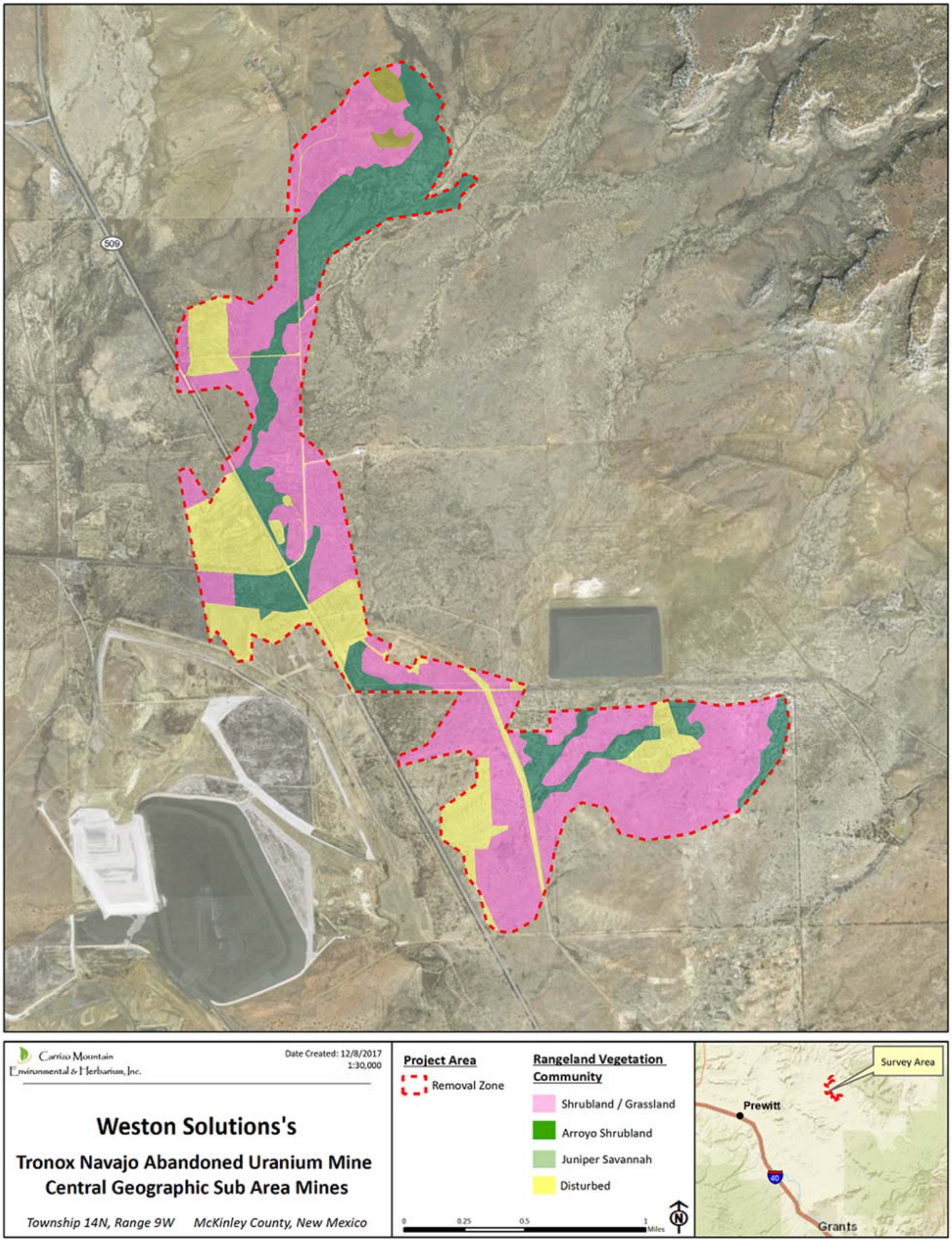
A.1 - Project Area Topographic Map



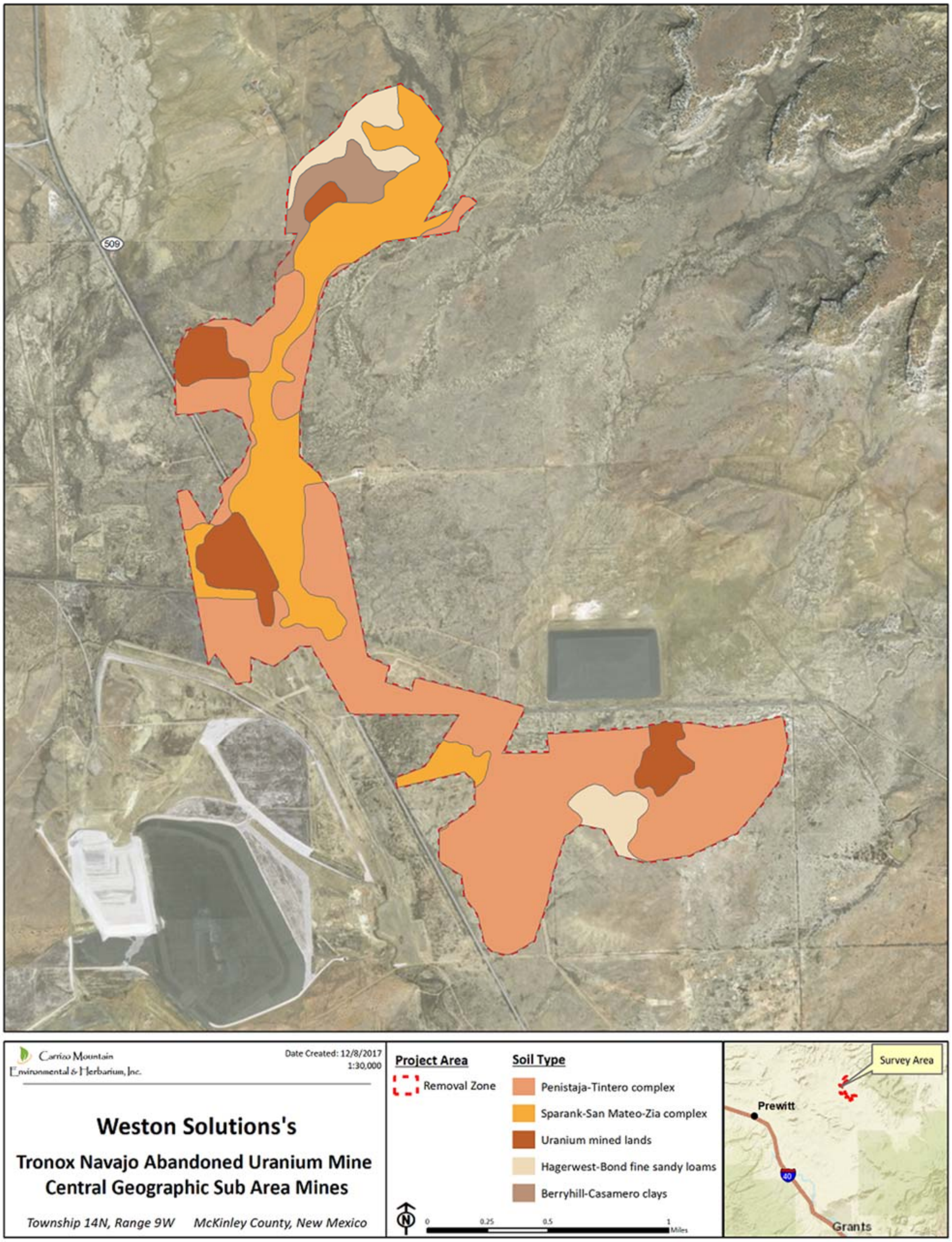
A.2 - Project Area Imagery and Surface Ownership Map



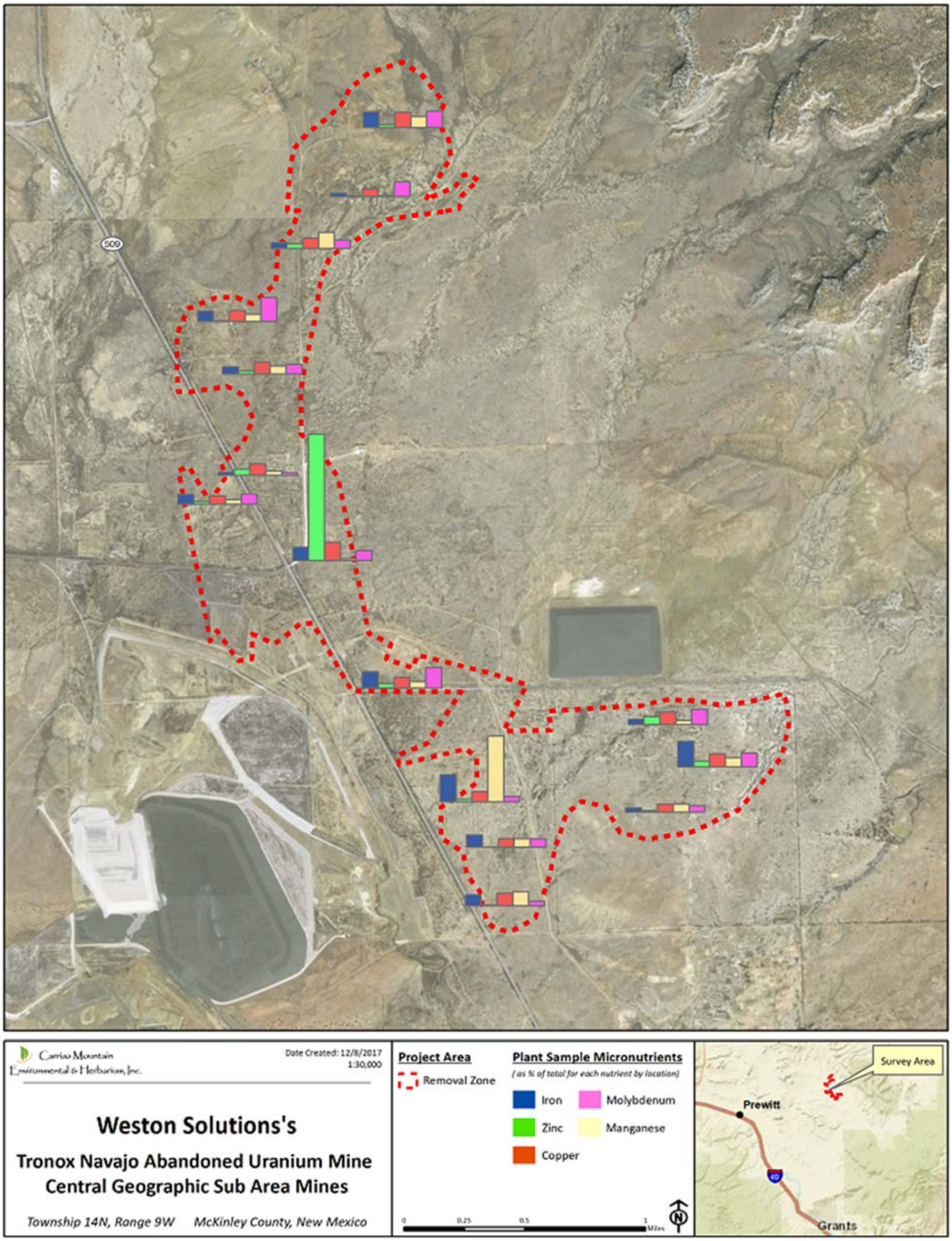
A.3 – Rangeland Vegetation Community Map



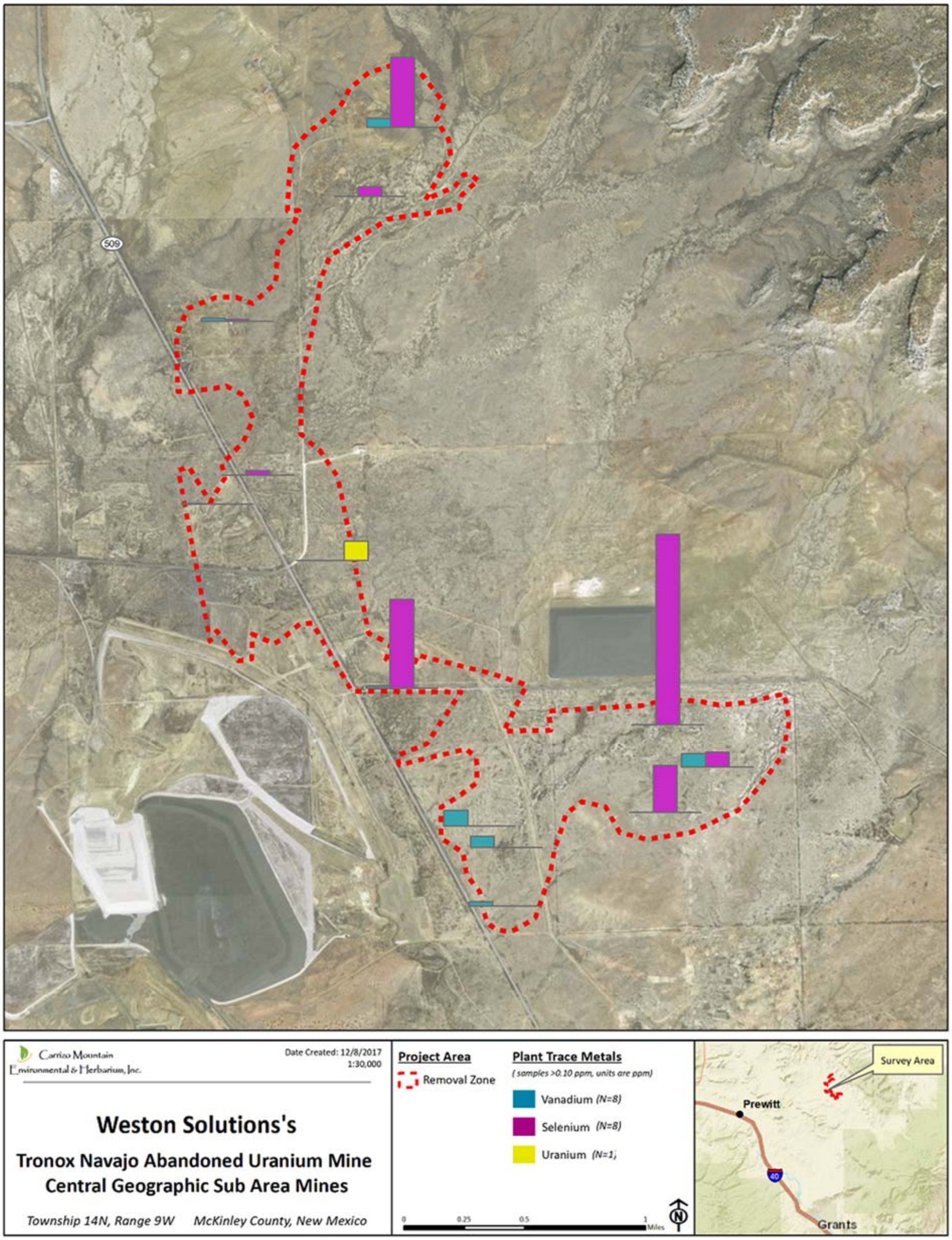
A.4 - Project Area Soil Type Map



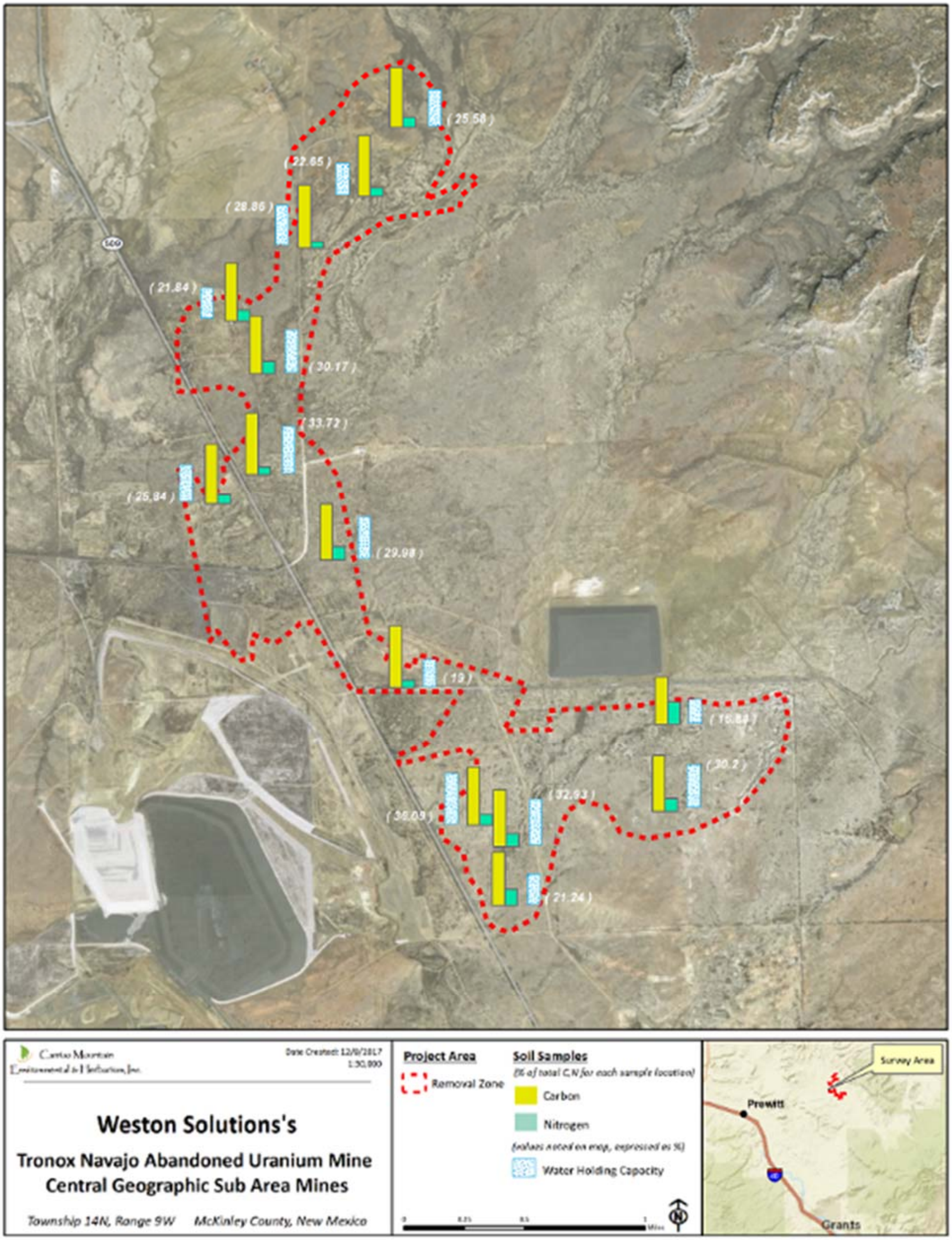
A.5 - Project Area Plant Micronutrient Map



A.6 - Project Area Plant Trace Metals Map



A.7 - Project Area Soil Condition Map



APPENDIX B. PHOTOGRAPHS OF THE PROJECT AREA

Example of pinyon-juniper vegetation community within the APE

Example of grassland/shrub vegetation community within the APE

Example of grassland vegetation community within the APE

Example of shrubland vegetation community within the APE

Example of southwest arroyo shrubland vegetation community within the APE

Example of low-lying pond areas within the APE (no obligate wetland species observed)

APPENDIX C. PLANT AND WILDLIFE SPECIES OBSERVED

C.1. Documented Plant List

F = Edible food	P = Protection	FLT = Federal Listed Threatened
M = Medicinal	C = Ceremonial Food	X = Toxic
C = Ceremonial	R =Rare	A = Agricultural
T = Tobaccos	E = Endemic	W = Weed
U = Utilitarian	S =Sensitive	Nx = Noxious Weed

AGAVACEAE - Agave Family

Yucca baccata Torrey — Broadleaf yucca, banana yucca, blue yucca (U,M,C,F)
Yucca baileyi Wooton & Standley — Bailey's yucca, Bailey's bouncing yucca (U,M,C,F)

AMARANTHACEAE - Amaranth Family, Pigweed Family

Amaranthus retroflexus Linnaeus — Redroot pigweed, redroot, amaranth (F,U,W)

ASCLEPIADACEAE - Milkweed Family

Asclepias subverticillata (A. Gray) Vail — Whorled milkweed, poison milkweed (U)

ASTERACEAE (COMPOSITAE) – Sunflower Family, Composite Family, Aster Family

Artemisia bigelovii A. Gray — Bigelow's sagebrush (C,U,M)
Artemisia ludoviciana Nuttall — Mountain wormwood (C,M,U)
Artemisia tridentata Nuttall — Big sage, big sagebrush, Great Basin sagebrush (C,M,U)
Chrysothamnus greenei (A. Gray) Greene — Greene's rabbitbrush (C,U,M)
Chrysothamnus nauseosus (Pallas) Britton var. bigelovii (A. Gray) H.M. Hall — Bigelow's rabbitbrush (C,U)
Chrysothamnus nauseosus (Pallas) Britton var. glabratus (A. Gray) Cronquist — Glabrate rabbitbrush(C,U)
Chrysothamnus viscidiflorus (Hooker) Nuttall — Viscid rabbitbrush, sticky leaved rabbitbrush (U,C)
Cirsium undulatum (Nuttall) Sprengel — Gray thistle, wavy leaf thistle (C)
Dyssodia papposa (Ventenat) A.S. Hitchcock — Pappose glandweed, prairie dogweed (C,M)
Encelia frutescens (A. Gray) A. Gray — Bush encelia
Grindelia squarrosa (Pursh) Dunal — Gumweed, curly gumweed, curly cup gumweed (Nx,U)
Gutierrezia sarothrae (Pursh) Britton & Rusby — Broom snakeweed, matchweed (C,U,M)
Haplopappus gracilis (Nuttall) A. Gray — Slender goldenbush (C,U)
Haplopappus spinulosus (Pursh) De Candolle — Spiny goldenweed, ironplant goldenweed (C,U)
Helianthus petoilaris Nuttall — Prairie sunflower (C,U)
Heterotheca villosa (Pursh) Shinners — Leafy goldenaster (C,U)
Lactuca serriola Linnaeus — Prickly lettuce (W)
Leucelene ericoides (Torrey) Greene — Rose heath, white aster, roseheath white aster (C,U)
Machaeranthera canescens (Pursh) A. Gray — Hoary aster, hoary tansy aster, sticky aster (M,U)
Psilotrophe sp. — Paperflower (C,U)
Senecio douglasii De Candolle var. longilobus (Bentham) Benson — Douglas' groundsel, threadleaf groundsel (U)
Senecio spartioides Torrey & A. Gray — Broom groundsel, broom ragwort (C,U)
Townsendia annua Beaman — Annual townsendia, annual Townsend daisy (C,M)
Townsendia incana Nuttall — Silvery townsendia, hoary townsendia (C,M)
Verbesina encelioides (Cavanilles) Bentham & Hooker — Crownbeard, golden crownbeard, cowpen daisy (W)
Viguiera annua (M.E. Jones) Blake — Annual goldeneye (C,U)

BORAGINACEAE - Borage Family, Forget-Me-Not Family

Cryptantha cinerea (Torrey) Cronquist — Ashy cryptanth, bow nut cryptanth (C,M)
Cryptantha crassisepala (Torrey & A. Gray) Greene — Greene Plains cryptanth, thick sepaled cryptanth (C)
Cryptantha fendleri (A. Gray) Greene — Fendler's cryptanth (C,M)
Lappula occidentalis (S. Watson) Greene — Western stickseed, spiny sheepbur (W)

BRASSICACEAE (CRUCIFERAE)- Mustard Family

Descurainia pinnata (Walter) Britton — Pinnate tansymustard, yellow tansymustard (M,U)
Descurainia sophia (Linnaeus) Webb ex Prantl — Flixweed (W,M,U)
Dithyrea wislizenii Engelmann — Spectacle pod, common spectacle pod (C)
Erysimum asperum (Nuttall) De Candolle — Pretty wallflower, western wallflower (C,M)
Lepidium montanum Nuttall — Jones' pepperplant, mountain pepperweed (C,M)
Sisymbrium altissimum Linnaeus — Tumbling mustard, Jim Hill mustard (Nx,W)
Streptanthella longirostris (S. Watson) Rydberg — Blackpod nippletwist, long beaked twist flower (C)

CACTACEAE - Cactus Family

Coryphantha vivipara (Nuttall) Britton & Rose — Arizona pinchusion, purple ball cactus (C)
Opuntia phaeacantha Engelmann — Engelmann's pricklypear, New Mexico pricklypear (U,F)
Opuntia polyacantha Haworth — Plains pricklypear, starvation cactus (U,F)

CAPPARACEAE (CAPPERIDACEAE) - Caper Family, Spider Flower Family

Cleome serrulata Pursh — Rocky Mountain bee plant, pink bee plant (C,F,U)

CHENOPODIACEAE - Goosefoot Family (46)

Atriplex canescens (Pursh) Nuttall — Four-wing saltbush, wing scale (C,U,M,F)
Atriplex confertifolia (Torrey & Fremont) Watson — Shadscale, shadscale saltbush (C,U,M,F)
Atriplex obovata Moquin — New Mexico saltbush (C,U,M,F)
Ceratoides lanata (Pursh) Howell — Winterfat, common winterfat (P,C,U)
Chenopodium botrys Linnaeus — Jerusalem oak, feather geranium, hidin-heal (U)
Chenopodium fremontii S. Watson — Fremont's goosefoot (F)
Chenopodium leptophyllum (Moquin) S. Watson — Narrowleaf goosefoot, slim leaf goosefoot (F)
Corispermum villosum Rydberg — Bugseed, common bugseed, tickseed
Kochia scoparia (Linnaeus) Schrader — Summer-cypress, burning bush (Nx)
Salsola tragus Linnaeus — Russian thistle, tumbleweed (Nx,W)
Sarcobatus vermiculatus (Hooker) Torrey — Greasewood, black greasewood (C,U)

CONVOLVULACEAE - Morning Glory Family, Convolvulus Family

Convolvulus arvensis Linnaeus — Field bindweed, small bindweed, morning glory (Nx)

CUPRESSACEAE - Cypress Family

Juniperus monosperma (Engelmann) Sargent — Single seed juniper (U,C,F,M)

ELAEAGNACEAE - Oleaster Family

Elaeagnus angustifolia Linnaeus — Russian olive, monkey eggs (Nx)

EPHEDRACEAE - Ephedra Family

Ephedra torreyana S. Watson — Torrey's ephedra, Torrey's joint fir (U,M)

EUPHORBIACEAE - Spurge Family

Euphorbia fendleri Torrey & A. Gray — Fendler's spurge (C,M)
Euphorbia glyptosperma Engelmann — Ridge-seeded spurge, rib seeded sand mat (C,M)

FABACEAE (LEGUMINOSAE) - Bean Family, Pea Family, Legume Family

Astragalus praelongus Sheldon var. lonchopus Barneby — Long-stipe milkvetch (C)

GERANIACEAE - Geranium Family

Erodium cicutarium (Linnaeus) L'Hertier var. corrugata (A. Nelson) Brand — Storksbill, cranes bill, filaree, red stem filaree (Nx)

LAMIACEAE (LABIATAE) - Mint Family

Salvia reflexa Hornemann — Slight sage, Rocky Mountain sage (M,C,Nx)

LOASACEAE - Stickleaf Family, Loasa Family

Mentzelia sp. — Stickleaf (C)

MALVACEAE - Mallow Family

Sphaeralcea ambigua A. Gray	Desert globemallow (M,C,U)
Sphaeralcea coccinea (Nuttall) Rydberg	Common globemallow, scarlet globemalllow (M,C,U)
Sphaeralcea fendleri A. Gray	Fendler's globemallow (M,C,U)
Sphaeralcea grossulariifolia (Hooker & Arnott) Rydberg	Gooseberry leaf globemallow (M,C,U)
PINACEAE - Pine Family	
Pinus edulis Engelmann	Pinyon pine
PLANTAGINACEAE - Plantain Family	
Plantago lanceolata Linnaeus	Buckhorn plantain, English plantain (W)
Plantago major Linnaeus	Broad leaf plantain, common plantain (W,M)
Plantago patagonica Jacquin	Woolly plantain (M,C)
POACEAE (GRAMINEAE) - Grass Family	
Andropogon gerardii Vitasey	Big bluestem (C)
Aristida purpurea Nuttall	Purple threeawn (C)
Bouteloua barbata Lagasca	Sixweeks grama (W)
Bouteloua curtipendula (Michaux) Torrey	Sideoats grama, tall grama grass (C,U)
Bouteloua gracilis (H., B.,K.) Lagasca ex Steudel	Blue grama, mesquite grass (C,U)
Bouteloua hirsuta Lagasca	Hairy grama (C,U)
Bouteloua simplex Lagasca	Mat grama (W)
Bromus tectorum Linnaeus	Cheatgrass, downy chess, cheatgrass brome (Nx)
Distichlis spicata (Linnaeus) Greene	Desert saltgrass, common saltgrass
Elymus elymoides (Rafinesque) Swezey	Squirreltail, long bristled wild rye
Elymus smithii (Rydberg) Gould	Western wheatgrass (C)
Festuca octoflora Walter	Sixweeks fescue, slender fescue
Hilaria jamesii (Torrey) Bentham	Galleta, common galleta, galleta grass (C,U,F)
Hordeum jubatum Linnaeus	Foxtail barley, squirreltail barley (Nx,W)
Muhlenbergia filiformis (Thurber) Rydberg	Pullup muhly
Muhlenbergia wrightii Vasey ex Coulter	Wright's muhly
Muhlenbergia pungens Thurber	Sandhill muhly (C,U)
Muhlenbergia torreyi (Kunth) A.S. Hitchcock	Torrey's muhly (C,U)
Munroa squarrosa (Nuttall) Torrey	False buffalograss, Munro's grass (W)
Oryzopsis hymenoides (Roemer & Schultes) Ricker	Indian ricegrass, Indian millet (F,C)
Sporobolus airoides (Torrey) Torrey	Alkali sacaton (C,U)
Sporobolus contractus A.S. Hitchcock	Spike dropseed (C,U)
Sporobolus cryptandrus (Torrey) A. Gray	Sand dropseed, poverty grass (C,U)
Stipa comata Trinius & Ruprecht	Needle and Thread (C,U)
POLYGONACEAE - Buckwheat Family, Knotweed Family, Smart Family	
Eriogonum cernuum Nuttall	Nodding buckwheat, nodding eriogonum (C,P)
Eriogonum jamesii Bentham	James buckwheat, pronghorn sage buckwheat (C,T)
Eriogonum leptophyllum (Torrey) Wooton & Standley	Slenderleaf buckwheat (C,P)
Eriogonum microthecum Nuttall	Slender buckwheat, Simpson's buckwheat (C,P)
Polygonum aviculare Linnaeus	Knotweed, prostrate knotweed (W)
PORTULACEAE - Purslane Family	
Portulaca oleracea Linnaeus	Purslane, common purslane, purslance (W,F)
SOLANACEAE - Potato Family, Night Shade Family	
Lycium pallidum Miers	Pale wolfberry, rabbit thorn (C,F,M)
TAMARICACEAE - Tamarisk Family	
Tamarix chinensis Siebold & Zuccarini	Saltcedar, saltcedar tamarisk (Nx)
ULMACEAE – Elm Family	
Ulmus pumila Linnaeus	Chinese elm, Siberian elm (Nx)
VERBENACEAE - Vervain Family	
Verbena bracteata Lagasca & Rodriquez	Prostrate vervain, large bracted vervain (W,C,U)

C.2. Documented Bird List

Green-winged teal	*Anas carolinensis*
American pipit	*Anthus rubescens*
Sagebrush sparrow	*Artemisiospiza nevadensis*
Red-tailed hawk	*Buteo jamaicensis*
Ferruginous hawk	*Buteo regalis*
Scaled quail	*Callipepla squamata*
Northern harrier	*Circus cyaneus*
Horned lark	*Eremophila alpestris*
Merlin	*Falco columbarius*
House finch	*Haemorhous mexicanus*
Dark-eyed junco	*Junco hyemalis*
Loggerhead shrike	*Lanius ludovicianus*
Song sparrow	*Melospiza melodia*
Sage thrasher	*Oreoscoptes montanus*
Mountain chickadee	*Poecile gambeli*
Mountain bluebird	*Sialia currucoides*
Western bluebird	*Sialia Mexicana*
American goldfinch	*Spinus tristis*
Western meadowlark	*Sturnella neglecta*
White-crowned sparrow	*Zonotrichia leucophrys*

C.3. Documented Mammals List

Coyote	*Canis latrans*
Prairie dog	*Cynomys* sp.
Kangaroo rat	*Dipodomys sp.*
Banner-tailed kangaroo rat	*Dipodomys spectabilis*
Bobcat	*Lynx rufus*
Pocket gopher	*Thomomys bottae*

APPENDIX B

CULTURAL RESOURCES SURVEY REPORT

ñRedacted due to sensitive cultural concerns by the Navajo Nation Tribal Historical Preservation Officer and the New Mexico State Historical Preservation Officer.ò

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APPENDIX C

EBERLINE ANALYTICAL SERVICES, INC. ANALYTICAL DATA PACKAGES AND DATA QUALITY ASSURANCE REVIEWS

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Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Olin Garren	SDG:	16-03035
Weston Solutions, Inc.	Purchase Order:	0087171
5599 San Felipe, Suite 700	Analysis Category:	ENVIRONMENTAL
Houston, TX 77056	Sample Matrix:	SO

Lab ID	Sample Type	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	CU	CSU	MDA	Report Units
16-03035-01	LCS	KNOWN	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Cobalt-60	LANL ER-130 Modified	1.37E+02	5.48E+00			pCi/g
16-03035-01	LCS	KNOWN	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Cesium-137	LANL ER-130 Modified	8.69E+01	3.48E+00			pCi/g
16-03035-01	LCS	SPIKE	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Cobalt-60	LANL ER-130 Modified	1.42E+02	9.80E+00	1.22E+01	1.69E+00	pCi/g
16-03035-01	LCS	SPIKE	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Cesium-137	LANL ER-130 Modified	8.78E+01	8.45E+00	9.58E+00	2.18E+00	pCi/g
16-03035-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Actinium-228	LANL ER-130 Modified	7.57E-02	1.33E-01	1.33E-01	2.82E-01	pCi/g
16-03035-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Bismuth-214	LANL ER-130 Modified	4.19E-02	8.63E-02	8.63E-02	1.53E-01	pCi/g
16-03035-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Potassium-40	LANL ER-130 Modified	3.02E-01	4.85E-01	4.85E-01	1.00E+00	pCi/g
16-03035-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	-1.66E+00	4.27E+00	4.27E+00	6.56E+00	pCi/g
16-03035-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Lead-212	LANL ER-130 Modified	3.05E-02	6.06E-02	6.06E-02	1.02E-01	pCi/g
16-03035-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Lead-214	LANL ER-130 Modified	1.20E-01	7.85E-02	7.87E-02	1.50E-01	pCi/g
16-03035-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Radium-226	LANL ER-130 Modified	4.19E-02	8.63E-02	8.63E-02	1.53E-01	pCi/g
16-03035-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Thorium-234	LANL ER-130 Modified	3.64E-01	4.20E-01	4.20E-01	6.97E-01	pCi/g
16-03035-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03035	Thallium-208	LANL ER-130 Modified	-9.27E-02	1.36E-01	1.36E-01	1.76E-01	pCi/g
16-03035-03	DUP	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	9.10E-01	1.97E-01	2.02E-01	3.60E-01	pCi/g
16-03035-03	DUP	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	1.05E+00	1.43E-01	1.52E-01	1.80E-01	pCi/g
16-03035-03	DUP	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.61E+01	1.86E+00	2.04E+00	1.14E+00	pCi/g
16-03035-03	DUP	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	-1.84E+00	5.12E+00	5.12E+00	7.37E+00	pCi/g
16-03035-03	DUP	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	1.09E+00	1.37E-01	1.48E-01	1.85E-01	pCi/g
16-03035-03	DUP	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	1.18E+00	1.55E-01	1.66E-01	2.10E-01	pCi/g
16-03035-03	DUP	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	1.05E+00	1.43E-01	1.52E-01	1.80E-01	pCi/g
16-03035-03	DUP	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	1.56E+00	1.33E+00	1.34E+00	1.79E+00	pCi/g
16-03035-03	DUP	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	8.00E-01	1.37E-01	1.43E-01	1.44E-01	pCi/g
16-03035-04	DO	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	9.37E-01	1.76E-01	1.83E-01	2.21E-01	pCi/g
16-03035-04	DO	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	1.14E+00	1.51E-01	1.62E-01	1.81E-01	pCi/g
16-03035-04	DO	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.58E+01	1.87E+00	2.04E+00	8.21E-01	pCi/g
16-03035-04	DO	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	7.13E+00	4.35E+00	4.37E+00	8.23E+00	pCi/g
16-03035-04	DO	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	1.14E+00	1.41E-01	1.53E-01	2.20E-01	pCi/g
16-03035-04	DO	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	1.07E+00	1.56E-01	1.65E-01	2.35E-01	pCi/g
16-03035-04	DO	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	1.14E+00	1.51E-01	1.62E-01	1.81E-01	pCi/g
16-03035-04	DO	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	1.54E+00	1.33E+00	1.33E+00	1.77E+00	pCi/g
16-03035-04	DO	26BKGD-01-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	8.02E-01	1.39E-01	1.45E-01	1.09E-01	pCi/g
16-03035-05	TRG	26BKGD-01-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	9.77E-01	2.16E-01	2.21E-01	3.86E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Olin Garren	SDG:	16-03035
Weston Solutions, Inc.	Purchase Order:	0087171
5599 San Felipe, Suite 700	Analysis Category:	ENVIRONMENTAL
Houston, TX 77056	Sample Matrix:	SO

Lab ID	Sample Type	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	CU	CSU	MDA	Report Units
16-03035-05	TRG	26BKGD-01-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	1.26E+00	1.70E-01	1.82E-01	7.36E-02	pCi/g
16-03035-05	TRG	26BKGD-01-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.58E+01	2.01E+00	2.17E+00	8.65E-01	pCi/g
16-03035-05	TRG	26BKGD-01-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	1.77E-01	5.92E+00	5.92E+00	9.23E+00	pCi/g
16-03035-05	TRG	26BKGD-01-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	1.01E+00	1.33E-01	1.43E-01	2.28E-01	pCi/g
16-03035-05	TRG	26BKGD-01-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	1.26E+00	1.67E-01	1.79E-01	2.88E-01	pCi/g
16-03035-05	TRG	26BKGD-01-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	1.26E+00	1.70E-01	1.82E-01	7.36E-02	pCi/g
16-03035-05	TRG	26BKGD-01-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	1.72E+00	1.36E+00	1.36E+00	2.25E+00	pCi/g
16-03035-05	TRG	26BKGD-01-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	1.03E+00	1.72E-01	1.80E-01	1.44E-01	pCi/g
16-03035-06	TRG	26BKGD-02-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	1.23E+00	4.34E-01	4.38E-01	6.98E-01	pCi/g
16-03035-06	TRG	26BKGD-02-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	8.94E-01	3.77E-01	3.80E-01	6.84E-01	pCi/g
16-03035-06	TRG	26BKGD-02-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.66E+01	2.95E+00	3.07E+00	1.30E+00	pCi/g
16-03035-06	TRG	26BKGD-02-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	-9.23E-01	1.11E+01	1.11E+01	1.79E+01	pCi/g
16-03035-06	TRG	26BKGD-02-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	1.52E+00	3.12E-01	3.22E-01	4.00E-01	pCi/g
16-03035-06	TRG	26BKGD-02-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	1.02E+00	2.56E-01	2.61E-01	4.46E-01	pCi/g
16-03035-06	TRG	26BKGD-02-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	8.94E-01	3.77E-01	3.80E-01	6.84E-01	pCi/g
16-03035-06	TRG	26BKGD-02-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	1.33E+00	1.28E+00	1.29E+00	2.03E+00	pCi/g
16-03035-06	TRG	26BKGD-02-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	1.28E+00	3.84E-01	3.90E-01	4.84E-01	pCi/g
16-03035-07	TRG	26BKGD-03-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	8.20E-01	2.22E-01	2.26E-01	4.45E-01	pCi/g
16-03035-07	TRG	26BKGD-03-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	1.05E+00	1.58E-01	1.67E-01	3.33E-01	pCi/g
16-03035-07	TRG	26BKGD-03-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.44E+01	1.91E+00	2.05E+00	1.01E+00	pCi/g
16-03035-07	TRG	26BKGD-03-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	3.90E+00	5.67E+00	5.67E+00	9.82E+00	pCi/g
16-03035-07	TRG	26BKGD-03-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	9.40E-01	1.32E-01	1.40E-01	2.45E-01	pCi/g
16-03035-07	TRG	26BKGD-03-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	1.08E+00	1.80E-01	1.89E-01	2.71E-01	pCi/g
16-03035-07	TRG	26BKGD-03-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	1.05E+00	1.58E-01	1.67E-01	3.33E-01	pCi/g
16-03035-07	TRG	26BKGD-03-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	2.21E-01	1.38E+00	1.38E+00	1.79E+00	pCi/g
16-03035-07	TRG	26BKGD-03-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	7.83E-01	1.67E-01	1.72E-01	1.42E-01	pCi/g
16-03035-08	TRG	26BKGD-04-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	8.64E-01	3.14E-01	3.17E-01	5.43E-01	pCi/g
16-03035-08	TRG	26BKGD-04-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	1.18E+00	2.35E-01	2.43E-01	1.39E-01	pCi/g
16-03035-08	TRG	26BKGD-04-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.36E+01	2.73E+00	2.82E+00	2.41E+00	pCi/g
16-03035-08	TRG	26BKGD-04-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	1.06E+00	1.04E+01	1.04E+01	1.73E+01	pCi/g
16-03035-08	TRG	26BKGD-04-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	1.20E+00	2.68E-01	2.75E-01	3.60E-01	pCi/g
16-03035-08	TRG	26BKGD-04-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	1.05E+00	2.53E-01	2.59E-01	3.92E-01	pCi/g
16-03035-08	TRG	26BKGD-04-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	1.18E+00	2.35E-01	2.43E-01	1.39E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Olin Garren	SDG:	16-03035
Weston Solutions, Inc.	Purchase Order:	0087171
5599 San Felipe, Suite 700	Analysis Category:	ENVIRONMENTAL
Houston, TX 77056	Sample Matrix:	SO

Lab ID	Sample Type	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	CU	CSU	MDA	Report Units
16-03035-08	TRG	26BKGD-04-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	6.07E-01	1.15E+00	1.15E+00	1.78E+00	pCi/g
16-03035-08	TRG	26BKGD-04-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	8.70E-01	2.43E-01	2.47E-01	8.21E-02	pCi/g
16-03035-09	TRG	26BKGD-05-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	1.09E+00	1.72E-01	1.81E-01	3.18E-01	pCi/g
16-03035-09	TRG	26BKGD-05-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	9.84E-01	1.43E-01	1.51E-01	1.96E-01	pCi/g
16-03035-09	TRG	26BKGD-05-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.50E+01	1.78E+00	1.94E+00	8.68E-01	pCi/g
16-03035-09	TRG	26BKGD-05-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	-2.28E+00	4.61E+00	4.61E+00	6.59E+00	pCi/g
16-03035-09	TRG	26BKGD-05-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	9.83E-01	1.24E-01	1.34E-01	1.86E-01	pCi/g
16-03035-09	TRG	26BKGD-05-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	9.65E-01	1.38E-01	1.47E-01	1.95E-01	pCi/g
16-03035-09	TRG	26BKGD-05-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	9.84E-01	1.43E-01	1.51E-01	1.96E-01	pCi/g
16-03035-09	TRG	26BKGD-05-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	3.24E+00	1.19E+00	1.21E+00	1.69E+00	pCi/g
16-03035-09	TRG	26BKGD-05-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	8.89E-01	1.45E-01	1.52E-01	1.61E-01	pCi/g
16-03035-10	TRG	26BKGD-06-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	9.57E-01	2.37E-01	2.42E-01	3.46E-01	pCi/g
16-03035-10	TRG	26BKGD-06-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	1.02E+00	1.72E-01	1.80E-01	2.37E-01	pCi/g
16-03035-10	TRG	26BKGD-06-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.48E+01	1.97E+00	2.11E+00	1.12E+00	pCi/g
16-03035-10	TRG	26BKGD-06-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	1.47E+00	5.63E+00	5.63E+00	8.87E+00	pCi/g
16-03035-10	TRG	26BKGD-06-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	1.01E+00	1.40E-01	1.49E-01	2.31E-01	pCi/g
16-03035-10	TRG	26BKGD-06-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	1.10E+00	1.61E-01	1.70E-01	2.54E-01	pCi/g
16-03035-10	TRG	26BKGD-06-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	1.02E+00	1.72E-01	1.80E-01	2.37E-01	pCi/g
16-03035-10	TRG	26BKGD-06-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	1.35E+00	1.49E+00	1.49E+00	1.95E+00	pCi/g
16-03035-10	TRG	26BKGD-06-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	8.39E-01	1.81E-01	1.86E-01	4.19E-02	pCi/g
16-03035-11	TRG	26BKGD-07-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	1.12E+00	3.42E-01	3.47E-01	4.62E-01	pCi/g
16-03035-11	TRG	26BKGD-07-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	1.30E+00	3.03E-01	3.10E-01	4.41E-01	pCi/g
16-03035-11	TRG	26BKGD-07-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.80E+01	3.05E+00	3.19E+00	1.36E+00	pCi/g
16-03035-11	TRG	26BKGD-07-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	3.37E+00	1.04E+01	1.04E+01	1.78E+01	pCi/g
16-03035-11	TRG	26BKGD-07-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	1.23E+00	2.29E-01	2.37E-01	3.67E-01	pCi/g
16-03035-11	TRG	26BKGD-07-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	9.70E-01	2.67E-01	2.72E-01	4.11E-01	pCi/g
16-03035-11	TRG	26BKGD-07-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	1.30E+00	3.03E-01	3.10E-01	4.41E-01	pCi/g
16-03035-11	TRG	26BKGD-07-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	2.16E+00	1.24E+00	1.25E+00	1.98E+00	pCi/g
16-03035-11	TRG	26BKGD-07-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	1.02E+00	2.67E-01	2.72E-01	8.76E-02	pCi/g
16-03035-12	TRG	26BKGD-08-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	8.01E-01	1.64E-01	1.70E-01	2.60E-01	pCi/g
16-03035-12	TRG	26BKGD-08-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	1.06E+00	1.50E-01	1.60E-01	1.98E-01	pCi/g
16-03035-12	TRG	26BKGD-08-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.59E+01	1.84E+00	2.02E+00	7.55E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical Final Report of Analysis	Report To:	Work Order Details:	
	Olin Garren	SDG:	16-03035
	Weston Solutions, Inc.	Purchase Order:	0087171
	5599 San Felipe, Suite 700	Analysis Category:	ENVIRONMENTAL
	Houston, TX 77056	Sample Matrix:	SO

Lab ID	Sample Type	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	CU	CSU	MDA	Report Units
16-03035-12	TRG	26BKGD-08-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	3.60E+00	3.89E+00	3.89E+00	6.74E+00	pCi/g
16-03035-12	TRG	26BKGD-08-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	9.61E-01	1.24E-01	1.33E-01	1.90E-01	pCi/g
16-03035-12	TRG	26BKGD-08-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	1.02E+00	1.35E-01	1.45E-01	2.01E-01	pCi/g
16-03035-12	TRG	26BKGD-08-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	1.06E+00	1.50E-01	1.60E-01	1.98E-01	pCi/g
16-03035-12	TRG	26BKGD-08-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	9.63E-01	1.10E+00	1.11E+00	1.85E+00	pCi/g
16-03035-12	TRG	26BKGD-08-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	7.06E-01	1.20E-01	1.26E-01	1.29E-01	pCi/g
16-03035-13	TRG	26BKGD-09-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	8.96E-01	2.14E-01	2.19E-01	6.80E-01	pCi/g
16-03035-13	TRG	26BKGD-09-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	1.15E+00	1.86E-01	1.95E-01	2.68E-01	pCi/g
16-03035-13	TRG	26BKGD-09-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.61E+01	2.14E+00	2.30E+00	1.37E+00	pCi/g
16-03035-13	TRG	26BKGD-09-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	5.82E+00	5.79E+00	5.79E+00	1.05E+01	pCi/g
16-03035-13	TRG	26BKGD-09-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	1.02E+00	1.42E-01	1.51E-01	2.59E-01	pCi/g
16-03035-13	TRG	26BKGD-09-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	1.13E+00	1.73E-01	1.82E-01	2.73E-01	pCi/g
16-03035-13	TRG	26BKGD-09-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	1.15E+00	1.86E-01	1.95E-01	2.68E-01	pCi/g
16-03035-13	TRG	26BKGD-09-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	1.75E+00	1.43E+00	1.43E+00	1.92E+00	pCi/g
16-03035-13	TRG	26BKGD-09-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	8.75E-01	1.73E-01	1.78E-01	4.29E-02	pCi/g
16-03035-14	TRG	26BKGD-10-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	1.50E+00	3.89E-01	3.97E-01	6.03E-01	pCi/g
16-03035-14	TRG	26BKGD-10-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	1.32E+00	2.75E-01	2.83E-01	3.71E-01	pCi/g
16-03035-14	TRG	26BKGD-10-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.61E+01	2.92E+00	3.04E+00	1.90E+00	pCi/g
16-03035-14	TRG	26BKGD-10-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	7.03E+00	1.10E+01	1.10E+01	1.95E+01	pCi/g
16-03035-14	TRG	26BKGD-10-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	1.24E+00	2.86E-01	2.93E-01	3.89E-01	pCi/g
16-03035-14	TRG	26BKGD-10-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	1.45E+00	3.01E-01	3.10E-01	4.46E-01	pCi/g
16-03035-14	TRG	26BKGD-10-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	1.32E+00	2.75E-01	2.83E-01	3.71E-01	pCi/g
16-03035-14	TRG	26BKGD-10-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	2.22E+00	1.30E+00	1.31E+00	2.07E+00	pCi/g
16-03035-14	TRG	26BKGD-10-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	8.74E-01	2.67E-01	2.70E-01	8.71E-02	pCi/g
16-03035-15	TRG	26BKGD-11-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Actinium-228	LANL ER-130 Modified	8.86E-01	4.18E-01	4.20E-01	8.44E-01	pCi/g
16-03035-15	TRG	26BKGD-11-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Bismuth-214	LANL ER-130 Modified	1.09E+00	2.69E-01	2.75E-01	3.91E-01	pCi/g
16-03035-15	TRG	26BKGD-11-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Potassium-40	LANL ER-130 Modified	1.61E+01	2.86E+00	2.98E+00	1.73E+00	pCi/g
16-03035-15	TRG	26BKGD-11-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Protactinium-234m	LANL ER-130 Modified	8.41E+00	9.22E+00	9.23E+00	1.72E+01	pCi/g
16-03035-15	TRG	26BKGD-11-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-212	LANL ER-130 Modified	1.21E+00	2.56E-01	2.63E-01	3.28E-01	pCi/g
16-03035-15	TRG	26BKGD-11-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Lead-214	LANL ER-130 Modified	1.32E+00	3.03E-01	3.10E-01	4.47E-01	pCi/g
16-03035-15	TRG	26BKGD-11-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Radium-226	LANL ER-130 Modified	1.09E+00	2.69E-01	2.75E-01	3.91E-01	pCi/g
16-03035-15	TRG	26BKGD-11-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thorium-234	LANL ER-130 Modified	1.75E+00	1.22E+00	1.22E+00	1.93E+00	pCi/g
16-03035-15	TRG	26BKGD-11-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03035	Thallium-208	LANL ER-130 Modified	8.24E-01	2.87E-01	2.90E-01	5.45E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

MEMO

DATE: June 28, 2019

TO: Keith Delhomme, Robert Sherman

FROM: Rick Haaker RF Haaker

SUBJECT: Review of Gamma Spectroscopy Data Package, 16-03035

Introduction

The file evaluated was SEC26BKGD_1603035_EDD.xls.

This package did not contain radiochemistry data. Only the gamma spec data was reviewed. All concentration units are in units of pCi/g, unless otherwise noted.

Conclusions

My impression is that the laboratory analyses are acceptable for use.

Gamma Spectroscopy data review.

Summary

General factors		
Factor	Value	Comment
Number of ClientID	12	Number of distinct samples submitted
Number of Lab Duplicates	1	
Isotopes Detected in Method Blank	None	Good!
Performance of Duplicate	Pa-234m	Exhibited high variability, Pa-234m is much more uncertain than usual, and it tends to be pretty unreliable under any circumstances on this project. Other isotopes were good!
Ra-226 pCi/g in Duplicate	~1.2	
Ra-226 pCi/g Range in Data Package	0.8 < Ra226 < 1.5	Definitely background range.
Ingrowth Days at Eberline	21-22	Should be 21 days or more.

The following samples were analyzed by gamma spectroscopy.

SampleID_Table		
ClientID	**LabID**	**Sample Type**
26BKGD-01-61-160303	16-03035-03	DUP
26BKGD-01-61-160303	16-03035-04	DO

16-03035

SampleID_Table		
ClientID	**LabID**	**Sample Type**
26BKGD-01-62-160303	16-03035-05	TRG
26BKGD-02-61-160303	16-03035-06	TRG
26BKGD-03-61-160303	16-03035-07	TRG
26BKGD-04-61-160303	16-03035-08	TRG
26BKGD-05-61-160303	16-03035-09	TRG
26BKGD-06-61-160303	16-03035-10	TRG
26BKGD-07-61-160303	16-03035-11	TRG
26BKGD-08-61-160303	16-03035-12	TRG
26BKGD-09-61-160303	16-03035-13	TRG
26BKGD-10-61-160303	16-03035-14	TRG
26BKGD-11-61-160303	16-03035-15	TRG

The data was delivered in the usual Microsoft excel data format; it did not contain radiochemistry data.

Thorium-234 results were considerably more precise than protactinium-234m results. The protactinium-234m results should not by themselves be considered reliable. Th-234 was reported as present at levels that exceed the minimum detectable activity in samples as follows. Results are in the units of pCi/g.

Detected Th234			
ClientID	**Analyte**	**Results**	**MDAC**
26BKGD-05-61-160303	Thorium-234	3.24	1.69
26BKGD-07-61-160303	Thorium-234	2.16	1.98
26BKGD-10-61-160303	Thorium-234	2.22	2.07

Ignoring protactinium-234m, all other uranium decay chain analytes were detected in all samples except as follows:

NonDetects6				
ClientID	Analyte	Result	MDAC	ReportUnits
26BKGD-01-61-160303	Thorium-234	1.56	1.7891	pCi/g
26BKGD-01-62-160303	Thorium-234	1.72	2.2455	pCi/g
26BKGD-02-61-160303	Thorium-234	1.33	2.0266	pCi/g
26BKGD-03-61-160303	Thorium-234	0.22	1.7887	pCi/g
26BKGD-04-61-160303	Thorium-234	0.61	1.7766	pCi/g
26BKGD-06-61-160303	Thorium-234	1.35	1.9489	pCi/g
26BKGD-08-61-160303	Thorium-234	0.96	1.8473	pCi/g
26BKGD-09-61-160303	Thorium-234	1.75	1.9247	pCi/g
26BKGD-11-61-160303	Thorium-234	1.75	1.9287	pCi/g

This Eberline data package reports radium-226 as equal to bismuth-214, the radium-226 being assigned from the bismuth-214 values.

The degree of agreement between thorium-234 and radium-226 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that the thorium-234 results might be seriously biased by systematic error. The test statistic is the number of standard deviations by which the thorium-234 result exceeds the radium-226 result. If the test statistic is substantially less than zero, it implies that the reported radium-226 concentration is greater than the thorium-234 concentration. Gamma spectroscopy cannot detect thorium-230 for all practical purposes, **so agreement between thorium-234 and radium-226 doesn't provide *any* information about equilibrium between thorium-230 and radium-226.**

'Equilibrium' Th234 → Ra-226		
ClientID	**Test Statistic**	**Disequilibrium Evidence**
26BKGD-10-61-160303	1.35	Weak or none
26BKGD-11-61-160303	1.06	Weak or none
26BKGD-01-61-160303	0.76	Weak or none
26BKGD-01-61-160303	0.6	Weak or none
26BKGD-01-62-160303	0.67	Weak or none
26BKGD-02-61-160303	0.65	Weak or none
26BKGD-03-61-160303	-1.19	Weak or none
26BKGD-04-61-160303	-0.97	Weak or none
26BKGD-05-61-160303	3.72	Strong
26BKGD-06-61-160303	0.43	Weak or none
26BKGD-07-61-160303	1.34	Weak or none
26BKGD-08-61-160303	-0.17	Weak or none
26BKGD-09-61-160303	0.83	Weak or none

The degree of agreement between radium-226 and lead-210 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that there is no proficiency testing of radiochemistry laboratories for isotopes having gamma energies similar to those for lead-210. The test statistic is the number of standard deviations by which the radium-226 result exceeds the lead-210 result. If the test statistic is substantially less than zero, it implies that the reported lead-210 concentration is greater than the radium-226 concentration. **Agreement between radium-226 and lead-210 doesn't provide *any* information about equilibrium between thorium-230 and radium-226.**

No lead-210 results are included in this package

The maximum and estimated 99%UCLs (assuming normal statistics) for nuisance radionuclides in pCi/g, based on all prior datasets reviewed to this point are:

Analyte	Maximum	UCL99%
Actinium-228	2.61	2.46
Lead-212	8.45	4.06

16-03035

Analyte	Maximum	UCL99%
Potassium-40	40.54	35.12
Thallium-208	2.48	2.23

It is good to keep in mind that around 10 – 15pCi/g potassium-40 looks like 1pCi/g of radium-226 to a 2x2 sodium iodide detector during field surveys.

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Olin Garren	SDG:	16-03036
Weston Solutions, Inc.	Purchase Order:	0087171
5599 San Felipe, Suite 700	Analysis Category:	ENVIRONMENTAL
Houston, TX 77056	Sample Matrix:	SO

Lab ID	Sample Type	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	CU	CSU	MDA	Report Units
16-03036-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Actinium-228	LANL ER-130 Modified	-5.30E-03	1.43E-01	1.43E-01	2.31E-01	pCi/g
16-03036-03	DUP	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Actinium-228	LANL ER-130 Modified	7.94E-01	1.67E-01	1.72E-01	3.44E-01	pCi/g
16-03036-04	DO	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Actinium-228	LANL ER-130 Modified	8.21E-01	1.72E-01	1.77E-01	2.68E-01	pCi/g
16-03036-05	TRG	26BKGD-12-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Actinium-228	LANL ER-130 Modified	8.39E-01	2.18E-01	2.22E-01	4.36E-01	pCi/g
16-03036-06	TRG	26BKGD-13-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Actinium-228	LANL ER-130 Modified	9.60E-01	2.22E-01	2.27E-01	4.40E-01	pCi/g
16-03036-07	TRG	26BKGD-14-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Actinium-228	LANL ER-130 Modified	8.78E-01	4.25E-01	4.28E-01	8.11E-01	pCi/g
16-03036-08	TRG	26BKGD-15-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Actinium-228	LANL ER-130 Modified	9.39E-01	1.83E-01	1.89E-01	2.70E-01	pCi/g
16-03036-09	TRG	26BKGD-16-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Actinium-228	LANL ER-130 Modified	9.51E-01	2.10E-01	2.16E-01	3.96E-01	pCi/g
16-03036-10	TRG	26BKGD-17-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Actinium-228	LANL ER-130 Modified	1.01E+00	3.72E-01	3.76E-01	1.19E+00	pCi/g
16-03036-11	TRG	26BKGD-18-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Actinium-228	LANL ER-130 Modified	1.07E+00	1.96E-01	2.03E-01	3.98E-01	pCi/g
16-03036-12	TRG	26BKGD-19-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Actinium-228	LANL ER-130 Modified	1.09E+00	2.41E-01	2.47E-01	3.56E-01	pCi/g
16-03036-13	TRG	26BKGD-20-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Actinium-228	LANL ER-130 Modified	1.40E+00	4.97E-01	5.02E-01	9.98E-01	pCi/g
16-03036-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Bismuth-214	LANL ER-130 Modified	-5.14E-02	9.24E-02	9.24E-02	1.39E-01	pCi/g
16-03036-03	DUP	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Bismuth-214	LANL ER-130 Modified	1.07E+00	1.42E-01	1.52E-01	1.93E-01	pCi/g
16-03036-04	DO	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Bismuth-214	LANL ER-130 Modified	1.19E+00	1.56E-01	1.67E-01	1.75E-01	pCi/g
16-03036-05	TRG	26BKGD-12-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Bismuth-214	LANL ER-130 Modified	1.19E+00	1.87E-01	1.97E-01	2.47E-01	pCi/g
16-03036-06	TRG	26BKGD-13-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Bismuth-214	LANL ER-130 Modified	8.50E-01	1.60E-01	1.65E-01	2.18E-01	pCi/g
16-03036-07	TRG	26BKGD-14-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Bismuth-214	LANL ER-130 Modified	1.27E+00	2.64E-01	2.72E-01	3.75E-01	pCi/g
16-03036-08	TRG	26BKGD-15-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Bismuth-214	LANL ER-130 Modified	1.35E+00	1.58E-01	1.72E-01	1.70E-01	pCi/g
16-03036-09	TRG	26BKGD-16-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Bismuth-214	LANL ER-130 Modified	8.38E-01	1.59E-01	1.65E-01	2.50E-01	pCi/g
16-03036-10	TRG	26BKGD-17-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Bismuth-214	LANL ER-130 Modified	9.60E-01	2.27E-01	2.32E-01	9.21E-01	pCi/g
16-03036-11	TRG	26BKGD-18-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Bismuth-214	LANL ER-130 Modified	1.35E+00	1.61E-01	1.75E-01	1.60E-01	pCi/g
16-03036-12	TRG	26BKGD-19-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Bismuth-214	LANL ER-130 Modified	1.06E+00	1.62E-01	1.71E-01	7.21E-02	pCi/g
16-03036-13	TRG	26BKGD-20-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Bismuth-214	LANL ER-130 Modified	9.78E-01	2.50E-01	2.55E-01	1.49E-01	pCi/g
16-03036-01	LCS	KNOWN	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Cesium-137	LANL ER-130 Modified	8.69E+01	3.48E+00			pCi/g
16-03036-01	LCS	SPIKE	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Cesium-137	LANL ER-130 Modified	8.84E+01	8.49E+00	9.63E+00	1.99E+00	pCi/g
16-03036-01	LCS	KNOWN	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Cobalt-60	LANL ER-130 Modified	1.37E+02	5.48E+00			pCi/g
16-03036-01	LCS	SPIKE	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Cobalt-60	LANL ER-130 Modified	1.43E+02	9.91E+00	1.23E+01	1.54E+00	pCi/g
16-03036-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Lead-212	LANL ER-130 Modified	1.73E-02	6.00E-02	6.00E-02	9.81E-02	pCi/g
16-03036-03	DUP	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-212	LANL ER-130 Modified	9.48E-01	1.24E-01	1.33E-01	1.96E-01	pCi/g
16-03036-04	DO	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-212	LANL ER-130 Modified	9.01E-01	1.21E-01	1.29E-01	1.97E-01	pCi/g
16-03036-05	TRG	26BKGD-12-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-212	LANL ER-130 Modified	9.97E-01	1.39E-01	1.48E-01	2.41E-01	pCi/g
16-03036-06	TRG	26BKGD-13-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-212	LANL ER-130 Modified	1.00E+00	1.30E-01	1.40E-01	2.16E-01	pCi/g
16-03036-07	TRG	26BKGD-14-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-212	LANL ER-130 Modified	1.14E+00	2.66E-01	2.72E-01	5.04E-01	pCi/g
16-03036-08	TRG	26BKGD-15-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-212	LANL ER-130 Modified	9.35E-01	1.24E-01	1.33E-01	2.19E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Olin Garren	SDG:	16-03036
Weston Solutions, Inc.	Purchase Order:	0087171
5599 San Felipe, Suite 700	Analysis Category:	ENVIRONMENTAL
Houston, TX 77056	Sample Matrix:	SO

Lab ID	Sample Type	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	CU	CSU	MDA	Report Units
16-03036-09	TRG	26BKGD-16-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-212	LANL ER-130 Modified	1.01E+00	1.31E-01	1.41E-01	2.71E-01	pCi/g
16-03036-10	TRG	26BKGD-17-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-212	LANL ER-130 Modified	1.28E+00	2.82E-01	2.90E-01	3.75E-01	pCi/g
16-03036-11	TRG	26BKGD-18-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-212	LANL ER-130 Modified	1.08E+00	1.34E-01	1.45E-01	1.90E-01	pCi/g
16-03036-12	TRG	26BKGD-19-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-212	LANL ER-130 Modified	9.74E-01	1.28E-01	1.37E-01	2.09E-01	pCi/g
16-03036-13	TRG	26BKGD-20-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-212	LANL ER-130 Modified	1.03E+00	2.55E-01	2.61E-01	3.54E-01	pCi/g
16-03036-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Lead-214	LANL ER-130 Modified	-2.49E-02	8.26E-02	8.26E-02	1.28E-01	pCi/g
16-03036-03	DUP	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-214	LANL ER-130 Modified	1.28E+00	1.63E-01	1.76E-01	2.07E-01	pCi/g
16-03036-04	DO	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-214	LANL ER-130 Modified	1.21E+00	1.56E-01	1.68E-01	1.96E-01	pCi/g
16-03036-05	TRG	26BKGD-12-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-214	LANL ER-130 Modified	1.33E+00	1.72E-01	1.85E-01	2.21E-01	pCi/g
16-03036-06	TRG	26BKGD-13-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-214	LANL ER-130 Modified	8.42E-01	1.61E-01	1.67E-01	2.40E-01	pCi/g
16-03036-07	TRG	26BKGD-14-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-214	LANL ER-130 Modified	1.30E+00	2.64E-01	2.72E-01	4.49E-01	pCi/g
16-03036-08	TRG	26BKGD-15-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-214	LANL ER-130 Modified	1.52E+00	1.53E-01	1.72E-01	2.19E-01	pCi/g
16-03036-09	TRG	26BKGD-16-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-214	LANL ER-130 Modified	9.66E-01	1.69E-01	1.76E-01	2.94E-01	pCi/g
16-03036-10	TRG	26BKGD-17-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-214	LANL ER-130 Modified	7.59E-01	2.47E-01	2.50E-01	4.38E-01	pCi/g
16-03036-11	TRG	26BKGD-18-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-214	LANL ER-130 Modified	1.45E+00	1.57E-01	1.73E-01	2.25E-01	pCi/g
16-03036-12	TRG	26BKGD-19-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-214	LANL ER-130 Modified	1.28E+00	1.96E-01	2.07E-01	2.82E-01	pCi/g
16-03036-13	TRG	26BKGD-20-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Lead-214	LANL ER-130 Modified	8.61E-01	2.41E-01	2.45E-01	3.88E-01	pCi/g
16-03036-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.75E-01	4.13E-01	4.14E-01	8.01E-01	pCi/g
16-03036-03	DUP	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.69E+01	1.95E+00	2.14E+00	6.95E-01	pCi/g
16-03036-04	DO	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.62E+01	1.96E+00	2.13E+00	1.14E+00	pCi/g
16-03036-05	TRG	26BKGD-12-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.47E+01	1.92E+00	2.07E+00	8.85E-01	pCi/g
16-03036-06	TRG	26BKGD-13-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.60E+01	2.04E+00	2.20E+00	9.83E-01	pCi/g
16-03036-07	TRG	26BKGD-14-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.62E+01	3.07E+00	3.18E+00	2.35E+00	pCi/g
16-03036-08	TRG	26BKGD-15-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.50E+01	1.75E+00	1.91E+00	1.09E+00	pCi/g
16-03036-09	TRG	26BKGD-16-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.41E+01	1.85E+00	1.99E+00	9.03E-01	pCi/g
16-03036-10	TRG	26BKGD-17-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.47E+01	2.71E+00	2.82E+00	1.53E+00	pCi/g
16-03036-11	TRG	26BKGD-18-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.59E+01	1.84E+00	2.01E+00	1.12E+00	pCi/g
16-03036-12	TRG	26BKGD-19-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.50E+01	1.95E+00	2.09E+00	9.94E-01	pCi/g
16-03036-13	TRG	26BKGD-20-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Potassium-40	LANL ER-130 Modified	1.55E+01	2.83E+00	2.94E+00	1.73E+00	pCi/g
16-03036-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	-4.06E-01	5.62E+00	5.62E+00	8.79E+00	pCi/g
16-03036-03	DUP	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	4.05E+00	4.40E+00	4.40E+00	7.69E+00	pCi/g
16-03036-04	DO	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	4.59E+00	4.70E+00	4.71E+00	8.21E+00	pCi/g
16-03036-05	TRG	26BKGD-12-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	-1.74E-01	6.78E+00	6.78E+00	1.00E+01	pCi/g
16-03036-06	TRG	26BKGD-13-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	-1.82E+00	6.26E+00	6.27E+00	8.70E+00	pCi/g
16-03036-07	TRG	26BKGD-14-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	8.11E+00	9.69E+00	9.70E+00	1.81E+01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Olin Garren	SDG:	16-03036
Weston Solutions, Inc.	Purchase Order:	0087171
5599 San Felipe, Suite 700	Analysis Category:	ENVIRONMENTAL
Houston, TX 77056	Sample Matrix:	SO

Lab ID	Sample Type	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	CU	CSU	MDA	Report Units
16-03036-08	TRG	26BKGD-15-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	8.74E-01	4.77E+00	4.78E+00	7.35E+00	pCi/g
16-03036-09	TRG	26BKGD-16-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	7.92E+00	5.60E+00	5.61E+00	1.05E+01	pCi/g
16-03036-10	TRG	26BKGD-17-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	-3.03E+00	1.05E+01	1.05E+01	1.65E+01	pCi/g
16-03036-11	TRG	26BKGD-18-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	6.52E+00	4.81E+00	4.82E+00	8.51E+00	pCi/g
16-03036-12	TRG	26BKGD-19-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	3.82E+00	5.83E+00	5.83E+00	9.79E+00	pCi/g
16-03036-13	TRG	26BKGD-20-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Protactinium-234m	LANL ER-130 Modified	-3.23E+00	9.73E+00	9.73E+00	1.53E+01	pCi/g
16-03036-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Radium-226	LANL ER-130 Modified	-5.14E-02	9.24E-02	9.24E-02	1.39E-01	pCi/g
16-03036-03	DUP	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Radium-226	LANL ER-130 Modified	1.07E+00	1.42E-01	1.52E-01	1.93E-01	pCi/g
16-03036-04	DO	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Radium-226	LANL ER-130 Modified	1.19E+00	1.56E-01	1.67E-01	1.75E-01	pCi/g
16-03036-05	TRG	26BKGD-12-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Radium-226	LANL ER-130 Modified	1.19E+00	1.87E-01	1.97E-01	2.47E-01	pCi/g
16-03036-06	TRG	26BKGD-13-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Radium-226	LANL ER-130 Modified	8.50E-01	1.60E-01	1.65E-01	2.18E-01	pCi/g
16-03036-07	TRG	26BKGD-14-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Radium-226	LANL ER-130 Modified	1.27E+00	2.64E-01	2.72E-01	3.75E-01	pCi/g
16-03036-08	TRG	26BKGD-15-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Radium-226	LANL ER-130 Modified	1.35E+00	1.58E-01	1.72E-01	1.70E-01	pCi/g
16-03036-09	TRG	26BKGD-16-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Radium-226	LANL ER-130 Modified	8.38E-01	1.59E-01	1.65E-01	2.50E-01	pCi/g
16-03036-10	TRG	26BKGD-17-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Radium-226	LANL ER-130 Modified	9.60E-01	2.27E-01	2.32E-01	9.21E-01	pCi/g
16-03036-11	TRG	26BKGD-18-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Radium-226	LANL ER-130 Modified	1.35E+00	1.61E-01	1.75E-01	1.60E-01	pCi/g
16-03036-12	TRG	26BKGD-19-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Radium-226	LANL ER-130 Modified	1.06E+00	1.62E-01	1.71E-01	7.21E-02	pCi/g
16-03036-13	TRG	26BKGD-20-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Radium-226	LANL ER-130 Modified	9.78E-01	2.50E-01	2.55E-01	1.49E-01	pCi/g
16-03036-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Thallium-208	LANL ER-130 Modified	6.68E-02	1.09E-01	1.09E-01	2.03E-01	pCi/g
16-03036-03	DUP	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thallium-208	LANL ER-130 Modified	6.38E-01	1.33E-01	1.37E-01	1.81E-01	pCi/g
16-03036-04	DO	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thallium-208	LANL ER-130 Modified	7.43E-01	1.33E-01	1.38E-01	1.09E-01	pCi/g
16-03036-05	TRG	26BKGD-12-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thallium-208	LANL ER-130 Modified	7.93E-01	1.68E-01	1.73E-01	4.24E-02	pCi/g
16-03036-06	TRG	26BKGD-13-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thallium-208	LANL ER-130 Modified	7.01E-01	1.71E-01	1.74E-01	3.03E-01	pCi/g
16-03036-07	TRG	26BKGD-14-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thallium-208	LANL ER-130 Modified	8.12E-01	2.78E-01	2.81E-01	3.85E-01	pCi/g
16-03036-08	TRG	26BKGD-15-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thallium-208	LANL ER-130 Modified	7.92E-01	1.37E-01	1.43E-01	1.37E-01	pCi/g
16-03036-09	TRG	26BKGD-16-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thallium-208	LANL ER-130 Modified	7.85E-01	1.73E-01	1.78E-01	3.98E-02	pCi/g
16-03036-10	TRG	26BKGD-17-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thallium-208	LANL ER-130 Modified	8.42E-01	2.36E-01	2.40E-01	8.92E-02	pCi/g
16-03036-11	TRG	26BKGD-18-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thallium-208	LANL ER-130 Modified	6.25E-01	1.25E-01	1.29E-01	1.07E-01	pCi/g
16-03036-12	TRG	26BKGD-19-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thallium-208	LANL ER-130 Modified	7.45E-01	1.54E-01	1.59E-01	1.88E-01	pCi/g
16-03036-13	TRG	26BKGD-20-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thallium-208	LANL ER-130 Modified	5.21E-01	2.36E-01	2.38E-01	3.77E-01	pCi/g
16-03036-02	MBL	BLANK	03/07/16 00:00	3/7/2016	3/28/2016	16-03036	Thorium-234	LANL ER-130 Modified	4.02E-01	4.07E-01	4.08E-01	6.79E-01	pCi/g
16-03036-03	DUP	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thorium-234	LANL ER-130 Modified	1.28E+00	1.31E+00	1.31E+00	2.18E+00	pCi/g
16-03036-04	DO	26BKGD-11-62-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thorium-234	LANL ER-130 Modified	2.42E+00	1.33E+00	1.34E+00	2.17E+00	pCi/g
16-03036-05	TRG	26BKGD-12-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thorium-234	LANL ER-130 Modified	7.68E-01	1.48E+00	1.48E+00	1.94E+00	pCi/g
16-03036-06	TRG	26BKGD-13-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thorium-234	LANL ER-130 Modified	1.55E+00	1.35E+00	1.36E+00	1.82E+00	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Olin Garren	SDG:	**16-03036**
Weston Solutions, Inc.	Purchase Order:	0087171
5599 San Felipe, Suite 700	Analysis Category:	ENVIRONMENTAL
Houston, TX 77056	Sample Matrix:	SO

Lab ID	Sample Type	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	CU	CSU	MDA	Report Units
16-03036-07	TRG	26BKGD-14-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thorium-234	LANL ER-130 Modified	1.65E+00	1.29E+00	1.29E+00	2.03E+00	pCi/g
16-03036-08	TRG	26BKGD-15-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thorium-234	LANL ER-130 Modified	2.99E+00	1.55E+00	1.56E+00	2.52E+00	pCi/g
16-03036-09	TRG	26BKGD-16-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thorium-234	LANL ER-130 Modified	1.65E+00	1.30E+00	1.31E+00	1.77E+00	pCi/g
16-03036-10	TRG	26BKGD-17-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thorium-234	LANL ER-130 Modified	1.01E+00	1.20E+00	1.20E+00	1.88E+00	pCi/g
16-03036-11	TRG	26BKGD-18-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thorium-234	LANL ER-130 Modified	2.12E+00	1.54E+00	1.54E+00	2.55E+00	pCi/g
16-03036-12	TRG	26BKGD-19-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thorium-234	LANL ER-130 Modified	1.52E+00	1.40E+00	1.41E+00	1.89E+00	pCi/g
16-03036-13	TRG	26BKGD-20-61-160303	03/03/16 00:00	3/7/2016	3/29/2016	16-03036	Thorium-234	LANL ER-130 Modified	8.29E-01	1.13E+00	1.13E+00	1.76E+00	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

MEMO

DATE: June 28, 2019

TO: Keith Delhomme, Robert Sherman

FROM: Rick Haaker RF Haaker

SUBJECT: Review of Gamma Spectroscopy Data Package, 16-03036

Introduction

The file evaluated was SEC26_16-03036 EDD.xls.

This package did not contain radiochemistry data. Only the gamma spec data was reviewed. All concentration units are in units of pCi/g, unless otherwise noted.

Conclusions

My impression is that the laboratory analyses are acceptable for use.

Gamma Spectroscopy data review.

Summary

General factors		
Factor	Value	Comment
Number of ClientID	10	Number of distinct samples submitted
Number of Lab Duplicates	1	
Isotopes Detected in Method Blank	None	Good!
Performance of Duplicate	--	Good!
Ra-226 pCi/g in Duplicate	~1.1	
Ra-226 pCi/g Range in Data Package	0.5 < Ra226 < 1.5	Definitely background range.
Ingrowth Days at Eberline	21-22	Should be 21 days or more.

The following samples were analyzed by gamma spectroscopy.

SampleID_Table		
ClientID	**LabID**	**Sample Type**
26BKGD-11-62-160303	16-03036-03	DUP
26BKGD-11-62-160303	16-03036-04	DO
26BKGD-12-61-160303	16-03036-05	TRG
26BKGD-13-61-160303	16-03036-06	TRG
26BKGD-14-61-160303	16-03036-07	TRG
26BKGD-15-61-160303	16-03036-08	TRG
26BKGD-16-61-160303	16-03036-09	TRG

SampleID_Table		
ClientID	LabID	Sample Type
26BKGD-17-61-160303	16-03036-10	TRG
26BKGD-18-61-160303	16-03036-11	TRG
26BKGD-19-61-160303	16-03036-12	TRG
26BKGD-20-61-160303	16-03036-13	TRG

The data was delivered in the usual Microsoft excel data format; it did not contain radiochemistry data.

Thorium-234 results were considerably more precise than protactinium-234m results. The protactinium-234m results should not by themselves be considered reliable. Th-234 was reported as present at levels that exceed the minimum detectable activity in samples as follows. Results are in the units of pCi/g.

Detected_Pa234m_Th234			
ClientID	Analyte	Results	MDAC
26BKGD-15-61-160303	Thorium-234	2.99	2.52

Ignoring protactinium-234m, all other uranium decay chain analytes were detected in all samples except as follows:

NonDetects6				
ClientID	Analyte	Result	MDAC	ReportUnits
26BKGD-11-62-160303	Thorium-234	1.28	2.1846	pCi/g
26BKGD-12-61-160303	Thorium-234	0.77	1.9409	pCi/g
26BKGD-13-61-160303	Thorium-234	1.55	1.8156	pCi/g
26BKGD-14-61-160303	Thorium-234	1.65	2.0279	pCi/g
26BKGD-16-61-160303	Thorium-234	1.65	1.7742	pCi/g
26BKGD-17-61-160303	Thorium-234	1.01	1.8765	pCi/g
26BKGD-18-61-160303	Thorium-234	2.12	2.547	pCi/g
26BKGD-19-61-160303	Thorium-234	1.52	1.8866	pCi/g
26BKGD-20-61-160303	Thorium-234	0.83	1.7601	pCi/g

This Eberline data package reports radium-226 as equal to bismuth-214, the radium-226 being assigned from the bismuth-214 values.

The degree of agreement between thorium-234 and radium-226 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that the thorium-234 results might be seriously biased by systematic error. The test statistic is the number of standard deviations by which the thorium-234 result exceeds the radium-226 result. If the test statistic is substantially less than zero, it implies that the reported radium-226 concentration is greater than the thorium-234 concentration. Gamma spectroscopy cannot detect thorium-230 for all practical purposes, **so agreement between thorium-234 and radium-226 doesn't provide *any* information about equilibrium between thorium-230 and radium-226.**

‘Equilibrium’ Th234 → Ra-226		
ClientID	**Test Statistic**	**Disequilibrium Evidence**
26BKGD-11-62-160303	0.32	Weak or none
26BKGD-11-62-160303	1.83	Weak or none
26BKGD-12-61-160303	-0.57	Weak or none
26BKGD-13-61-160303	1.02	Weak or none
26BKGD-14-61-160303	0.57	Weak or none
26BKGD-15-61-160303	2.1	Moderate
26BKGD-16-61-160303	1.23	Weak or none
26BKGD-17-61-160303	0.08	Weak or none
26BKGD-18-61-160303	1	Weak or none
26BKGD-19-61-160303	0.65	Weak or none
26BKGD-20-61-160303	-0.26	Weak or none

The degree of agreement between radium-226 and lead-210 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that there is no proficiency testing of radiochemistry laboratories for isotopes having gamma energies similar to those for lead-210. The test statistic is the number of standard deviations by which the radium-226 result exceeds the lead-210 result. If the test statistic is substantially less than zero, it implies that the reported lead-210 concentration is greater than the radium-226 concentration. **Agreement between radium-226 and lead-210 doesn't provide *any* information about equilibrium between thorium-230 and radium-226.**

No lead-210 results are included in this package

The maximum and estimated 99%UCLs (assuming normal statistics) for nuisance radionuclides in pCi/g, based on all prior datasets reviewed to this point are:

Analyte	Maximum	UCL99%
Actinium-228	2.61	2.48
Lead-212	8.45	4.1
Potassium-40	40.54	35.3
Thallium-208	2.48	2.25

It is good to keep in mind that around 10 – 15pCi/g potassium-40 looks like 1pCi/g of radium-226 to a 2x2 sodium iodide detector during field surveys.

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-04077
Weston Solutions, Inc.	Purchase Order:	0094169
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

Lab ID	Sample Type	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	CU	CSU	MDA	Report Units
17-04077-01	LCS	KNOWN	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Cobalt-60	LANL ER-130 Modified	1.35E+02	5.27E+00			pCi/g
17-04077-01	LCS	KNOWN	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Cesium-137	LANL ER-130 Modified	8.44E+01	3.38E+00			pCi/g
17-04077-01	LCS	SPIKE	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Cobalt-60	LANL ER-130 Modified	1.33E+02	7.96E+00	1.05E+01	1.15E+00	pCi/g
17-04077-01	LCS	SPIKE	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Cesium-137	LANL ER-130 Modified	8.69E+01	7.88E+00	9.06E+00	1.42E+00	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Actinium-228	LANL ER-130 Modified	3.32E-02	5.97E-02	5.97E-02	1.12E-01	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Bismuth-214	LANL ER-130 Modified	7.22E-03	4.53E-02	4.53E-02	6.58E-02	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Potassium-40	LANL ER-130 Modified	3.14E-01	2.02E-01	2.02E-01	4.73E-01	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Protactinium-234m	LANL ER-130 Modified	-6.34E-01	2.02E+00	2.02E+00	2.87E+00	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Lead-210	LANL ER-130 Modified	5.87E-01	3.55E-01	3.56E-01	6.42E-01	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Lead-212	LANL ER-130 Modified	-4.99E-03	3.74E-02	3.74E-02	4.87E-02	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Lead-214	LANL ER-130 Modified	-1.35E-02	5.37E-02	5.38E-02	6.96E-02	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Radium-226	LANL ER-130 Modified	7.22E-03	4.53E-02	4.53E-02	6.58E-02	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Thorium-234	LANL ER-130 Modified	4.13E-01	2.61E-01	2.62E-01	4.83E-01	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Thallium-208	LANL ER-130 Modified	4.63E-02	4.88E-02	4.89E-02	8.91E-02	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/1/2017	17-04077	Uranium-235	LANL ER-130 Modified	8.24E-03	1.15E-01	1.15E-01	1.55E-01	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Actinium-228	LANL ER-130 Modified	2.63E-01	1.06E+00	1.06E+00	2.33E+00	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Bismuth-214	LANL ER-130 Modified	1.56E+02	7.70E+00	1.11E+01	1.73E+00	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Potassium-40	LANL ER-130 Modified	1.72E+01	5.65E+00	5.72E+00	8.81E+00	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Protactinium-234m	LANL ER-130 Modified	7.56E+01	4.70E+01	4.72E+01	7.73E+01	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Lead-210	LANL ER-130 Modified	8.74E+01	1.11E+01	1.19E+01	1.21E+01	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Lead-212	LANL ER-130 Modified	1.39E+00	8.84E-01	8.87E-01	1.26E+00	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Lead-214	LANL ER-130 Modified	1.56E+02	9.27E+00	1.22E+01	1.96E+00	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Radium-226	LANL ER-130 Modified	1.56E+02	7.70E+00	1.11E+01	1.73E+00	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-234	LANL ER-130 Modified	8.67E+01	1.04E+01	1.13E+01	1.31E+01	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Thallium-208	LANL ER-130 Modified	1.20E+00	1.09E+00	1.09E+00	7.62E-01	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-235	LANL ER-130 Modified	9.55E+00	2.78E+00	2.82E+00	4.33E+00	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Actinium-228	LANL ER-130 Modified	4.23E-02	1.73E+00	1.73E+00	2.30E+00	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Bismuth-214	LANL ER-130 Modified	1.57E+02	7.76E+00	1.12E+01	1.90E+00	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Potassium-40	LANL ER-130 Modified	2.46E+01	6.49E+00	6.61E+00	9.81E+00	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Protactinium-234m	LANL ER-130 Modified	9.29E+01	5.56E+01	5.58E+01	9.14E+01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Lead-210	LANL ER-130 Modified	9.00E+01	1.13E+01	1.22E+01	1.21E+01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Lead-212	LANL ER-130 Modified	1.03E+00	8.82E-01	8.84E-01	1.26E+00	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Lead-214	LANL ER-130 Modified	1.56E+02	9.29E+00	1.23E+01	2.11E+00	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-04077
Weston Solutions, Inc.	Purchase Order:	0094169
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

Lab ID	Sample Type	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	CU	CSU	MDA	Report Units
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Radium-226	LANL ER-130 Modified	1.57E+02	7.76E+00	1.12E+01	1.90E+00	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-234	LANL ER-130 Modified	8.50E+01	1.03E+01	1.12E+01	1.32E+01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Thallium-208	LANL ER-130 Modified	1.29E+00	1.09E+00	1.09E+00	8.23E-01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-235	LANL ER-130 Modified	7.00E+00	2.36E+00	2.39E+00	3.85E+00	pCi/g
17-04077-01	LCS	KNOWN	04/20/17 00:00	4/20/2017	5/11/2017	17-04077	Lead-210	EML Pb-01 Modified	2.02E+01	7.49E-01			pCi/g
17-04077-01	LCS	SPIKE	04/20/17 00:00	4/20/2017	5/11/2017	17-04077	Lead-210	EML Pb-01 Modified	2.08E+01	8.98E-01	2.86E+00	6.72E-01	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/11/2017	17-04077	Lead-210	EML Pb-01 Modified	1.36E-01	2.74E-01	2.75E-01	5.73E-01	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/11/2017	17-04077	Lead-210	EML Pb-01 Modified	8.26E+01	1.65E+00	1.09E+01	5.56E-01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/11/2017	17-04077	Lead-210	EML Pb-01 Modified	8.42E+01	1.68E+00	1.11E+01	5.70E-01	pCi/g
17-04077-01	LCS	KNOWN	04/20/17 00:00	4/20/2017	5/10/2017	17-04077	Polonium-210	EML Po-2 Modified	7.53E+00	2.79E-01			pCi/g
17-04077-01	LCS	SPIKE	04/20/17 00:00	4/20/2017	5/10/2017	17-04077	Polonium-210	EML Po-2 Modified	8.93E+00	1.31E+00	1.47E+00	1.07E-01	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/10/2017	17-04077	Polonium-210	EML Po-2 Modified	1.19E-01	8.76E-02	8.80E-02	8.76E-02	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/10/2017	17-04077	Polonium-210	EML Po-2 Modified	9.13E+01	1.22E+01	1.40E+01	1.53E-01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/10/2017	17-04077	Polonium-210	EML Po-2 Modified	7.96E+01	1.03E+01	1.20E+01	1.15E-01	pCi/g
17-04077-01	LCS	KNOWN	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-228	EPA 907.0 Modified	4.80E+00	1.73E-01			pCi/g
17-04077-01	LCS	SPIKE	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-228	EPA 907.0 Modified	5.90E+00	1.01E+00	1.16E+00	9.86E-02	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-228	EPA 907.0 Modified	-8.13E-03	3.38E-02	3.38E-02	1.09E-01	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-228	EPA 907.0 Modified	1.12E+00	4.59E-01	4.71E-01	1.73E-01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-228	EPA 907.0 Modified	5.45E-01	3.53E-01	3.57E-01	2.22E-01	pCi/g
17-04077-01	LCS	KNOWN	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-230	EPA 907.0 Modified	5.33E+00	1.44E-01			pCi/g
17-04077-01	LCS	SPIKE	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-230	EPA 907.0 Modified	6.55E+00	1.10E+00	1.37E+00	1.24E-01	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-230	EPA 907.0 Modified	2.46E-01	1.31E-01	1.34E-01	9.21E-02	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-230	EPA 907.0 Modified	1.15E+02	2.74E+01	3.08E+01	1.64E-01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-230	EPA 907.0 Modified	2.11E+02	5.91E+01	6.46E+01	1.61E-01	pCi/g
17-04077-01	LCS	KNOWN	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-232	EPA 907.0 Modified	4.80E+00	1.73E-01			pCi/g
17-04077-01	LCS	SPIKE	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-232	EPA 907.0 Modified	5.86E+00	1.01E+00	1.13E+00	1.43E-01	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-232	EPA 907.0 Modified	-2.61E-03	3.05E-02	3.05E-02	6.40E-02	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-232	EPA 907.0 Modified	5.17E+00	1.45E+00	1.52E+00	1.44E-01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Thorium-232	EPA 907.0 Modified	2.22E+00	8.80E-01	9.01E-01	2.16E-01	pCi/g
17-04077-01	LCS	KNOWN	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-234	EPA 908.0 Modified	7.28E+00	2.62E-01			pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-04077
Weston Solutions, Inc.	Purchase Order:	0094169
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

Lab ID	Sample Type	Client ID	Sample Date	Receipt Date	Analysis Date	Batch ID	Analyte	Method	Result	CU	CSU	MDA	Report Units
17-04077-01	LCS	SPIKE	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-234	EPA 908.0 Modified	6.40E+00	8.91E-01	1.00E+00	8.30E-02	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-234	EPA 908.0 Modified	4.97E-01	1.70E-01	1.73E-01	6.96E-02	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-234	EPA 908.0 Modified	8.04E+01	1.43E+01	1.55E+01	2.36E-01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-234	EPA 908.0 Modified	1.17E+02	2.01E+01	2.18E+01	2.02E-01	pCi/g
17-04077-01	LCS	SPIKE	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-235	EPA 908.0 Modified	6.78E-01	2.15E-01	2.21E-01	7.43E-02	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-235	EPA 908.0 Modified	1.47E-01	1.03E-01	1.03E-01	9.81E-02	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-235	EPA 908.0 Modified	1.56E+01	3.16E+00	3.35E+00	2.64E-01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-235	EPA 908.0 Modified	1.33E+01	2.68E+00	2.85E+00	2.85E-01	pCi/g
17-04077-01	LCS	KNOWN	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-238	EPA 908.0 Modified	7.05E+00	2.54E-01			pCi/g
17-04077-01	LCS	SPIKE	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-238	EPA 908.0 Modified	6.16E+00	8.63E-01	9.69E-01	7.52E-02	pCi/g
17-04077-02	MBL	BLANK	04/20/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-238	EPA 908.0 Modified	1.28E-01	8.33E-02	8.38E-02	6.31E-02	pCi/g
17-04077-03	DUP	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-238	EPA 908.0 Modified	1.05E+02	1.85E+01	2.00E+01	2.01E-01	pCi/g
17-04077-04	DO	17-01-31-170415	04/05/17 00:00	4/20/2017	5/2/2017	17-04077	Uranium-238	EPA 908.0 Modified	1.25E+02	2.15E+01	2.32E+01	2.30E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Report Eberline Data Package # 17-04077

DATE: September 25, 2020

ANALYST: Rick Haaker, CHP, CIH, Weston Solutions, LLC. RF Haaker

Validated data table file *17-04077 - Validated result tableR0.xlsx* is submitted along with this validation report. All values reported herein are in pCi/g, except where stated otherwise.

Statement of Data Usability

Based on a limited review of the results presented in this laboratory package, the following observations are offered:

- All uranium-235results by alpha spectroscopy are rejected with an "Rr" qualifier. Do not rely on the reported values. Specify isotopic uranium analysis by ICP-MS if inferences about uranium-235 or the ratio of uranium-235 to uranium-238 are required.[a]
- All thorium-234 and protactinium-234m results by gamma spectroscopy are rejected with an "Rr" qualifier. Do not rely on the reported values.
- Some Uranium-238 results are more certain than usual and carry a J qualifier.
- All uranium-234 results are unremarkable and acceptable.
- All thorium and polonium-210 results appear to be more uncertain than usual and carry a "J" qualifier.
- Radium-226 (bismuth-214) results are unremarkable and acceptable.
- Whether to use or reject samples that have a J or J+ qualifiers depends on several factors that the data vaiidation analyst cannot possibly know. These include the client's tolerance for risk, the consequences of decision errors, the likelihood that re-running the sample will provide a result with better data quality attributes, and the respective costs of factors.

Subject to these points, my impression is that the data is suitable for use.

Abbreviations and Acronyms

See the section "Data Qualifiers" section for a discussion of data qualifier symbology. The following acronyms or abbreviations could be used in this report.

Term	Meaning
AKA	Also known as
DER	Duplicate Error Ratio
EPA	Environmental Protection Agency
ISO	International Standards Organization
LCS	Laboratory Control Standard
MB	Method Blank
MDA	Minimum Detectable Activity
MDC	Minimum Detectable Concentration AKA MDA

[a] Minteer et al., "RELIABILITY OF USING 238U/235U AND 234U/238U RATIOS FROM ALPHA SPECTROMETRY AS QUALITATIVE INDICATORS OF ENRICHED URANIUM CONTAMINATION."

Term	Meaning
NIST	National Institute for Standards Technology
pCi/g	PicoCuries/gram
QAPP	Quality Assurance Project Plan

Data Package Description

Type of Data Package

Nominal Level II data package

Numbers and types of samples

Soil samples. One Field sample that became a laboratory split.

Lab Sample ID and Field Sample ID Crosswalk

SampleID_Table		
ClientID	**LabID**	**Sample Type**
17-01-31-170415	17-04077-03	DUP
17-01-31-170415	17-04077-04	DO

DO, DUP are laboratory splits of samples collected in the field.

TRG – regular samples

Chain of Custody

Chain of Custody was not part of the package I was provided for review.

Standards Used

Information on the pedigree of the laboratory standards was not part of the package I was provided.

Data Qualifiers

The independent data validator employs the following data qualifiers

Qualifier	**Meaning**
	No data qualifier means that the reported value exceeded the minimum detectable activity and within the scope of the review, the reviewer found the results unremarkable and did not have a reason to reject or qualify the data.
U	Reported value does not exceed the limit of detection as defined by Currie. Results that carry this qualifier should still be the bast estimates of the true concentration of the analyte.
R	Result is rejected because of data quality fail to meet those that are established in the Project QAPP.

Qualifier	**Meaning**
Rr	Result should be disregarded because the method does not provide reliable results for the particular isotope. Results assigned an “Rr” have little or no value in predicting the true concentration of the analyte, even if the reported statistics appear to be good.
J	J, the result is more uncertain than usual. Applied to samples that exceed the minimum detectable activity but exhibit a large duplicate error ratio, or marginal performance of LCS.
J+	The reported result tends to overestimate the true value, most often because the analyte was detected in the method blank at a value greater than 20% of the value observed in the sample of interest.

Tracer and Spike Performance

Detailed tracer and spike information information was not available for review.

Method	Tracer	Spike
Radium-226 EPA 903.0 Modified	Barium-133 added to all samples of all types.	Only the LCS was spiked. The spike recovery was 105% from the LCS.
Iso-Thorium (EPA 907.0 Modified)	Thorium-229 added to all samples of all types.	Only the LCS was spiked.
Iso-Uranium 908.0 (Modified)	Uranium-232 added to all samples of all types.	Only the LCS was spiked.
ANL ER-130 Modified (gamma spectroscopy)	None	Cobalt-60 and cesium-137 were added to the LCS

General Observations

Only the EDD was available for review.

Evidence of instrument pulser checks was not available for review.

Dilutions of the standards into working stock solutions were not available for review.

Laboratory Control Standard Performance

The spike results for the laboratory control standard suggest that the reported values for thorium isotopes, polonium-210 and uranium-238 were more uncertain than usual.

Performance of other LCS results were acceptable.

SampleType	LabID	Analyte	DER	LCS Status
LCS	17-04077-01	Uranium-238	1.99	More uncertain than usual

SampleType	LabID	Analyte	DER	LCS Status
LCS	17-04077-01	Cobalt-60	0.39	Good
LCS	17-04077-01	Cesium-137	0.58	Good
LCS	17-04077-01	Lead-210	0.99	Good
LCS	17-04077-01	Polonium-210	2.09	More uncertain than usual
LCS	17-04077-01	Thorium-228	2.15	More uncertain than usual
LCS	17-04077-01	Thorium-230	2.19	More uncertain than usual
LCS	17-04077-01	Thorium-232	2.09	More uncertain than usual
LCS	17-04077-01	Uranium-234	1.91	Good

Blank Performance

U-234, U-235, U-238, Po-210 and Th-230 were all detected in the blank at concentrations that exceeded the MDA. No field samples were qualified because of this since the amounts of activity in field samples were far higher than in the method blank.

Laboratory Duplicate

LabID	Analyte	% Difference	DER	Dup Status
17-04077-03	Thorium-230	59	2.94	High
17-04077-03	Thorium-232	80	3.47	High
17-04077-03	Uranium-234	37	2.95	High
17-04077-03	Thorium-228	69	1.97	More uncertain than usual

The laboratory split of the field sample yielded a high or marginally high duplicate error ratio for uranium-234, and the thorium isotopes. These results should be considered more uncertain than usual.

Agreement Radium-226 by Method 903.0 Modified and Bismuth-214 by Gamma Spectroscopy

Not applicable. Radium-226 was inferred from the bismuth-214 gamma spectroscopy results; method 903.0 was not used to determine radium-226.

Gamma spectroscopy Ingrowth Days

Twelve days from date of receipt at the Eberline laboratory. During this time Weston was processing and sealing samples at a field lab near Milan, NM. Altogether the samples were sealed for at least 12 days. The concentration of radium-226 (e.g. bismuth-214) by gamma spectroscopy would have been at least about 87% of the true value at secular equilibrium.

Disequilibrium Evidence

Disequilibrium is not actually a data quality issue, but it still is of general interest. The null hypothesis is that there is equilibrium in the uranium-238 decay chain in nature. A null hypothesis cannot be proved; but sometimes it can be disproved. This section provides a summary of the strength of evidence each sample exhibits that the null hypothesis is false. The test statistic is the number of standard deviations by which the concentration of the first analyte exceeds the second analyte. The disequilibrium evidence may be

- Weak or none,
- Moderate, or
- Strong

Ra-226 (Bi-214) and Pb-210

Equilibrium Ra-226 & Pb-210				
ClientID	**Ra-226pCi/g**	**Lead-210pCi/g**	**Test Statistic**	**Disequilibrium Evidence**
17-01-31-170415	156.28	87.4 (γ spec)	8.44	Strong
17-01-31-170415	157.38	90.02 (γ spec)	8.15	Strong
17-01-31-170415	156.28	82.64	9.45	Strong
17-01-31-170415	157.38	84.21	9.27	Strong

Ra-226 (Bi-214) and Th-230

Equilibrium Th-230 Ra-226				
LabID	**Ra-226pCi/g**	**Th-230pCi/g**	**Test Statistic**	**Disequilibrium Evidence**
17-04077-03	156.28	114.86	2.91	Strong
17-04077-04	157.38	210.71	-1.79	Weak or none

Th-230 and U-238

EquilibriumU238Th230				
LabID	Th-230pCi/g	U-238pCi/g	Test Statistic	Disequilibrium Evidence
17-04077-03	114.86	104.56	0.62	Weak or none
17-04077-04	210.71	124.81	2.73	Strong

References

Minteer, Mark, Paul Winkler, Bill Wyatt, Scott Moreland, Jamie Johnson, and Tim Winters. “RELIABILITY OF USING 238U/235U AND 234U/238U RATIOS FROM ALPHA SPECTROMETRY AS QUALITATIVE INDICATORS OF ENRICHED URANIUM CONTAMINATION.” *Health Physics* 92, no. 5 (May 2007): 488. https://doi.org/10.1097/01.HP.0000254847.21026.7c.

Unknown. “Radiological Data Review and Validation Guidelines For Isotopic Analyses By Alpha Spectroscopy. Welsbach/General Gas Mantle Site, Revised August 2006,” 2006.

Data Table with Assigned Qualifiers

Data Table with assigned qualifiers; Concentration, TPU and MDC are in units of pCi/g.

LabID	ClientID	Sample Type	Sample Date	Analyte	Method	Conc	TPU	MDC	Qualifier
17-04077-04	17-01-31-170415	DO	05-Apr-17	Actinium-228	LANL ER-130 Modified	0.04	1.73	2.3	U
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Actinium-228	LANL ER-130 Modified	0.26	1.06	2.33	
17-04077-04	17-01-31-170415	DO	05-Apr-17	Bismuth-214	LANL ER-130 Modified	157.4	11.2	1.9	
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Bismuth-214	LANL ER-130 Modified	156.3	11.12	1.73	
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Lead-210	LANL ER-130 Modified	87.4	11.94	12.07	
17-04077-04	17-01-31-170415	DO	05-Apr-17	Lead-210	LANL ER-130 Modified	90.02	12.17	12.1	
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Lead-210	EML Pb-01 Modified	82.64	10.92	0.56	
17-04077-04	17-01-31-170415	DO	05-Apr-17	Lead-210	EML Pb-01 Modified	84.21	11.13	0.57	
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Lead-212	LANL ER-130 Modified	1.39	0.89	1.26	
17-04077-04	17-01-31-170415	DO	05-Apr-17	Lead-212	LANL ER-130 Modified	1.03	0.88	1.26	
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Lead-214	LANL ER-130 Modified	155.8	12.24	1.96	
17-04077-04	17-01-31-170415	DO	05-Apr-17	Lead-214	LANL ER-130 Modified	156.3	12.27	2.11	
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Polonium-210	EML Po-2 Modified	91.32	13.99	0.15	J
17-04077-04	17-01-31-170415	DO	05-Apr-17	Polonium-210	EML Po-2 Modified	79.57	11.96	0.12	J
17-04077-04	17-01-31-170415	DO	05-Apr-17	Potassium-40	LANL ER-130 Modified	24.6	6.61	9.81	
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Potassium-40	LANL ER-130 Modified	17.21	5.72	8.81	
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Protactinium-234m	LANL ER-130 Modified	75.65	47.15	77.25	U
17-04077-04	17-01-31-170415	DO	05-Apr-17	Protactinium-234m	LANL ER-130 Modified	92.87	55.79	91.41	Rr
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Radium-226	LANL ER-130 Modified	156.3	11.12	1.73	
17-04077-04	17-01-31-170415	DO	05-Apr-17	Radium-226	LANL ER-130 Modified	157.4	11.2	1.9	
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Thallium-208	LANL ER-130 Modified	1.2	1.09	0.76	
17-04077-04	17-01-31-170415	DO	05-Apr-17	Thallium-208	LANL ER-130 Modified	1.29	1.09	0.82	
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Thorium-228	EPA 907.0 Modified	1.12	0.47	0.17	J
17-04077-04	17-01-31-170415	DO	05-Apr-17	Thorium-228	EPA 907.0 Modified	0.55	0.36	0.22	J
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Thorium-230	EPA 907.0 Modified	114.9	30.83	0.16	J
17-04077-04	17-01-31-170415	DO	05-Apr-17	Thorium-230	EPA 907.0 Modified	210.7	64.62	0.16	J
17-04077-04	17-01-31-170415	DO	05-Apr-17	Thorium-232	EPA 907.0 Modified	2.22	0.9	0.22	J
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Thorium-232	EPA 907.0 Modified	5.17	1.52	0.14	J
17-04077-04	17-01-31-170415	DO	05-Apr-17	Thorium-234	LANL ER-130 Modified	85.04	11.17	13.16	Rr
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Thorium-234	LANL ER-130 Modified	86.67	11.27	13.13	Rr
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Uranium-234	EPA 908.0 Modified	80.43	15.46	0.24	
17-04077-04	17-01-31-170415	DO	05-Apr-17	Uranium-234	EPA 908.0 Modified	117	21.79	0.2	

LabID	ClientID	Sample Type	Sample Date	Analyte	Method	Conc	TPU	MDC	Qualifier
17-04077-04	17-01-31-170415	DO	05-Apr-17	Uranium-235	LANL ER-130 Modified	7	2.39	3.85	Rr
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Uranium-235	EPA 908.0 Modified	15.62	3.35	0.26	Rr
17-04077-04	17-01-31-170415	DO	05-Apr-17	Uranium-235	EPA 908.0 Modified	13.32	2.85	0.28	Rr
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Uranium-235	LANL ER-130 Modified	9.55	2.82	4.33	Rr
17-04077-04	17-01-31-170415	DO	05-Apr-17	Uranium-238	EPA 908.0 Modified	124.8	23.23	0.23	J
17-04077-03	17-01-31-170415	DUP	05-Apr-17	Uranium-238	EPA 908.0 Modified	104.6	19.98	0.2	J

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	19-03019
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-03019-01	LCS	KNOWN	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Cobalt-60	EPA 901.1 Modified	1.31E+02	5.10E+00			pCi/g
19-03019-01	LCS	KNOWN	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	8.26E+01	3.39E+00			pCi/g
19-03019-01	LCS	SPIKE	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Cobalt-60	EPA 901.1 Modified	1.45E+02	9.33E+00	1.19E+01	1.38E+00	pCi/g
19-03019-01	LCS	SPIKE	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	9.40E+01	1.03E+01	1.14E+01	1.93E+00	pCi/g
19-03019-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	-7.75E-03	5.17E-02	5.17E-02	1.88E-01	pCi/g
19-03019-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	8.91E-02	8.18E-02	8.19E-02	1.40E-01	pCi/g
19-03019-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	2.27E-02	3.64E-02	3.64E-02	6.21E-02	pCi/g
19-03019-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	1.82E-01	3.19E-01	3.19E-01	6.49E-01	pCi/g
19-03019-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	-5.45E-01	3.77E+00	3.77E+00	5.69E+00	pCi/g
19-03019-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	1.36E-01	3.27E-01	3.27E-01	5.11E-01	pCi/g
19-03019-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	1.07E-02	3.49E-02	3.49E-02	6.17E-02	pCi/g
19-03019-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	2.27E-02	5.48E-02	5.48E-02	9.13E-02	pCi/g
19-03019-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	8.91E-02	8.18E-02	8.19E-02	1.40E-01	pCi/g
19-03019-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	3.69E-01	3.71E-01	3.71E-01	6.06E-01	pCi/g
19-03019-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	-2.73E-02	9.34E-02	9.35E-02	1.27E-01	pCi/g
19-03019-03	DUP	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	8.00E-01	2.67E-01	2.70E-01	5.21E-01	pCi/g
19-03019-03	DUP	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	3.93E+00	3.66E-01	4.18E-01	3.89E-01	pCi/g
19-03019-03	DUP	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	1.93E-01	9.12E-02	9.17E-02	2.03E-01	pCi/g
19-03019-03	DUP	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	2.13E+01	2.48E+00	2.71E+00	1.94E+00	pCi/g
19-03019-03	DUP	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	3.78E-01	6.50E+00	6.50E+00	9.89E+00	pCi/g
19-03019-03	DUP	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	3.50E+00	2.18E+00	2.18E+00	3.55E+00	pCi/g
19-03019-03	DUP	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	1.14E+00	1.86E-01	1.95E-01	3.40E-01	pCi/g
19-03019-03	DUP	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	5.03E+00	4.57E-01	5.25E-01	5.23E-01	pCi/g
19-03019-03	DUP	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	3.93E+00	3.66E-01	4.18E-01	3.89E-01	pCi/g
19-03019-03	DUP	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	2.87E+00	1.62E+00	1.62E+00	2.63E+00	pCi/g
19-03019-03	DUP	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	1.02E+00	2.16E-01	2.22E-01	1.82E-01	pCi/g
19-03019-04	DO	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	1.31E+00	3.21E-01	3.28E-01	6.07E-01	pCi/g
19-03019-04	DO	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	4.41E+00	4.03E-01	4.62E-01	4.42E-01	pCi/g
19-03019-04	DO	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	2.69E-01	1.25E-01	1.26E-01	1.96E-01	pCi/g
19-03019-04	DO	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	2.10E+01	2.48E+00	2.70E+00	1.41E+00	pCi/g
19-03019-04	DO	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	-1.57E+00	7.16E+00	7.16E+00	1.06E+01	pCi/g
19-03019-04	DO	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	2.44E+00	1.95E+00	1.95E+00	3.22E+00	pCi/g
19-03019-04	DO	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	1.14E+00	2.02E-01	2.10E-01	3.50E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical Final Report of Analysis	Report To:		Work Order Details:	
	Jeff Wright		SDG:	19-03019
	Weston Solutions, Inc.		Purchase Order:	0095131
	13702 Coursey Blvd, Bldg 7 Suite A		Analysis Category:	ENVIRONMENTAL
	Baton Rouge, LA 70817-1370		Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-03019-04	DO	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	5.01E+00	4.50E-01	5.18E-01	4.89E-01	pCi/g
19-03019-04	DO	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	4.41E+00	4.03E-01	4.62E-01	4.42E-01	pCi/g
19-03019-04	DO	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	2.44E+00	2.59E+00	2.60E+00	4.34E+00	pCi/g
19-03019-04	DO	17-43-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	1.33E+00	2.23E-01	2.33E-01	2.07E-01	pCi/g
19-03019-05	TRG	17-43-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	1.43E+00	4.02E-01	4.08E-01	7.49E-01	pCi/g
19-03019-05	TRG	17-43-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	5.02E+00	5.26E-01	5.85E-01	4.70E-01	pCi/g
19-03019-05	TRG	17-43-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	4.08E-01	1.58E-01	1.59E-01	2.41E-01	pCi/g
19-03019-05	TRG	17-43-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	3.01E+01	5.54E+00	5.75E+00	2.56E+00	pCi/g
19-03019-05	TRG	17-43-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	6.39E-01	1.09E+01	1.09E+01	1.74E+01	pCi/g
19-03019-05	TRG	17-43-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	3.73E+00	1.81E+00	1.82E+00	2.91E+00	pCi/g
19-03019-05	TRG	17-43-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	1.37E+00	2.50E-01	2.59E-01	3.98E-01	pCi/g
19-03019-05	TRG	17-43-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	5.38E+00	4.84E-01	5.57E-01	5.76E-01	pCi/g
19-03019-05	TRG	17-43-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	5.02E+00	5.26E-01	5.85E-01	4.70E-01	pCi/g
19-03019-05	TRG	17-43-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	-1.93E-01	1.50E+00	1.50E+00	2.14E+00	pCi/g
19-03019-05	TRG	17-43-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	1.69E+00	4.80E-01	4.88E-01	2.48E-01	pCi/g
19-03019-06	TRG	19-01-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	1.21E+00	3.41E-01	3.46E-01	1.11E+00	pCi/g
19-03019-06	TRG	19-01-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	3.36E+00	3.79E-01	4.16E-01	3.53E-01	pCi/g
19-03019-06	TRG	19-01-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	2.64E-01	1.08E-01	1.09E-01	1.64E-01	pCi/g
19-03019-06	TRG	19-01-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	2.51E+01	4.75E+00	4.92E+00	2.74E+00	pCi/g
19-03019-06	TRG	19-01-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	1.10E+01	1.12E+01	1.12E+01	1.86E+01	pCi/g
19-03019-06	TRG	19-01-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	1.83E+00	1.51E+00	1.52E+00	2.51E+00	pCi/g
19-03019-06	TRG	19-01-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	1.36E+00	2.17E-01	2.28E-01	3.28E-01	pCi/g
19-03019-06	TRG	19-01-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	3.50E+00	3.50E-01	3.93E-01	4.34E-01	pCi/g
19-03019-06	TRG	19-01-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	3.36E+00	3.79E-01	4.16E-01	3.53E-01	pCi/g
19-03019-06	TRG	19-01-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	1.02E+00	1.20E+00	1.20E+00	1.75E+00	pCi/g
19-03019-06	TRG	19-01-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	1.29E+00	3.35E-01	3.42E-01	4.66E-01	pCi/g
19-03019-07	TRG	19-01-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	1.39E+00	2.67E-01	2.76E-01	3.70E-01	pCi/g
19-03019-07	TRG	19-01-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	4.45E+00	3.75E-01	4.39E-01	2.57E-01	pCi/g
19-03019-07	TRG	19-01-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	2.29E-01	7.44E-02	7.53E-02	1.65E-01	pCi/g
19-03019-07	TRG	19-01-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	2.38E+01	2.99E+00	3.23E+00	1.36E+00	pCi/g
19-03019-07	TRG	19-01-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	4.23E+00	6.69E+00	6.69E+00	1.10E+01	pCi/g
19-03019-07	TRG	19-01-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	5.38E+00	4.16E+00	4.17E+00	6.78E+00	pCi/g
19-03019-07	TRG	19-01-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	1.10E+00	2.38E-01	2.44E-01	3.23E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical Final Report of Analysis	Report To:	Work Order Details:	
	Jeff Wright	SDG:	19-03019
	Weston Solutions, Inc.	Purchase Order:	0095131
	13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
	Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-03019-07	TRG	19-01-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	4.67E+00	4.45E-01	5.06E-01	3.55E-01	pCi/g
19-03019-07	TRG	19-01-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	4.45E+00	3.75E-01	4.39E-01	2.57E-01	pCi/g
19-03019-07	TRG	19-01-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	3.04E+00	2.51E+00	2.51E+00	4.15E+00	pCi/g
19-03019-07	TRG	19-01-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	9.64E-01	1.58E-01	1.65E-01	1.01E-01	pCi/g
19-03019-08	TRG	19-02-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	1.40E+00	4.52E-01	4.58E-01	8.74E-01	pCi/g
19-03019-08	TRG	19-02-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	6.41E+00	5.85E-01	6.71E-01	4.76E-01	pCi/g
19-03019-08	TRG	19-02-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	3.03E-01	1.19E-01	1.20E-01	3.32E-01	pCi/g
19-03019-08	TRG	19-02-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	1.97E+01	3.02E+00	3.19E+00	2.50E+00	pCi/g
19-03019-08	TRG	19-02-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	1.54E+01	1.29E+01	1.30E+01	2.26E+01	pCi/g
19-03019-08	TRG	19-02-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	4.50E+00	1.89E+00	1.90E+00	3.04E+00	pCi/g
19-03019-08	TRG	19-02-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	8.70E-01	2.03E-01	2.08E-01	5.08E-01	pCi/g
19-03019-08	TRG	19-02-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	6.71E+00	5.14E-01	6.18E-01	5.09E-01	pCi/g
19-03019-08	TRG	19-02-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	6.41E+00	5.85E-01	6.71E-01	4.76E-01	pCi/g
19-03019-08	TRG	19-02-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	5.02E+00	2.36E+00	2.38E+00	5.22E+00	pCi/g
19-03019-08	TRG	19-02-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	9.80E-01	2.87E-01	2.91E-01	2.03E-01	pCi/g
19-03019-09	TRG	19-02-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	8.61E-01	2.60E-01	2.64E-01	5.00E-01	pCi/g
19-03019-09	TRG	19-02-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	6.64E+00	5.07E-01	6.11E-01	4.08E-01	pCi/g
19-03019-09	TRG	19-02-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	2.00E-01	8.12E-02	8.18E-02	2.83E-01	pCi/g
19-03019-09	TRG	19-02-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	2.02E+01	2.56E+00	2.76E+00	2.14E+00	pCi/g
19-03019-09	TRG	19-02-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	6.54E+00	7.41E+00	7.42E+00	1.24E+01	pCi/g
19-03019-09	TRG	19-02-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	3.33E+00	2.59E+00	2.60E+00	4.29E+00	pCi/g
19-03019-09	TRG	19-02-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	5.42E-01	1.28E-01	1.31E-01	3.82E-01	pCi/g
19-03019-09	TRG	19-02-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	6.85E+00	5.29E-01	6.36E-01	4.84E-01	pCi/g
19-03019-09	TRG	19-02-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	6.64E+00	5.07E-01	6.11E-01	4.08E-01	pCi/g
19-03019-09	TRG	19-02-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	4.87E+00	2.96E+00	2.97E+00	4.88E+00	pCi/g
19-03019-09	TRG	19-02-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	3.57E-01	1.25E-01	1.26E-01	1.63E-01	pCi/g
19-03019-10	TRG	20-17-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	1.38E+00	4.92E-01	4.97E-01	1.16E+00	pCi/g
19-03019-10	TRG	20-17-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	9.27E+00	8.25E-01	9.53E-01	5.46E-01	pCi/g
19-03019-10	TRG	20-17-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	4.52E-01	1.35E-01	1.37E-01	3.36E-01	pCi/g
19-03019-10	TRG	20-17-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	2.90E+01	5.47E+00	5.67E+00	3.19E+00	pCi/g
19-03019-10	TRG	20-17-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	1.34E+01	1.53E+01	1.53E+01	2.56E+01	pCi/g
19-03019-10	TRG	20-17-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	5.19E+00	2.18E+00	2.20E+00	3.50E+00	pCi/g
19-03019-10	TRG	20-17-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	1.55E+00	2.91E-01	3.01E-01	6.14E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical Final Report of Analysis	Report To:	Work Order Details:	
	Jeff Wright	SDG:	19-03019
	Weston Solutions, Inc.	Purchase Order:	0095131
	13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
	Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-03019-10	TRG	20-17-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	1.01E+01	7.70E-01	9.28E-01	5.60E-01	pCi/g
19-03019-10	TRG	20-17-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	9.27E+00	8.25E-01	9.53E-01	5.46E-01	pCi/g
19-03019-10	TRG	20-17-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	4.15E+00	2.97E+00	2.98E+00	4.76E+00	pCi/g
19-03019-10	TRG	20-17-31-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	1.48E+00	4.21E-01	4.28E-01	1.16E+00	pCi/g
19-03019-11	TRG	20-17-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	1.35E+00	3.77E-01	3.83E-01	7.54E-01	pCi/g
19-03019-11	TRG	20-17-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	9.46E+00	6.75E-01	8.32E-01	3.63E-01	pCi/g
19-03019-11	TRG	20-17-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	3.40E-01	9.48E-02	9.64E-02	1.96E-01	pCi/g
19-03019-11	TRG	20-17-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	2.38E+01	3.14E+00	3.37E+00	2.04E+00	pCi/g
19-03019-11	TRG	20-17-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	1.05E+01	8.70E+00	8.72E+00	1.46E+01	pCi/g
19-03019-11	TRG	20-17-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	6.57E+00	4.29E+00	4.30E+00	6.89E+00	pCi/g
19-03019-11	TRG	20-17-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	1.47E+00	2.36E-01	2.47E-01	5.08E-01	pCi/g
19-03019-11	TRG	20-17-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	1.06E+01	8.96E-01	1.05E+00	4.27E-01	pCi/g
19-03019-11	TRG	20-17-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	9.46E+00	6.75E-01	8.32E-01	3.63E-01	pCi/g
19-03019-11	TRG	20-17-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	4.65E+00	2.02E+00	2.04E+00	4.74E+00	pCi/g
19-03019-11	TRG	20-17-41-181130	11/30/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	8.97E-01	1.68E-01	1.74E-01	1.61E-01	pCi/g
19-03019-12	TRG	29-67-31-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	9.50E-01	5.21E-01	5.23E-01	9.85E-01	pCi/g
19-03019-12	TRG	29-67-31-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	7.92E+00	6.65E-01	7.79E-01	3.68E-01	pCi/g
19-03019-12	TRG	29-67-31-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	1.62E-01	1.29E-01	1.29E-01	1.94E-01	pCi/g
19-03019-12	TRG	29-67-31-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	1.60E+01	2.62E+00	2.74E+00	2.48E+00	pCi/g
19-03019-12	TRG	29-67-31-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	1.29E+01	1.24E+01	1.24E+01	2.04E+01	pCi/g
19-03019-12	TRG	29-67-31-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	6.87E+00	2.46E+00	2.48E+00	3.93E+00	pCi/g
19-03019-12	TRG	29-67-31-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	9.28E-01	2.21E-01	2.26E-01	4.02E-01	pCi/g
19-03019-12	TRG	29-67-31-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	7.73E+00	5.97E-01	7.17E-01	5.27E-01	pCi/g
19-03019-12	TRG	29-67-31-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	7.92E+00	6.65E-01	7.79E-01	3.68E-01	pCi/g
19-03019-12	TRG	29-67-31-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	1.49E+00	1.70E+00	1.70E+00	2.84E+00	pCi/g
19-03019-12	TRG	29-67-31-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	5.87E-01	2.08E-01	2.10E-01	1.74E-01	pCi/g
19-03019-13	TRG	29-67-41-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	8.56E-01	3.25E-01	3.28E-01	7.14E-01	pCi/g
19-03019-13	TRG	29-67-41-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	1.07E+01	7.54E-01	9.32E-01	4.97E-01	pCi/g
19-03019-13	TRG	29-67-41-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	5.03E-03	4.83E-02	4.83E-02	1.36E-01	pCi/g
19-03019-13	TRG	29-67-41-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	1.83E+01	2.36E+00	2.54E+00	2.04E+00	pCi/g
19-03019-13	TRG	29-67-41-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	-4.27E-01	8.23E+00	8.23E+00	1.21E+01	pCi/g
19-03019-13	TRG	29-67-41-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	5.89E+00	3.05E+00	3.07E+00	4.97E+00	pCi/g
19-03019-13	TRG	29-67-41-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	5.53E-01	2.33E-01	2.35E-01	3.41E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:

Jeff Wright
Weston Solutions, Inc.
13702 Coursey Blvd, Bldg 7 Suite A
Baton Rouge, LA 70817-1370

Work Order Details:

SDG:	**19-03019**
Purchase Order:	0095131
Analysis Category:	ENVIRONMENTAL
Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-03019-13	TRG	29-67-41-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	1.18E+01	8.65E-01	1.05E+00	6.52E-01	pCi/g
19-03019-13	TRG	29-67-41-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	1.07E+01	7.54E-01	9.32E-01	4.97E-01	pCi/g
19-03019-13	TRG	29-67-41-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	1.51E+00	2.07E+00	2.07E+00	3.29E+00	pCi/g
19-03019-13	TRG	29-67-41-181113	11/13/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	2.71E-01	1.10E-01	1.11E-01	1.52E-01	pCi/g
19-03019-14	TRG	32-85-31-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	1.26E+00	5.17E-01	5.21E-01	1.05E+00	pCi/g
19-03019-14	TRG	32-85-31-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	1.38E+01	1.08E+00	1.29E+00	4.34E-01	pCi/g
19-03019-14	TRG	32-85-31-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	-3.00E-03	7.76E-02	7.76E-02	1.96E-01	pCi/g
19-03019-14	TRG	32-85-31-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	2.91E+01	5.64E+00	5.84E+00	4.22E+00	pCi/g
19-03019-14	TRG	32-85-31-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	4.92E+00	1.22E+01	1.22E+01	1.96E+01	pCi/g
19-03019-14	TRG	32-85-31-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	6.75E+00	2.36E+00	2.39E+00	3.72E+00	pCi/g
19-03019-14	TRG	32-85-31-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	3.49E+00	4.87E-01	5.19E-01	5.38E-01	pCi/g
19-03019-14	TRG	32-85-31-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	1.46E+01	1.05E+00	1.29E+00	5.85E-01	pCi/g
19-03019-14	TRG	32-85-31-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	1.38E+01	1.08E+00	1.29E+00	4.34E-01	pCi/g
19-03019-14	TRG	32-85-31-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	6.86E-02	7.65E-01	7.65E-01	2.64E+00	pCi/g
19-03019-14	TRG	32-85-31-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	1.43E+00	5.08E-01	5.13E-01	8.02E-01	pCi/g
19-03019-15	TRG	32-85-41-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Actinium-228	EPA 901.1 Modified	1.54E+00	3.01E-01	3.11E-01	5.93E-01	pCi/g
19-03019-15	TRG	32-85-41-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Bismuth-214	EPA 901.1 Modified	1.27E+01	8.71E-01	1.09E+00	5.34E-01	pCi/g
19-03019-15	TRG	32-85-41-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Cesium-137	EPA 901.1 Modified	-8.35E-02	1.18E-01	1.18E-01	1.54E-01	pCi/g
19-03019-15	TRG	32-85-41-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Potassium-40	EPA 901.1 Modified	2.09E+01	2.85E+00	3.05E+00	2.11E+00	pCi/g
19-03019-15	TRG	32-85-41-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Protactinium-234m	EPA 901.1 Modified	-2.16E+00	8.83E+00	8.83E+00	1.27E+01	pCi/g
19-03019-15	TRG	32-85-41-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-210	EPA 901.1 Modified	1.94E+01	5.02E+00	5.12E+00	6.98E+00	pCi/g
19-03019-15	TRG	32-85-41-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-212	EPA 901.1 Modified	9.21E-02	2.86E-01	2.86E-01	3.54E-01	pCi/g
19-03019-15	TRG	32-85-41-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Lead-214	EPA 901.1 Modified	1.46E+01	1.18E+00	1.40E+00	4.57E-01	pCi/g
19-03019-15	TRG	32-85-41-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Radium-226	EPA 901.1 Modified	1.27E+01	8.71E-01	1.09E+00	5.34E-01	pCi/g
19-03019-15	TRG	32-85-41-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Thorium-234	EPA 901.1 Modified	1.89E+00	1.73E+00	1.73E+00	2.87E+00	pCi/g
19-03019-15	TRG	32-85-41-181012	10/12/18 00:00	3/7/2019	4/1/2019	19-03019	Thallium-208	EPA 901.1 Modified	9.67E-01	1.54E-01	1.62E-01	9.63E-02	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

1903019

MEMO

DATE: July 22, 2019

TO: Keith Delhomme, Robert Sherman

FROM: Rick Haaker RF Haaker

SUBJECT: Review of Gamma Spectroscopy Data Package, 1903019

Introduction

The file evaluated was 1903019.xlsx.

This package did not contain radiochemistry data. Only the gamma spec data was reviewed. All concentration units are in units of pCi/g, unless otherwise noted.

Conclusions

My impression is that the laboratory analyses are acceptable for use. Don't rely on the thorium-234 or protactinium-234m results.

Gamma Spectroscopy data review.

Summary

General factors		
Factor	Value	Comment
Number of ClientID	12	Number of distinct samples submitted
Number of Lab Duplicates	1	
Isotopes Detected in Method Blank	None	Good!
Performance of Duplicate	All values had acceptable duplicate error ratios, except Actinium-228	Not an isotope of interest. OK
Ra-226 pCi/g in Duplicate	~3.9	OK
Ra-226 pCi/g Range in Data Package	3< Ra226 < 14	
Ingrowth Days at Eberline	25	Should be 21 days or more; good!
% Difference between (Measured – True)/True for Cs-137 & Co-60 spike sample.	+11%	Lab control standard overestimated concentrations for Cs-137 and Co-60 by +11%.

The following samples were analyzed by gamma spectroscopy.

SampleID_Table		
ClientID	LabID	Sample Type
17-43-31-181130	19-03019-03	DUP
17-43-31-181130	19-03019-04	DO
17-43-41-181130	19-03019-05	TRG

1903019

SampleID_Table		
ClientID	LabID	Sample Type
19-01-31-181130	19-03019-06	TRG
19-01-41-181130	19-03019-07	TRG
19-02-31-181130	19-03019-08	TRG
19-02-41-181130	19-03019-09	TRG
20-17-31-181130	19-03019-10	TRG
20-17-41-181130	19-03019-11	TRG
29-67-31-181113	19-03019-12	TRG
29-67-41-181113	19-03019-13	TRG
32-85-31-181012	19-03019-14	TRG
32-85-41-181012	19-03019-15	TRG

The data was delivered in the usual Microsoft excel data format; it did not contain radiochemistry data.

Thorium-234 results were considerably more precise than protactinium-234m results. The protactinium-234m results should not by themselves be considered reliable. Lead-210 and Th-234 was reported as present at levels that exceed the minimum detectable activity in samples as follows. Results are in the units of pCi/g.

Detected_Pb210 & Th234				
ClientID	Method	Analyte	Results	MDAC
17-43-41-181130	EPA 901.1 Modified	Lead-210	3.73	2.91
19-02-31-181130	EPA 901.1 Modified	Lead-210	4.5	3.04
20-17-31-181130	EPA 901.1 Modified	Lead-210	5.19	3.5
29-67-31-181113	EPA 901.1 Modified	Lead-210	6.87	3.93
29-67-41-181113	EPA 901.1 Modified	Lead-210	5.89	4.97
32-85-31-181012	EPA 901.1 Modified	Lead-210	6.75	3.72
32-85-41-181012	EPA 901.1 Modified	Lead-210	19.37	6.98
17-43-31-181130	EPA 901.1 Modified	Thorium-234	2.87	2.63

Ignoring protactinium-234m, all other uranium decay chain analytes were detected in all samples except as follows:

NonDetects6					
ClientID	Analyte	Method	Result	MDAC	ReportUnits
29-67-31-181113	Actinium-228	EPA 901.1 Modified	0.95	0.9847	pCi/g
17-43-31-181130	Cesium-137	EPA 901.1 Modified	0.19	0.2027	pCi/g
19-02-31-181130	Cesium-137	EPA 901.1 Modified	0.3	0.3319	pCi/g
19-02-41-181130	Cesium-137	EPA 901.1 Modified	0.2	0.2833	pCi/g
29-67-31-181113	Cesium-137	EPA 901.1 Modified	0.16	0.194	pCi/g
29-67-41-181113	Cesium-137	EPA 901.1 Modified	0.01	0.1356	pCi/g
32-85-31-181012	Cesium-137	EPA 901.1 Modified	0	0.196	pCi/g

NonDetects6					
ClientID	Analyte	Method	Result	MDAC	ReportUnits
17-43-31-181130	Lead-210	EPA 901.1 Modified	3.5	3.5543	pCi/g
19-01-31-181130	Lead-210	EPA 901.1 Modified	1.83	2.5077	pCi/g
19-01-41-181130	Lead-210	EPA 901.1 Modified	5.38	6.7791	pCi/g
19-02-41-181130	Lead-210	EPA 901.1 Modified	3.33	4.2869	pCi/g
20-17-41-181130	Lead-210	EPA 901.1 Modified	6.57	6.8925	pCi/g
17-43-41-181130	Thorium-234	EPA 901.1 Modified	-0.19	2.1421	pCi/g
19-01-31-181130	Thorium-234	EPA 901.1 Modified	1.02	1.7484	pCi/g
19-01-41-181130	Thorium-234	EPA 901.1 Modified	3.04	4.1534	pCi/g
19-02-31-181130	Thorium-234	EPA 901.1 Modified	5.02	5.2226	pCi/g
19-02-41-181130	Thorium-234	EPA 901.1 Modified	4.87	4.8805	pCi/g
20-17-31-181130	Thorium-234	EPA 901.1 Modified	4.15	4.7588	pCi/g
20-17-41-181130	Thorium-234	EPA 901.1 Modified	4.65	4.738	pCi/g
29-67-31-181113	Thorium-234	EPA 901.1 Modified	1.49	2.841	pCi/g
29-67-41-181113	Thorium-234	EPA 901.1 Modified	1.51	3.2855	pCi/g
32-85-31-181012	Thorium-234	EPA 901.1 Modified	0.07	2.6428	pCi/g
32-85-41-181012	Thorium-234	EPA 901.1 Modified	1.89	2.8729	pCi/g

This Eberline data package reports radium-226 as equal to bismuth-214, the radium-226 being assigned from the bismuth-214 values.

The degree of agreement between thorium-234 and radium-226 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that the thorium-234 results might be seriously biased by systematic error. The test statistic is the number of standard deviations by which the thorium-234 result exceeds the radium-226 result. If the test statistic is substantially less than zero, it implies that the reported radium-226 concentration is greater than the thorium-234 concentration. Gamma spectroscopy cannot detect thorium-230 for all practical purposes, **so agreement between thorium-234 and radium-226 doesn't provide *any* information at all about equilibrium between thorium-230 and radium-226.**

EquilibriumTh234				
ClientID	Ra-226pCi/g	Thorium-234pCi/g	Test Statistic	Disequilibrium Evidence
17-43-31-181130	3.93	2.87	-1.27	Weak or none
17-43-31-181130	4.41	2.44	-1.49	Weak or none
17-43-41-181130	5.02	-0.19	-6.49	Strong
19-01-31-181130	3.36	1.02	-3.68	Strong
19-01-41-181130	4.45	3.04	-1.11	Weak or none
19-02-31-181130	6.41	5.02	-1.12	Weak or none
19-02-41-181130	6.64	4.87	-1.17	Weak or none
20-17-31-181130	9.27	4.15	-3.27	Strong
20-17-41-181130	9.46	4.65	-4.37	Strong
29-67-31-181113	7.92	1.49	-6.88	Strong

EquilibriumTh234				
ClientID	Ra-226pCi/g	Thorium-234pCi/g	Test Statistic	Disequilibrium Evidence
29-67-41-181113	10.66	1.51	-8.05	Strong
32-85-31-181012	13.79	0.07	-18.32	Strong
32-85-41-181012	12.67	1.89	-10.53	Strong

The degree of agreement between radium-226 and lead-210 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that there is no proficiency testing of radiochemistry laboratories for isotopes having gamma energies similar to those for lead-210. Lead-210 results by gamma spectroscopy are best thought of as estimates. The test statistic is the number of standard deviations by which the radium-226 result exceeds the lead-210 result. If the test statistic is substantially less than zero, it implies that the reported lead-210 concentration is greater than the radium-226 concentration. **Agreement between radium-226 and lead-210 doesn't provide *any* information about equilibrium between thorium-230 and radium-226.**

EquilibriumPb210				
ClientID	Ra-226pCi/g	Lead-210pCi/g	Test Statistic	Disequilibrium Evidence
17-43-31-181130	3.93	3.5	0.39	Weak or none
17-43-31-181130	4.41	2.44	1.96	Moderate
17-43-41-181130	5.02	3.73	1.34	Weak or none
19-01-31-181130	3.36	1.83	1.94	Weak or none
19-01-41-181130	4.45	5.38	-0.45	Weak or none
19-02-31-181130	6.41	4.5	1.89	Weak or none
19-02-41-181130	6.64	3.33	2.48	Moderate
20-17-31-181130	9.27	5.19	3.4	Strong
20-17-41-181130	9.46	6.57	1.32	Weak or none
29-67-31-181113	7.92	6.87	0.8	Weak or none
29-67-41-181113	10.66	5.89	2.98	Strong
32-85-31-181012	13.79	6.75	5.19	Strong
32-85-41-181012	12.67	19.37	-2.56	Moderate

The maximum and estimated 99%UCLs (assuming normal statistics) for nuisance radionuclides in pCi/g, based on all prior datasets reviewed to this point are:

Analyte	Maximum	UCL99%
Actinium-228	2.61	2.4
Lead-212	8.45	4.15
Potassium-40	40.54	35.36
Thallium-208	2.48	2.16
Thorium-228	5.93	5.11

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Analyte	Maximum	UCL99%
Thorium-232	5.96	5.1

It is good to keep in mind that around 10 – 15pCi/g potassium-40 looks like 1pCi/g of radium-226 to a 2x2 sodium iodide detector during field surveys.

Eberline Analytical **Final Report of Analysis**	Report To:	Work Order Details:	
	Jeff Wright	*SDG:*	**19-03020**
	Weston Solutions, Inc.	*Purchase Order:*	0095131
	13702 Coursey Blvd, Bldg 7 Suite A	*Analysis Category:*	ENVIRONMENTAL
	Baton Rouge, LA 70817-1370	*Sample Matrix:*	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-03020-01	LCS	KNOWN	03/07/19 00:00	3/7/2019	4/1/2019	19-03020	Cobalt-60	EPA 901.1 Modified	1.31E+02	5.10E+00			pCi/g
19-03020-01	LCS	KNOWN	03/07/19 00:00	3/7/2019	4/1/2019	19-03020	Cesium-137	EPA 901.1 Modified	8.26E+01	3.39E+00			pCi/g
19-03020-01	LCS	SPIKE	03/07/19 00:00	3/7/2019	4/1/2019	19-03020	Cobalt-60	EPA 901.1 Modified	1.45E+02	9.37E+00	1.20E+01	1.43E+00	pCi/g
19-03020-01	LCS	SPIKE	03/07/19 00:00	3/7/2019	4/1/2019	19-03020	Cesium-137	EPA 901.1 Modified	9.31E+01	1.02E+01	1.13E+01	1.56E+00	pCi/g
19-03020-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	6.00E-02	4.61E-02	4.62E-02	1.05E-01	pCi/g
19-03020-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	8.29E-02	4.31E-02	4.33E-02	3.93E-02	pCi/g
19-03020-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	1.14E-02	1.53E-02	1.53E-02	2.89E-02	pCi/g
19-03020-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	2.12E-01	1.50E-01	1.50E-01	3.67E-01	pCi/g
19-03020-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	1.98E+00	2.25E+00	2.25E+00	3.71E+00	pCi/g
19-03020-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	1.86E-01	3.76E-01	3.76E-01	6.43E-01	pCi/g
19-03020-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	3.26E-02	3.26E-02	3.27E-02	5.46E-02	pCi/g
19-03020-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	-3.05E-03	4.26E-02	4.26E-02	6.51E-02	pCi/g
19-03020-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	8.29E-02	4.31E-02	4.33E-02	3.93E-02	pCi/g
19-03020-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	6.78E-01	3.60E-01	3.62E-01	6.62E-01	pCi/g
19-03020-02	MBL	BLANK	03/07/19 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	1.89E-02	4.24E-02	4.24E-02	7.00E-02	pCi/g
19-03020-03	DUP	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	1.47E+00	3.84E-01	3.91E-01	7.56E-01	pCi/g
19-03020-03	DUP	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	1.29E+01	8.65E-01	1.09E+00	3.92E-01	pCi/g
19-03020-03	DUP	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	2.30E-01	8.30E-02	8.39E-02	2.39E-01	pCi/g
19-03020-03	DUP	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	2.24E+01	2.97E+00	3.19E+00	2.01E+00	pCi/g
19-03020-03	DUP	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	1.64E+00	9.86E+00	9.86E+00	1.47E+01	pCi/g
19-03020-03	DUP	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	1.69E+01	5.30E+00	5.37E+00	8.15E+00	pCi/g
19-03020-03	DUP	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	2.73E-01	2.96E-01	2.96E-01	3.74E-01	pCi/g
19-03020-03	DUP	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	1.48E+01	1.21E+00	1.43E+00	5.26E-01	pCi/g
19-03020-03	DUP	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	1.29E+01	8.65E-01	1.09E+00	3.92E-01	pCi/g
19-03020-03	DUP	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	3.08E+00	2.61E+00	2.62E+00	3.40E+00	pCi/g
19-03020-03	DUP	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	9.78E-01	1.80E-01	1.87E-01	1.87E-01	pCi/g
19-03020-04	DO	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	1.55E+00	3.58E-01	3.67E-01	6.61E-01	pCi/g
19-03020-04	DO	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	1.31E+01	8.72E-01	1.10E+00	3.74E-01	pCi/g
19-03020-04	DO	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	2.59E-01	8.99E-02	9.09E-02	2.35E-01	pCi/g
19-03020-04	DO	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	2.37E+01	3.17E+00	3.39E+00	2.33E+00	pCi/g
19-03020-04	DO	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	4.72E+00	9.92E+00	9.92E+00	1.53E+01	pCi/g
19-03020-04	DO	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	2.03E+01	5.19E+00	5.30E+00	7.11E+00	pCi/g
19-03020-04	DO	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	1.89E+00	3.68E-01	3.81E-01	5.83E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	19-03020
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-03020-04	DO	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	1.52E+01	1.24E+00	1.46E+00	4.46E-01	pCi/g
19-03020-04	DO	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	1.31E+01	8.72E-01	1.10E+00	3.74E-01	pCi/g
19-03020-04	DO	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	1.89E+00	2.66E+00	2.66E+00	3.43E+00	pCi/g
19-03020-04	DO	32-86-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	8.93E-01	1.65E-01	1.71E-01	2.17E-01	pCi/g
19-03020-05	TRG	32-86-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	2.28E+00	6.18E-01	6.29E-01	1.17E+00	pCi/g
19-03020-05	TRG	32-86-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	1.16E+01	9.64E-01	1.13E+00	6.13E-01	pCi/g
19-03020-05	TRG	32-86-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	2.25E-01	1.35E-01	1.36E-01	2.24E-01	pCi/g
19-03020-05	TRG	32-86-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	3.17E+01	5.75E+00	5.97E+00	3.55E+00	pCi/g
19-03020-05	TRG	32-86-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	1.02E+01	1.21E+01	1.21E+01	2.02E+01	pCi/g
19-03020-05	TRG	32-86-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	5.96E+00	2.33E+00	2.35E+00	3.71E+00	pCi/g
19-03020-05	TRG	32-86-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	1.79E+00	3.38E-01	3.50E-01	6.61E-01	pCi/g
19-03020-05	TRG	32-86-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	1.20E+01	8.89E-01	1.08E+00	6.63E-01	pCi/g
19-03020-05	TRG	32-86-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	1.16E+01	9.64E-01	1.13E+00	6.13E-01	pCi/g
19-03020-05	TRG	32-86-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	1.79E+00	1.64E+00	1.64E+00	2.67E+00	pCi/g
19-03020-05	TRG	32-86-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	1.36E+00	5.29E-01	5.34E-01	2.31E-01	pCi/g
19-03020-06	TRG	32-87-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	1.53E+00	4.75E-01	4.81E-01	8.66E-01	pCi/g
19-03020-06	TRG	32-87-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	9.74E+00	8.44E-01	9.81E-01	7.41E-01	pCi/g
19-03020-06	TRG	32-87-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	4.40E-01	1.58E-01	1.60E-01	4.04E-01	pCi/g
19-03020-06	TRG	32-87-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	2.26E+01	3.79E+00	3.97E+00	3.98E+00	pCi/g
19-03020-06	TRG	32-87-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	2.79E+01	1.60E+01	1.61E+01	2.85E+01	pCi/g
19-03020-06	TRG	32-87-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	5.74E+00	2.26E+00	2.28E+00	3.62E+00	pCi/g
19-03020-06	TRG	32-87-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	1.66E+00	2.77E-01	2.90E-01	7.36E-01	pCi/g
19-03020-06	TRG	32-87-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	1.04E+01	7.77E-01	9.43E-01	7.08E-01	pCi/g
19-03020-06	TRG	32-87-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	9.74E+00	8.44E-01	9.81E-01	7.41E-01	pCi/g
19-03020-06	TRG	32-87-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	2.40E+00	2.16E+00	2.17E+00	3.60E+00	pCi/g
19-03020-06	TRG	32-87-31-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	1.41E+00	3.46E-01	3.54E-01	3.85E-01	pCi/g
19-03020-07	TRG	32-87-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	1.56E+00	3.59E-01	3.67E-01	6.95E-01	pCi/g
19-03020-07	TRG	32-87-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	9.11E+00	6.60E-01	8.08E-01	4.80E-01	pCi/g
19-03020-07	TRG	32-87-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	4.86E-01	1.65E-01	1.67E-01	2.48E-01	pCi/g
19-03020-07	TRG	32-87-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	2.50E+01	3.06E+00	3.31E+00	2.42E+00	pCi/g
19-03020-07	TRG	32-87-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	7.13E+00	7.87E+00	7.88E+00	1.28E+01	pCi/g
19-03020-07	TRG	32-87-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	8.60E+00	2.91E+00	2.95E+00	4.52E+00	pCi/g
19-03020-07	TRG	32-87-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	1.49E+00	2.53E-01	2.64E-01	4.88E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	
Jeff Wright	
Weston Solutions, Inc.	
13702 Coursey Blvd, Bldg 7 Suite A	
Baton Rouge, LA 70817-1370	

Work Order Details:	
SDG:	19-03020
Purchase Order:	0095131
Analysis Category:	ENVIRONMENTAL
Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-03020-07	TRG	32-87-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	9.31E+00	7.06E-01	8.52E-01	5.27E-01	pCi/g
19-03020-07	TRG	32-87-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	9.11E+00	6.60E-01	8.08E-01	4.80E-01	pCi/g
19-03020-07	TRG	32-87-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	4.59E+00	3.45E+00	3.46E+00	5.73E+00	pCi/g
19-03020-07	TRG	32-87-41-181012	10/12/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	1.20E+00	2.38E-01	2.46E-01	3.00E-01	pCi/g
19-03020-08	TRG	33-63-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	1.62E+00	4.21E-01	4.30E-01	8.48E-01	pCi/g
19-03020-08	TRG	33-63-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	7.45E+00	6.68E-01	7.70E-01	5.04E-01	pCi/g
19-03020-08	TRG	33-63-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	2.84E-01	1.15E-01	1.16E-01	2.64E-01	pCi/g
19-03020-08	TRG	33-63-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	2.76E+01	5.26E+00	5.44E+00	3.35E+00	pCi/g
19-03020-08	TRG	33-63-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	5.93E-01	1.07E+01	1.07E+01	1.70E+01	pCi/g
19-03020-08	TRG	33-63-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	3.79E+00	2.25E+00	2.26E+00	3.68E+00	pCi/g
19-03020-08	TRG	33-63-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	9.56E-01	2.52E-01	2.57E-01	4.72E-01	pCi/g
19-03020-08	TRG	33-63-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	7.64E+00	6.20E-01	7.34E-01	5.18E-01	pCi/g
19-03020-08	TRG	33-63-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	7.45E+00	6.68E-01	7.70E-01	5.04E-01	pCi/g
19-03020-08	TRG	33-63-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	2.92E+00	2.12E+00	2.12E+00	3.52E+00	pCi/g
19-03020-08	TRG	33-63-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	1.35E+00	3.97E-01	4.03E-01	5.89E-01	pCi/g
19-03020-09	TRG	33-63-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	9.16E-01	5.10E-01	5.12E-01	8.83E-01	pCi/g
19-03020-09	TRG	33-63-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	9.05E+00	7.46E-01	8.79E-01	4.00E-01	pCi/g
19-03020-09	TRG	33-63-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	3.53E-01	1.72E-01	1.73E-01	3.22E-01	pCi/g
19-03020-09	TRG	33-63-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	1.99E+01	3.00E+00	3.17E+00	2.52E+00	pCi/g
19-03020-09	TRG	33-63-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	9.59E+00	1.35E+01	1.35E+01	2.25E+01	pCi/g
19-03020-09	TRG	33-63-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	5.15E+00	1.89E+00	1.90E+00	3.00E+00	pCi/g
19-03020-09	TRG	33-63-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	1.06E+00	2.60E-01	2.66E-01	5.15E-01	pCi/g
19-03020-09	TRG	33-63-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	8.81E+00	6.61E-01	8.01E-01	5.91E-01	pCi/g
19-03020-09	TRG	33-63-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	9.05E+00	7.46E-01	8.79E-01	4.00E-01	pCi/g
19-03020-09	TRG	33-63-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	2.05E+00	2.11E+00	2.12E+00	3.08E+00	pCi/g
19-03020-09	TRG	33-63-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	9.66E-01	2.60E-01	2.65E-01	1.89E-01	pCi/g
19-03020-10	TRG	33-64-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	1.42E+00	3.47E-01	3.54E-01	7.57E-01	pCi/g
19-03020-10	TRG	33-64-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	6.90E+00	5.24E-01	6.33E-01	4.76E-01	pCi/g
19-03020-10	TRG	33-64-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	2.13E-02	8.38E-02	8.38E-02	1.25E-01	pCi/g
19-03020-10	TRG	33-64-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	2.23E+01	2.78E+00	3.00E+00	2.37E+00	pCi/g
19-03020-10	TRG	33-64-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	6.10E+00	7.10E+00	7.11E+00	1.15E+01	pCi/g
19-03020-10	TRG	33-64-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	4.09E+00	2.39E+00	2.40E+00	4.21E+00	pCi/g
19-03020-10	TRG	33-64-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	1.67E+00	2.24E-01	2.40E-01	3.91E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical Final Report of Analysis	Report To:	Work Order Details:	
	Jeff Wright	SDG:	19-03020
	Weston Solutions, Inc.	Purchase Order:	0095131
	13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
	Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-03020-10	TRG	33-64-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	7.73E+00	6.05E-01	7.23E-01	5.04E-01	pCi/g
19-03020-10	TRG	33-64-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	6.90E+00	5.24E-01	6.33E-01	4.76E-01	pCi/g
19-03020-10	TRG	33-64-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	2.31E+00	2.50E+00	2.50E+00	4.17E+00	pCi/g
19-03020-10	TRG	33-64-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	1.43E+00	2.24E-01	2.35E-01	1.07E-01	pCi/g
19-03020-11	TRG	33-64-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	1.27E+00	3.08E-01	3.15E-01	6.02E-01	pCi/g
19-03020-11	TRG	33-64-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	5.92E+00	4.82E-01	5.70E-01	3.06E-01	pCi/g
19-03020-11	TRG	33-64-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	-5.02E-02	9.12E-02	9.13E-02	1.27E-01	pCi/g
19-03020-11	TRG	33-64-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	2.38E+01	3.02E+00	3.26E+00	1.45E+00	pCi/g
19-03020-11	TRG	33-64-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	5.95E+00	8.16E+00	8.16E+00	1.33E+01	pCi/g
19-03020-11	TRG	33-64-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	5.65E+00	3.59E+00	3.60E+00	5.74E+00	pCi/g
19-03020-11	TRG	33-64-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	7.80E-01	1.93E-01	1.98E-01	3.72E-01	pCi/g
19-03020-11	TRG	33-64-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	6.42E+00	5.77E-01	6.64E-01	3.36E-01	pCi/g
19-03020-11	TRG	33-64-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	5.92E+00	4.82E-01	5.70E-01	3.06E-01	pCi/g
19-03020-11	TRG	33-64-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	2.21E+00	2.08E+00	2.08E+00	3.45E+00	pCi/g
19-03020-11	TRG	33-64-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	9.85E-01	1.57E-01	1.65E-01	1.53E-01	pCi/g
19-03020-12	TRG	33-65-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	8.30E-01	2.93E-01	2.96E-01	5.63E-01	pCi/g
19-03020-12	TRG	33-65-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	5.76E+00	5.29E-01	6.06E-01	3.65E-01	pCi/g
19-03020-12	TRG	33-65-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	1.96E-01	9.86E-02	9.91E-02	1.55E-01	pCi/g
19-03020-12	TRG	33-65-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	2.44E+01	4.56E+00	4.73E+00	2.59E+00	pCi/g
19-03020-12	TRG	33-65-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	-3.25E+00	8.88E+00	8.88E+00	1.35E+01	pCi/g
19-03020-12	TRG	33-65-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	3.36E+00	1.46E+00	1.47E+00	2.33E+00	pCi/g
19-03020-12	TRG	33-65-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	8.04E-01	2.12E-01	2.16E-01	4.07E-01	pCi/g
19-03020-12	TRG	33-65-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	5.73E+00	4.73E-01	5.57E-01	4.72E-01	pCi/g
19-03020-12	TRG	33-65-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	5.76E+00	5.29E-01	6.06E-01	3.65E-01	pCi/g
19-03020-12	TRG	33-65-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	3.87E-01	1.23E+00	1.23E+00	1.76E+00	pCi/g
19-03020-12	TRG	33-65-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	8.44E-01	3.48E-01	3.51E-01	1.86E-01	pCi/g
19-03020-13	TRG	33-65-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	1.05E+00	3.59E-01	3.63E-01	6.82E-01	pCi/g
19-03020-13	TRG	33-65-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	3.92E+00	4.30E-01	4.75E-01	3.98E-01	pCi/g
19-03020-13	TRG	33-65-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	1.29E-01	1.15E-01	1.15E-01	1.76E-01	pCi/g
19-03020-13	TRG	33-65-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	1.97E+01	2.83E+00	3.00E+00	2.00E+00	pCi/g
19-03020-13	TRG	33-65-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	8.89E-01	9.97E+00	9.97E+00	1.61E+01	pCi/g
19-03020-13	TRG	33-65-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	2.33E+00	1.30E+00	1.30E+00	2.11E+00	pCi/g
19-03020-13	TRG	33-65-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	9.00E-01	1.70E-01	1.76E-01	3.60E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	19-03020
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-03020-13	TRG	33-65-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	4.06E+00	3.64E-01	4.20E-01	7.65E-01	pCi/g
19-03020-13	TRG	33-65-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	3.92E+00	4.30E-01	4.75E-01	3.98E-01	pCi/g
19-03020-13	TRG	33-65-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	1.42E+00	1.54E+00	1.54E+00	2.28E+00	pCi/g
19-03020-13	TRG	33-65-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	6.61E-01	2.13E-01	2.16E-01	1.82E-01	pCi/g
19-03020-14	TRG	33-66-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	7.35E-01	2.60E-01	2.63E-01	5.10E-01	pCi/g
19-03020-14	TRG	33-66-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	4.69E+00	3.88E-01	4.56E-01	3.28E-01	pCi/g
19-03020-14	TRG	33-66-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	2.79E-01	9.43E-02	9.54E-02	1.82E-01	pCi/g
19-03020-14	TRG	33-66-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	1.34E+01	1.76E+00	1.89E+00	1.34E+00	pCi/g
19-03020-14	TRG	33-66-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	6.12E+00	4.87E+00	4.88E+00	8.55E+00	pCi/g
19-03020-14	TRG	33-66-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	4.11E+00	2.26E+00	2.27E+00	3.67E+00	pCi/g
19-03020-14	TRG	33-66-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	1.67E+00	2.58E-01	2.72E-01	3.24E-01	pCi/g
19-03020-14	TRG	33-66-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	4.66E+00	4.15E-01	4.79E-01	4.12E-01	pCi/g
19-03020-14	TRG	33-66-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	4.69E+00	3.88E-01	4.56E-01	3.28E-01	pCi/g
19-03020-14	TRG	33-66-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	5.39E+00	2.80E+00	2.81E+00	4.59E+00	pCi/g
19-03020-14	TRG	33-66-31-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	7.96E-01	1.69E-01	1.74E-01	1.00E-01	pCi/g
19-03020-15	TRG	33-66-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Actinium-228	EPA 901.1 Modified	7.69E-01	2.21E-01	2.24E-01	4.49E-01	pCi/g
19-03020-15	TRG	33-66-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Bismuth-214	EPA 901.1 Modified	4.24E+00	3.45E-01	4.08E-01	2.48E-01	pCi/g
19-03020-15	TRG	33-66-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Cesium-137	EPA 901.1 Modified	2.37E-01	9.29E-02	9.37E-02	1.38E-01	pCi/g
19-03020-15	TRG	33-66-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Potassium-40	EPA 901.1 Modified	1.60E+01	2.10E+00	2.26E+00	1.42E+00	pCi/g
19-03020-15	TRG	33-66-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Protactinium-234m	EPA 901.1 Modified	7.81E+00	6.43E+00	6.44E+00	1.04E+01	pCi/g
19-03020-15	TRG	33-66-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-210	EPA 901.1 Modified	5.55E+00	3.25E+00	3.27E+00	5.17E+00	pCi/g
19-03020-15	TRG	33-66-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-212	EPA 901.1 Modified	6.31E-01	1.35E-01	1.39E-01	3.07E-01	pCi/g
19-03020-15	TRG	33-66-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Lead-214	EPA 901.1 Modified	4.57E+00	4.08E-01	4.71E-01	2.57E-01	pCi/g
19-03020-15	TRG	33-66-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Radium-226	EPA 901.1 Modified	4.24E+00	3.45E-01	4.08E-01	2.48E-01	pCi/g
19-03020-15	TRG	33-66-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thorium-234	EPA 901.1 Modified	-5.09E-01	1.67E+00	1.67E+00	2.10E+00	pCi/g
19-03020-15	TRG	33-66-41-181201	12/01/18 00:00	3/7/2019	4/2/2019	19-03020	Thallium-208	EPA 901.1 Modified	4.84E-01	1.21E-01	1.23E-01	1.20E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

MEMO

DATE: July 22, 2019

TO: Keith Delhomme, Robert Sherman

FROM: Rick Haaker RF Haaker

SUBJECT: Review of Gamma Spectroscopy Data Package, 1903020

Introduction

The file evaluated was 1903020.xlsx.

This package did not contain radiochemistry data. Only the gamma spec data was reviewed. All concentration units are in units of pCi/g, unless otherwise noted.

Conclusions

My impression is that the laboratory analyses are acceptable for use. Don't rely on the thorium-234 or protactinium-234m results. Use data with caution for purposes of characterizing variations in background.

Gamma Spectroscopy data review.

Summary

General factors		
Factor	Value	Comment
Number of ClientID	12	Number of distinct samples submitted
Number of Lab Duplicates	1	
Isotopes Detected in Method Blank	Th-234, Radium-226/Bi-214	Consider more uncertain than usual and to have a positive bias when results are less than 3.5, 0.45, 0.45 pCi/g. Th-234 is usually a poorly quantified result by gamma spectroscopy.
Performance of Duplicate	All values had acceptable duplicate error ratios, except Lead-212	Not an isotope of interest. OK
Ra-226 pCi/g in Duplicate	~13	OK
Ra-226 pCi/g Range in Data Package	3< Ra226 < 13	
Ingrowth Days at Eberline	25-26	Should be 21 days or more; good!
% Difference between (Measured – True)/True for Cs-137 & Co-60 spike sample.	+10%	Lab control standard overestimated concentrations for Cs-137 and Co-60 by +10%.

The following samples were analyzed by gamma spectroscopy.

SampleID_Table		
ClientID	**LabID**	**Sample Type**
32-86-31-181012	19-03020-03	DUP

1903020

SampleID_Table		
ClientID	LabID	Sample Type
32-86-31-181012	19-03020-04	DO
32-86-41-181012	19-03020-05	TRG
32-87-31-181012	19-03020-06	TRG
32-87-41-181012	19-03020-07	TRG
33-63-31-181201	19-03020-08	TRG
33-63-41-181201	19-03020-09	TRG
33-64-31-181201	19-03020-10	TRG
33-64-41-181201	19-03020-11	TRG
33-65-31-181201	19-03020-12	TRG
33-65-41-181201	19-03020-13	TRG
33-66-31-181201	19-03020-14	TRG
33-66-41-181201	19-03020-15	TRG

The data was delivered in the usual Microsoft excel data format; it did not contain radiochemistry data.

Thorium-234 results were considerably more precise than protactinium-234m results. The protactinium-234m results should not by themselves be considered reliable. Lead-210 and Th-234 was reported as present at levels that exceed the minimum detectable activity in samples as follows. Results are in the units of pCi/g.

Detected Pb210 & Th234				
ClientID	Method	Analyte	Results	MDAC
32-86-31-181012	EPA 901.1 Modified	Lead-210	16.92	8.15
32-86-41-181012	EPA 901.1 Modified	Lead-210	5.96	3.71
32-87-31-181012	EPA 901.1 Modified	Lead-210	5.74	3.62
32-87-41-181012	EPA 901.1 Modified	Lead-210	8.6	4.52
33-63-31-181201	EPA 901.1 Modified	Lead-210	3.79	3.68
33-63-41-181201	EPA 901.1 Modified	Lead-210	5.15	3
33-65-31-181201	EPA 901.1 Modified	Lead-210	3.36	2.33
33-65-41-181201	EPA 901.1 Modified	Lead-210	2.33	2.11
33-66-31-181201	EPA 901.1 Modified	Lead-210	4.11	3.67
33-66-41-181201	EPA 901.1 Modified	Lead-210	5.55	5.17
33-66-31-181201	EPA 901.1 Modified	Thorium-234	5.39	4.59

Ignoring protactinium-234m, all other uranium decay chain analytes were detected in all samples except as follows:

NonDetects					
ClientID	Analyte	Method	Result	MDAC	ReportUnits
32-86-31-181012	Cesium-137	EPA 901.1 Modified	0.23	0.2395	pCi/g
33-64-31-181201	Cesium-137	EPA 901.1 Modified	0.02	0.1246	pCi/g

NonDetects					
ClientID	Analyte	Method	Result	MDAC	ReportUnits
33-64-31-181201	Lead-210	EPA 901.1 Modified	4.09	4.2056	pCi/g
33-64-41-181201	Lead-210	EPA 901.1 Modified	5.65	5.7412	pCi/g
32-86-31-181012	Thorium-234	EPA 901.1 Modified	3.08	3.404	pCi/g
32-86-41-181012	Thorium-234	EPA 901.1 Modified	1.79	2.6678	pCi/g
32-87-31-181012	Thorium-234	EPA 901.1 Modified	2.4	3.6044	pCi/g
32-87-41-181012	Thorium-234	EPA 901.1 Modified	4.59	5.7283	pCi/g
33-63-31-181201	Thorium-234	EPA 901.1 Modified	2.92	3.5178	pCi/g
33-63-41-181201	Thorium-234	EPA 901.1 Modified	2.05	3.0781	pCi/g
33-64-31-181201	Thorium-234	EPA 901.1 Modified	2.31	4.1726	pCi/g
33-64-41-181201	Thorium-234	EPA 901.1 Modified	2.21	3.4478	pCi/g
33-65-31-181201	Thorium-234	EPA 901.1 Modified	0.39	1.7649	pCi/g
33-65-41-181201	Thorium-234	EPA 901.1 Modified	1.42	2.2768	pCi/g
33-66-41-181201	Thorium-234	EPA 901.1 Modified	-0.51	2.0953	pCi/g

This Eberline data package reports radium-226 as equal to bismuth-214, the radium-226 being assigned from the bismuth-214 values.

The degree of agreement between thorium-234 and radium-226 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that the thorium-234 results might be seriously biased by systematic error. The test statistic is the number of standard deviations by which the thorium-234 result exceeds the radium-226 result. If the test statistic is substantially less than zero, it implies that the reported radium-226 concentration is greater than the thorium-234 concentration. Gamma spectroscopy cannot detect thorium-230 for all practical purposes, **so agreement between thorium-234 and radium-226 doesn't provide *any* information at all about equilibrium between thorium-230 and radium-226.**

"Equilibrium" Th234 → Ra-226				
ClientID	Ra-226pCi/g	Thorium-234pCi/g	Test Statistic	Disequilibrium Evidence
32-87-31-181012	9.74	2.4	-6.17	Strong
32-86-31-181012	12.88	3.08	-6.91	Strong
32-86-31-181012	13.15	1.89	-7.83	Strong
32-86-41-181012	11.59	1.79	-9.84	Strong
32-87-41-181012	9.11	4.59	-2.55	Moderate
33-63-31-181201	7.45	2.92	-4.01	Strong
33-63-41-181201	9.05	2.05	-6.11	Strong
33-64-31-181201	6.9	2.31	-3.56	Strong
33-64-41-181201	5.92	2.21	-3.44	Strong
33-65-31-181201	5.76	0.39	-7.85	Strong
33-65-41-181201	3.92	1.42	-3.1	Strong
33-66-31-181201	4.69	5.39	0.49	Weak or none
33-66-41-181201	4.24	-0.51	-5.54	Strong

The degree of agreement between radium-226 and lead-210 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that there is no proficiency testing of radiochemistry laboratories for isotopes having gamma energies similar to those for lead-210. Lead-210 results by gamma spectroscopy are best thought of as estimates. The test statistic is the number of standard deviations by which the radium-226 result exceeds the lead-210 result. If the test statistic is substantially less than zero, it implies that the reported lead-210 concentration is greater than the radium-226 concentration. **Agreement between radium-226 and lead-210 doesn't provide *any* information about equilibrium between thorium-230 and radium-226.**

EquilibriumPb210				
ClientID	Ra-226pCi/g	Lead-210pCi/g	Test Statistic	Disequilibrium Evidence
32-87-31-181012	9.74	5.74	3.22	Strong
32-87-41-181012	9.11	8.6	0.34	Weak or none
32-86-31-181012	12.88	16.92	-1.47	Weak or none
32-86-31-181012	13.15	20.28	-2.64	Strong
32-86-41-181012	11.59	5.96	4.31	Strong
33-63-31-181201	7.45	3.79	3.07	Strong
33-63-41-181201	9.05	5.15	3.72	Strong
33-64-31-181201	6.9	4.09	2.27	Moderate
33-64-41-181201	5.92	5.65	0.15	Weak or none
33-65-31-181201	5.76	3.36	3.02	Strong
33-65-41-181201	3.92	2.33	2.3	Moderate
33-66-31-181201	4.69	4.11	0.51	Weak or none
33-66-41-181201	4.24	5.55	-0.79	Weak or none

The maximum and estimated 99%UCLs (assuming normal statistics) for nuisance radionuclides in pCi/g, based on all prior datasets reviewed to this point are:

Analyte	Maximum	UCL99%
Actinium-228	2.61	2.41
Lead-212	8.45	4.17
Potassium-40	40.54	35.27
Thallium-208	2.48	2.17
Thorium-228	5.93	5.11
Thorium-232	5.96	5.1

It is good to keep in mind that around 10 – 15pCi/g potassium-40 looks like 1pCi/g of radium-226 to a 2x2 sodium iodide detector during field surveys.

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	19-04106
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-04106-01	LCS	KNOWN	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Cobalt-60	EPA 901.1 Modified	1.31E+02	5.10E+00			pCi/g
19-04106-01	LCS	KNOWN	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Cesium-137	EPA 901.1 Modified	8.26E+01	3.39E+00			pCi/g
19-04106-01	LCS	SPIKE	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Cobalt-60	EPA 901.1 Modified	1.41E+02	1.02E+01	1.25E+01	8.84E-01	pCi/g
19-04106-01	LCS	SPIKE	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Cesium-137	EPA 901.1 Modified	8.39E+01	9.19E+00	1.02E+01	1.05E+00	pCi/g
19-04106-02	MBL	BLANK	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Actinium-228	EPA 901.1 Modified	-7.41E-03	6.74E-02	6.74E-02	1.18E-01	pCi/g
19-04106-02	MBL	BLANK	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Bismuth-214	EPA 901.1 Modified	3.37E-02	5.42E-02	5.42E-02	8.88E-02	pCi/g
19-04106-02	MBL	BLANK	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Potassium-40	EPA 901.1 Modified	3.88E-02	2.40E-01	2.40E-01	4.67E-01	pCi/g
19-04106-02	MBL	BLANK	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Protactinium-234m	EPA 901.1 Modified	7.49E-01	2.82E+00	2.83E+00	5.18E+00	pCi/g
19-04106-02	MBL	BLANK	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Lead-210	EPA 901.1 Modified	3.82E-01	3.22E-01	3.23E-01	5.27E-01	pCi/g
19-04106-02	MBL	BLANK	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Lead-212	EPA 901.1 Modified	1.68E-02	3.18E-02	3.18E-02	5.21E-02	pCi/g
19-04106-02	MBL	BLANK	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Lead-214	EPA 901.1 Modified	5.22E-02	4.72E-02	4.73E-02	9.15E-02	pCi/g
19-04106-02	MBL	BLANK	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Radium-226	EPA 901.1 Modified	3.37E-02	5.42E-02	5.42E-02	8.88E-02	pCi/g
19-04106-02	MBL	BLANK	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Thorium-234	EPA 901.1 Modified	4.95E-01	2.58E-01	2.60E-01	4.47E-01	pCi/g
19-04106-02	MBL	BLANK	04/22/19 00:00	4/22/2019	5/14/2019	19-04106	Thallium-208	EPA 901.1 Modified	6.32E-03	7.76E-02	7.76E-02	1.16E-01	pCi/g
19-04106-03	DUP	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Actinium-228	EPA 901.1 Modified	1.05E+00	2.11E-01	2.17E-01	3.64E-01	pCi/g
19-04106-03	DUP	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Bismuth-214	EPA 901.1 Modified	1.65E+00	2.04E-01	2.21E-01	2.65E-01	pCi/g
19-04106-03	DUP	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Potassium-40	EPA 901.1 Modified	1.84E+01	2.24E+00	2.43E+00	1.46E+00	pCi/g
19-04106-03	DUP	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Protactinium-234m	EPA 901.1 Modified	3.28E+00	5.05E+00	5.06E+00	8.42E+00	pCi/g
19-04106-03	DUP	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Lead-210	EPA 901.1 Modified	1.86E+00	1.45E+00	1.45E+00	3.01E+00	pCi/g
19-04106-03	DUP	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Lead-212	EPA 901.1 Modified	9.08E-01	1.76E-01	1.82E-01	3.21E-01	pCi/g
19-04106-03	DUP	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Lead-214	EPA 901.1 Modified	1.80E+00	2.14E-01	2.33E-01	2.57E-01	pCi/g
19-04106-03	DUP	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Radium-226	EPA 901.1 Modified	1.65E+00	2.04E-01	2.21E-01	2.65E-01	pCi/g
19-04106-03	DUP	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Thorium-234	EPA 901.1 Modified	3.07E+00	2.26E+00	2.27E+00	3.75E+00	pCi/g
19-04106-03	DUP	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Thallium-208	EPA 901.1 Modified	8.25E-01	1.50E-01	1.56E-01	1.57E-01	pCi/g
19-04106-04	DO	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Actinium-228	EPA 901.1 Modified	9.93E-01	2.41E-01	2.46E-01	3.93E-01	pCi/g
19-04106-04	DO	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Bismuth-214	EPA 901.1 Modified	1.77E+00	2.13E-01	2.31E-01	2.68E-01	pCi/g
19-04106-04	DO	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Potassium-40	EPA 901.1 Modified	1.65E+01	2.23E+00	2.39E+00	2.01E+00	pCi/g
19-04106-04	DO	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Protactinium-234m	EPA 901.1 Modified	-1.50E+00	5.15E+00	5.15E+00	7.60E+00	pCi/g
19-04106-04	DO	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Lead-210	EPA 901.1 Modified	9.69E-01	1.18E+00	1.18E+00	1.94E+00	pCi/g
19-04106-04	DO	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Lead-212	EPA 901.1 Modified	1.07E+00	1.76E-01	1.85E-01	2.92E-01	pCi/g
19-04106-04	DO	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Lead-214	EPA 901.1 Modified	1.83E+00	2.22E-01	2.41E-01	3.39E-01	pCi/g
19-04106-04	DO	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Radium-226	EPA 901.1 Modified	1.77E+00	2.13E-01	2.31E-01	2.68E-01	pCi/g
19-04106-04	DO	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Thorium-234	EPA 901.1 Modified	1.85E+00	1.18E+00	1.19E+00	1.95E+00	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	19-04106
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-04106-04	DO	17-44-31-190416	04/16/19 11:08	4/22/2019	5/15/2019	19-04106	Thallium-208	EPA 901.1 Modified	5.26E-01	1.63E-01	1.65E-01	1.69E-01	pCi/g
19-04106-05	TRG	17-44-41-190416	04/16/19 11:10	4/22/2019	5/15/2019	19-04106	Actinium-228	EPA 901.1 Modified	9.48E-01	2.27E-01	2.32E-01	3.80E-01	pCi/g
19-04106-05	TRG	17-44-41-190416	04/16/19 11:10	4/22/2019	5/15/2019	19-04106	Bismuth-214	EPA 901.1 Modified	1.41E+00	1.83E-01	1.97E-01	1.91E-01	pCi/g
19-04106-05	TRG	17-44-41-190416	04/16/19 11:10	4/22/2019	5/15/2019	19-04106	Potassium-40	EPA 901.1 Modified	1.71E+01	2.27E+00	2.43E+00	1.05E+00	pCi/g
19-04106-05	TRG	17-44-41-190416	04/16/19 11:10	4/22/2019	5/15/2019	19-04106	Protactinium-234m	EPA 901.1 Modified	-2.56E+00	5.46E+00	5.46E+00	7.88E+00	pCi/g
19-04106-05	TRG	17-44-41-190416	04/16/19 11:10	4/22/2019	5/15/2019	19-04106	Lead-210	EPA 901.1 Modified	3.29E+00	2.22E+00	2.22E+00	3.55E+00	pCi/g
19-04106-05	TRG	17-44-41-190416	04/16/19 11:10	4/22/2019	5/15/2019	19-04106	Lead-212	EPA 901.1 Modified	1.01E+00	1.58E-01	1.66E-01	3.41E-01	pCi/g
19-04106-05	TRG	17-44-41-190416	04/16/19 11:10	4/22/2019	5/15/2019	19-04106	Lead-214	EPA 901.1 Modified	1.53E+00	2.09E-01	2.24E-01	2.09E-01	pCi/g
19-04106-05	TRG	17-44-41-190416	04/16/19 11:10	4/22/2019	5/15/2019	19-04106	Radium-226	EPA 901.1 Modified	1.41E+00	1.83E-01	1.97E-01	1.91E-01	pCi/g
19-04106-05	TRG	17-44-41-190416	04/16/19 11:10	4/22/2019	5/15/2019	19-04106	Thorium-234	EPA 901.1 Modified	1.42E+00	1.33E+00	1.33E+00	1.80E+00	pCi/g
19-04106-05	TRG	17-44-41-190416	04/16/19 11:10	4/22/2019	5/15/2019	19-04106	Thallium-208	EPA 901.1 Modified	6.85E-01	1.22E-01	1.27E-01	1.74E-01	pCi/g
19-04106-06	TRG	17-45-31-190416	04/16/19 12:08	4/22/2019	5/15/2019	19-04106	Actinium-228	EPA 901.1 Modified	1.57E+00	2.69E-01	2.80E-01	6.83E-01	pCi/g
19-04106-06	TRG	17-45-31-190416	04/16/19 12:08	4/22/2019	5/15/2019	19-04106	Bismuth-214	EPA 901.1 Modified	1.52E+00	2.16E-01	2.29E-01	2.82E-01	pCi/g
19-04106-06	TRG	17-45-31-190416	04/16/19 12:08	4/22/2019	5/15/2019	19-04106	Potassium-40	EPA 901.1 Modified	2.46E+01	4.53E+00	4.70E+00	1.73E+00	pCi/g
19-04106-06	TRG	17-45-31-190416	04/16/19 12:08	4/22/2019	5/15/2019	19-04106	Protactinium-234m	EPA 901.1 Modified	8.32E+00	7.60E+00	7.61E+00	1.37E+01	pCi/g
19-04106-06	TRG	17-45-31-190416	04/16/19 12:08	4/22/2019	5/15/2019	19-04106	Lead-210	EPA 901.1 Modified	1.17E+00	1.05E+00	1.05E+00	1.73E+00	pCi/g
19-04106-06	TRG	17-45-31-190416	04/16/19 12:08	4/22/2019	5/15/2019	19-04106	Lead-212	EPA 901.1 Modified	1.37E+00	1.95E-01	2.07E-01	3.35E-01	pCi/g
19-04106-06	TRG	17-45-31-190416	04/16/19 12:08	4/22/2019	5/15/2019	19-04106	Lead-214	EPA 901.1 Modified	1.64E+00	2.03E-01	2.20E-01	3.22E-01	pCi/g
19-04106-06	TRG	17-45-31-190416	04/16/19 12:08	4/22/2019	5/15/2019	19-04106	Radium-226	EPA 901.1 Modified	1.52E+00	2.16E-01	2.29E-01	2.82E-01	pCi/g
19-04106-06	TRG	17-45-31-190416	04/16/19 12:08	4/22/2019	5/15/2019	19-04106	Thorium-234	EPA 901.1 Modified	1.75E+00	1.30E+00	1.30E+00	2.15E+00	pCi/g
19-04106-06	TRG	17-45-31-190416	04/16/19 12:08	4/22/2019	5/15/2019	19-04106	Thallium-208	EPA 901.1 Modified	1.51E+00	3.73E-01	3.81E-01	5.51E-01	pCi/g
19-04106-07	TRG	17-45-41-190416	04/16/19 12:10	4/22/2019	5/15/2019	19-04106	Actinium-228	EPA 901.1 Modified	1.74E+00	3.83E-01	3.93E-01	8.37E-01	pCi/g
19-04106-07	TRG	17-45-41-190416	04/16/19 12:10	4/22/2019	5/15/2019	19-04106	Bismuth-214	EPA 901.1 Modified	1.72E+00	2.79E-01	2.92E-01	3.60E-01	pCi/g
19-04106-07	TRG	17-45-41-190416	04/16/19 12:10	4/22/2019	5/15/2019	19-04106	Potassium-40	EPA 901.1 Modified	1.65E+01	2.69E+00	2.82E+00	2.38E+00	pCi/g
19-04106-07	TRG	17-45-41-190416	04/16/19 12:10	4/22/2019	5/15/2019	19-04106	Protactinium-234m	EPA 901.1 Modified	-1.86E+00	9.14E+00	9.14E+00	1.44E+01	pCi/g
19-04106-07	TRG	17-45-41-190416	04/16/19 12:10	4/22/2019	5/15/2019	19-04106	Lead-210	EPA 901.1 Modified	2.18E+00	1.38E+00	1.38E+00	2.26E+00	pCi/g
19-04106-07	TRG	17-45-41-190416	04/16/19 12:10	4/22/2019	5/15/2019	19-04106	Lead-212	EPA 901.1 Modified	1.60E+00	2.06E-01	2.22E-01	4.35E-01	pCi/g
19-04106-07	TRG	17-45-41-190416	04/16/19 12:10	4/22/2019	5/15/2019	19-04106	Lead-214	EPA 901.1 Modified	1.73E+00	2.49E-01	2.64E-01	3.15E-01	pCi/g
19-04106-07	TRG	17-45-41-190416	04/16/19 12:10	4/22/2019	5/15/2019	19-04106	Radium-226	EPA 901.1 Modified	1.72E+00	2.79E-01	2.92E-01	3.60E-01	pCi/g
19-04106-07	TRG	17-45-41-190416	04/16/19 12:10	4/22/2019	5/15/2019	19-04106	Thorium-234	EPA 901.1 Modified	2.05E+00	1.40E+00	1.40E+00	2.10E+00	pCi/g
19-04106-07	TRG	17-45-41-190416	04/16/19 12:10	4/22/2019	5/15/2019	19-04106	Thallium-208	EPA 901.1 Modified	1.45E+00	2.93E-01	3.02E-01	3.64E-01	pCi/g
19-04106-08	TRG	17-46-31-190416	04/16/19 13:22	4/22/2019	5/15/2019	19-04106	Actinium-228	EPA 901.1 Modified	1.17E+00	2.79E-01	2.86E-01	6.31E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	19-04106
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-04106-08	TRG	17-46-31-190416	04/16/19 13:22	4/22/2019	5/15/2019	19-04106	Bismuth-214	EPA 901.1 Modified	1.30E+01	8.43E-01	1.08E+00	3.72E-01	pCi/g
19-04106-08	TRG	17-46-31-190416	04/16/19 13:22	4/22/2019	5/15/2019	19-04106	Potassium-40	EPA 901.1 Modified	2.24E+01	2.94E+00	3.16E+00	1.94E+00	pCi/g
19-04106-08	TRG	17-46-31-190416	04/16/19 13:22	4/22/2019	5/15/2019	19-04106	Protactinium-234m	EPA 901.1 Modified	2.59E+00	9.65E+00	9.66E+00	1.46E+01	pCi/g
19-04106-08	TRG	17-46-31-190416	04/16/19 13:22	4/22/2019	5/15/2019	19-04106	Lead-210	EPA 901.1 Modified	1.09E+01	4.70E+00	4.73E+00	7.17E+00	pCi/g
19-04106-08	TRG	17-46-31-190416	04/16/19 13:22	4/22/2019	5/15/2019	19-04106	Lead-212	EPA 901.1 Modified	2.93E-01	2.84E-01	2.84E-01	3.62E-01	pCi/g
19-04106-08	TRG	17-46-31-190416	04/16/19 13:22	4/22/2019	5/15/2019	19-04106	Lead-214	EPA 901.1 Modified	1.40E+01	1.16E+00	1.36E+00	4.97E-01	pCi/g
19-04106-08	TRG	17-46-31-190416	04/16/19 13:22	4/22/2019	5/15/2019	19-04106	Radium-226	EPA 901.1 Modified	1.30E+01	8.43E-01	1.08E+00	3.72E-01	pCi/g
19-04106-08	TRG	17-46-31-190416	04/16/19 13:22	4/22/2019	5/15/2019	19-04106	Thorium-234	EPA 901.1 Modified	5.08E+00	3.36E+00	3.37E+00	5.53E+00	pCi/g
19-04106-08	TRG	17-46-31-190416	04/16/19 13:22	4/22/2019	5/15/2019	19-04106	Thallium-208	EPA 901.1 Modified	1.02E+00	1.68E-01	1.76E-01	9.07E-02	pCi/g
19-04106-09	TRG	17-46-41-190416	04/16/19 13:30	4/22/2019	5/15/2019	19-04106	Actinium-228	EPA 901.1 Modified	1.19E+00	3.99E-01	4.04E-01	8.47E-01	pCi/g
19-04106-09	TRG	17-46-41-190416	04/16/19 13:30	4/22/2019	5/15/2019	19-04106	Bismuth-214	EPA 901.1 Modified	9.51E+00	7.86E-01	9.25E-01	4.46E-01	pCi/g
19-04106-09	TRG	17-46-41-190416	04/16/19 13:30	4/22/2019	5/15/2019	19-04106	Potassium-40	EPA 901.1 Modified	2.69E+01	5.19E+00	5.37E+00	3.53E+00	pCi/g
19-04106-09	TRG	17-46-41-190416	04/16/19 13:30	4/22/2019	5/15/2019	19-04106	Protactinium-234m	EPA 901.1 Modified	2.58E+01	1.83E+01	1.83E+01	2.98E+01	pCi/g
19-04106-09	TRG	17-46-41-190416	04/16/19 13:30	4/22/2019	5/15/2019	19-04106	Lead-210	EPA 901.1 Modified	3.51E+00	1.93E+00	1.94E+00	3.15E+00	pCi/g
19-04106-09	TRG	17-46-41-190416	04/16/19 13:30	4/22/2019	5/15/2019	19-04106	Lead-212	EPA 901.1 Modified	1.64E+00	2.66E-01	2.79E-01	5.87E-01	pCi/g
19-04106-09	TRG	17-46-41-190416	04/16/19 13:30	4/22/2019	5/15/2019	19-04106	Lead-214	EPA 901.1 Modified	9.73E+00	7.21E-01	8.77E-01	5.18E-01	pCi/g
19-04106-09	TRG	17-46-41-190416	04/16/19 13:30	4/22/2019	5/15/2019	19-04106	Radium-226	EPA 901.1 Modified	9.51E+00	7.86E-01	9.25E-01	4.46E-01	pCi/g
19-04106-09	TRG	17-46-41-190416	04/16/19 13:30	4/22/2019	5/15/2019	19-04106	Thorium-234	EPA 901.1 Modified	3.18E+00	2.14E+00	2.15E+00	3.55E+00	pCi/g
19-04106-09	TRG	17-46-41-190416	04/16/19 13:30	4/22/2019	5/15/2019	19-04106	Thallium-208	EPA 901.1 Modified	1.64E+00	4.81E-01	4.88E-01	6.31E-01	pCi/g
19-04106-10	TRG	33-67-31-190416	04/16/19 16:32	4/22/2019	5/15/2019	19-04106	Actinium-228	EPA 901.1 Modified	1.61E+00	6.77E-01	6.82E-01	1.31E+00	pCi/g
19-04106-10	TRG	33-67-31-190416	04/16/19 16:32	4/22/2019	5/15/2019	19-04106	Bismuth-214	EPA 901.1 Modified	2.72E+01	1.79E+00	2.27E+00	8.59E-01	pCi/g
19-04106-10	TRG	33-67-31-190416	04/16/19 16:32	4/22/2019	5/15/2019	19-04106	Potassium-40	EPA 901.1 Modified	2.17E+01	4.13E+00	4.28E+00	5.16E+00	pCi/g
19-04106-10	TRG	33-67-31-190416	04/16/19 16:32	4/22/2019	5/15/2019	19-04106	Protactinium-234m	EPA 901.1 Modified	1.21E+01	2.06E+01	2.07E+01	3.29E+01	pCi/g
19-04106-10	TRG	33-67-31-190416	04/16/19 16:32	4/22/2019	5/15/2019	19-04106	Lead-210	EPA 901.1 Modified	1.04E+01	2.59E+00	2.64E+00	4.86E+00	pCi/g
19-04106-10	TRG	33-67-31-190416	04/16/19 16:32	4/22/2019	5/15/2019	19-04106	Lead-212	EPA 901.1 Modified	1.21E+00	3.85E-01	3.90E-01	7.85E-01	pCi/g
19-04106-10	TRG	33-67-31-190416	04/16/19 16:32	4/22/2019	5/15/2019	19-04106	Lead-214	EPA 901.1 Modified	2.73E+01	1.72E+00	2.22E+00	8.88E-01	pCi/g
19-04106-10	TRG	33-67-31-190416	04/16/19 16:32	4/22/2019	5/15/2019	19-04106	Radium-226	EPA 901.1 Modified	2.72E+01	1.79E+00	2.27E+00	8.59E-01	pCi/g
19-04106-10	TRG	33-67-31-190416	04/16/19 16:32	4/22/2019	5/15/2019	19-04106	Thorium-234	EPA 901.1 Modified	7.91E+00	4.10E+00	4.12E+00	1.58E+01	pCi/g
19-04106-10	TRG	33-67-31-190416	04/16/19 16:32	4/22/2019	5/15/2019	19-04106	Thallium-208	EPA 901.1 Modified	7.94E-01	2.94E-01	2.97E-01	4.46E-01	pCi/g
19-04106-11	TRG	33-67-41-190416	04/16/19 16:48	4/22/2019	5/15/2019	19-04106	Actinium-228	EPA 901.1 Modified	1.11E+00	4.08E-01	4.12E-01	1.05E+00	pCi/g
19-04106-11	TRG	33-67-41-190416	04/16/19 16:48	4/22/2019	5/15/2019	19-04106	Bismuth-214	EPA 901.1 Modified	2.32E+01	1.33E+00	1.79E+00	7.62E-01	pCi/g
19-04106-11	TRG	33-67-41-190416	04/16/19 16:48	4/22/2019	5/15/2019	19-04106	Potassium-40	EPA 901.1 Modified	2.36E+01	3.18E+00	3.40E+00	3.23E+00	pCi/g
19-04106-11	TRG	33-67-41-190416	04/16/19 16:48	4/22/2019	5/15/2019	19-04106	Protactinium-234m	EPA 901.1 Modified	6.54E+00	1.10E+01	1.10E+01	1.68E+01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	19-04106
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
19-04106-11	TRG	33-67-41-190416	04/16/19 16:48	4/22/2019	5/15/2019	19-04106	Lead-210	EPA 901.1 Modified	1.24E+01	4.05E+00	4.10E+00	6.33E+00	pCi/g
19-04106-11	TRG	33-67-41-190416	04/16/19 16:48	4/22/2019	5/15/2019	19-04106	Lead-212	EPA 901.1 Modified	1.67E+00	2.94E-01	3.06E-01	6.18E-01	pCi/g
19-04106-11	TRG	33-67-41-190416	04/16/19 16:48	4/22/2019	5/15/2019	19-04106	Lead-214	EPA 901.1 Modified	2.38E+01	1.60E+00	2.02E+00	8.11E-01	pCi/g
19-04106-11	TRG	33-67-41-190416	04/16/19 16:48	4/22/2019	5/15/2019	19-04106	Radium-226	EPA 901.1 Modified	2.32E+01	1.33E+00	1.79E+00	7.62E-01	pCi/g
19-04106-11	TRG	33-67-41-190416	04/16/19 16:48	4/22/2019	5/15/2019	19-04106	Thorium-234	EPA 901.1 Modified	3.97E+00	2.89E+00	2.89E+00	4.58E+00	pCi/g
19-04106-11	TRG	33-67-41-190416	04/16/19 16:48	4/22/2019	5/15/2019	19-04106	Thallium-208	EPA 901.1 Modified	9.87E-01	2.12E-01	2.18E-01	2.33E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

1904106

MEMO

DATE: July 22, 2019

TO: Keith Delhomme, Robert Sherman

FROM: Rick Haaker RF Haaker

SUBJECT: Review of Gamma Spectroscopy Data Package, 1904106

Introduction

The file evaluated was 1904106.xlsx.

This package did not contain radiochemistry data. Only the gamma spec data was reviewed. All concentration units are in units of pCi/g, unless otherwise noted.

Conclusions

My impression is that the laboratory analyses are acceptable for use. Don't rely on thorium-234 or protactinium-234m data.

Gamma Spectroscopy data review.

Summary

General factors		
Factor	Value	Comment
Number of ClientID	8	Number of distinct samples submitted
Number of Lab Duplicates	1	
Isotopes Detected in Method Blank	Th-234	Consider Th-234 more uncertain than usual and to have a positive bias when results are less than 3.0 pCi/g. Th-234 is usually a poorly quantified result by gamma spectroscopy.
Performance of Duplicate	All values had acceptable duplicate error ratios, except Thallium-208	Good!
Ra-226 pCi/g in Duplicate	~1.6	Good.
Ra-226 pCi/g Range in Data Package	1< Ra226 < 28	
Ingrowth Days at Eberline	22-23	Should be 21 days or more; good!
% Difference between (Measured – True)/True for Cs-137 & Co-60 spike sample.	+8%	Lab control standard overestimated concentrations for Cs-137 and Co-60 by +8%.

The following samples were analyzed by gamma spectroscopy.

SampleID_Table		
ClientID	LabID	Sample Type
17-44-31-190416	19-04106-03	DUP

1904106

SampleID_Table		
ClientID	LabID	Sample Type
17-44-31-190416	19-04106-04	DO
17-44-41-190416	19-04106-05	TRG
17-45-31-190416	19-04106-06	TRG
17-45-41-190416	19-04106-07	TRG
17-46-31-190416	19-04106-08	TRG
17-46-41-190416	19-04106-09	TRG
33-67-31-190416	19-04106-10	TRG
33-67-41-190416	19-04106-11	TRG

The data was delivered in the usual Microsoft excel data format; it did not contain radiochemistry data.

Thorium-234 results were considerably more precise than protactinium-234m results. The protactinium-234m results should not by themselves be considered reliable. Lead-210 and Th-234 was reported as present at levels that exceed the minimum detectable activity in samples as follows. Results are in the units of pCi/g.

Detected_Pb210 & Th234				
ClientID	Method	Analyte	Results	MDAC
17-46-31-190416	EPA 901.1 Modified	Lead-210	10.86	7.17
17-46-41-190416	EPA 901.1 Modified	Lead-210	3.51	3.15
33-67-31-190416	EPA 901.1 Modified	Lead-210	10.37	4.86
33-67-41-190416	EPA 901.1 Modified	Lead-210	12.36	6.33

Ignoring protactinium-234m, all other uranium decay chain analytes were detected in all samples except as follows:

NonDetects					
ClientID	Analyte	Method	Result	MDAC	ReportUnits
17-44-31-190416	Lead-210	EPA 901.1 Modified	1.86	3.0066	pCi/g
17-44-41-190416	Lead-210	EPA 901.1 Modified	3.29	3.5453	pCi/g
17-45-31-190416	Lead-210	EPA 901.1 Modified	1.17	1.7347	pCi/g
17-45-41-190416	Lead-210	EPA 901.1 Modified	2.18	2.2609	pCi/g
17-44-31-190416	Thorium-234	EPA 901.1 Modified	3.07	3.7466	pCi/g
17-44-41-190416	Thorium-234	EPA 901.1 Modified	1.42	1.7987	pCi/g
17-45-31-190416	Thorium-234	EPA 901.1 Modified	1.75	2.1485	pCi/g
17-45-41-190416	Thorium-234	EPA 901.1 Modified	2.05	2.1001	pCi/g
17-46-31-190416	Thorium-234	EPA 901.1 Modified	5.08	5.527	pCi/g
17-46-41-190416	Thorium-234	EPA 901.1 Modified	3.18	3.5511	pCi/g
33-67-31-190416	Thorium-234	EPA 901.1 Modified	7.91	15.763	pCi/g
33-67-41-190416	Thorium-234	EPA 901.1 Modified	3.97	4.578	pCi/g

This Eberline data package reports radium-226 as equal to bismuth-214, the radium-226 being assigned from the bismuth-214 values.

The degree of agreement between thorium-234 and radium-226 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that the thorium-234 results might be seriously biased by systematic error. The test statistic is the number of standard deviations by which the thorium-234 result exceeds the radium-226 result. If the test statistic is substantially less than zero, it implies that the reported radium-226 concentration is greater than the thorium-234 concentration. Gamma spectroscopy cannot detect thorium-230 for all practical purposes, **so agreement between thorium-234 and radium-226 doesn't provide *any* information at all about equilibrium between thorium-230 and radium-226.**

"Equilibrium" Th234				
ClientID	**Ra-226pCi/g**	**Thorium-234pCi/g**	**Test Statistic**	**Disequilibrium Evidence**
17-44-31-190416	1.65	3.07	1.25	Weak or none
17-44-31-190416	1.77	1.85	0.14	Weak or none
17-44-41-190416	1.41	1.42	0.01	Weak or none
17-45-31-190416	1.52	1.75	0.35	Weak or none
17-45-41-190416	1.72	2.05	0.47	Weak or none
17-46-31-190416	13	5.08	-4.48	Strong
17-46-41-190416	9.51	3.18	-5.41	Strong
33-67-31-190416	27.21	7.91	-8.2	Strong
33-67-41-190416	23.24	3.97	-11.33	Strong

The degree of agreement between radium-226 and lead-210 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that there is no proficiency testing of radiochemistry laboratories for isotopes having gamma energies similar to those for lead-210. Lead-210 results by gamma spectroscopy are best thought of as estimates. The test statistic is the number of standard deviations by which the radium-226 result exceeds the lead-210 result. If the test statistic is substantially less than zero, it implies that the reported lead-210 concentration is greater than the radium-226 concentration. **Agreement between radium-226 and lead-210 doesn't provide *any* information about equilibrium between thorium-230 and radium-226.**

Equilibrium Ra226 -> Pb210				
ClientID	**Ra-226pCi/g**	**Lead-210pCi/g**	**Test Statistic**	**Disequilibrium Evidence**
17-44-31-190416	1.65	1.86	-0.29	Weak or none
17-44-31-190416	1.77	0.97	1.33	Weak or none
17-44-41-190416	1.41	3.29	-1.68	Weak or none
17-45-31-190416	1.52	1.17	0.66	Weak or none
17-45-41-190416	1.72	2.18	-0.65	Weak or none
17-46-31-190416	13	10.86	0.88	Weak or none
17-46-41-190416	9.51	3.51	5.58	Strong
33-67-31-190416	27.21	10.37	9.67	Strong
33-67-41-190416	23.24	12.36	4.86	Strong

1904106

The maximum and estimated 99%UCLs (assuming normal statistics) for nuisance radionuclides in pCi/g, based on all prior datasets reviewed to this point are:

Analyte	Maximum	UCL99%
Actinium-228	2.61	2.41
Lead-212	8.45	4.2
Potassium-40	40.54	35.18
Thallium-208	2.48	2.18
Thorium-228	5.93	5.11
Thorium-232	5.96	5.1

It is good to keep in mind that around 10 – 15pCi/g potassium-40 looks like 1pCi/g of radium-226 to a 2x2 sodium iodide detector during field surveys.

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-08003
Weston Solutions, Inc.	Purchase Order:	0094169
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
		RUN 1 - AS RECEIVED											
17-08003-01	LCS	KNOWN	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Cobalt-60	EPA 901.1 Modified	6.21E+01	2.48E+00			pCi/g
17-08003-01	LCS	KNOWN	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Cesium-137	EPA 901.1 Modified	3.94E+01	1.58E+00			pCi/g
17-08003-01	LCS	SPIKE	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Cobalt-60	EPA 901.1 Modified	7.01E+01	4.65E+00	5.88E+00	7.32E-01	pCi/g
17-08003-01	LCS	SPIKE	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Cesium-137	EPA 901.1 Modified	4.28E+01	3.86E+00	4.44E+00	6.02E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Actinium-228	EPA 901.1 Modified	-2.35E-02	1.00E-01	1.00E-01	1.24E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Bismuth-214	EPA 901.1 Modified	5.86E-02	3.60E-02	3.61E-02	7.52E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Potassium-40	EPA 901.1 Modified	1.43E-01	1.26E-01	1.26E-01	3.75E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	-1.53E+00	2.86E+00	2.86E+00	3.41E+00	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-210	EPA 901.1 Modified	1.24E-03	5.28E-02	5.28E-02	2.03E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-212	EPA 901.1 Modified	-1.13E-02	2.45E-02	2.45E-02	3.54E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-214	EPA 901.1 Modified	3.98E-02	3.17E-02	3.18E-02	5.89E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Radium-226	EPA 901.1 Modified	5.86E-02	3.60E-02	3.61E-02	7.52E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Thorium-234	EPA 901.1 Modified	3.35E-01	1.70E-01	1.71E-01	2.99E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/3/2017	17-08003	Thallium-208	EPA 901.1 Modified	2.20E-02	5.07E-02	5.07E-02	8.87E-02	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Actinium-228	EPA 901.1 Modified	2.02E+00	3.16E-01	3.32E-01	4.55E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.62E+00	3.12E-01	3.23E-01	2.97E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.38E+01	2.56E+00	2.84E+00	1.14E+00	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	2.99E-01	5.73E+00	5.73E+00	8.73E+00	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-210	EPA 901.1 Modified	2.02E+00	1.53E+00	1.54E+00	2.52E+00	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-212	EPA 901.1 Modified	2.17E+00	2.05E-01	2.33E-01	2.32E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-214	EPA 901.1 Modified	1.84E+00	5.06E-01	5.15E-01	2.24E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Radium-226	EPA 901.1 Modified	1.62E+00	3.12E-01	3.23E-01	2.97E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Thorium-234	EPA 901.1 Modified	2.06E+00	1.33E+00	1.34E+00	2.20E+00	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.21E+00	2.34E-01	2.42E-01	1.76E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Actinium-228	EPA 901.1 Modified	2.05E+00	2.73E-01	2.92E-01	5.50E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.53E+00	3.34E-01	3.43E-01	2.11E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.36E+01	2.54E+00	2.81E+00	1.12E+00	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	1.88E+00	5.77E+00	5.77E+00	9.06E+00	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-210	EPA 901.1 Modified	1.91E+00	2.06E+00	2.06E+00	3.43E+00	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-212	EPA 901.1 Modified	2.28E+00	2.11E-01	2.41E-01	2.89E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-214	EPA 901.1 Modified	1.98E+00	5.37E-01	5.46E-01	2.49E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Radium-226	EPA 901.1 Modified	1.53E+00	3.34E-01	3.43E-01	2.11E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical **Final Report of Analysis**	*Report To:*	*Work Order Details:*	
	Jeff Wright	*SDG:*	**17-08003**
	Weston Solutions, Inc.	*Purchase Order:*	0094169
	13702 Coursey Blvd, Bldg 7 Suite A	*Analysis Category:*	ENVIRONMENTAL
	Baton Rouge, LA 70817-1370	*Sample Matrix:*	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Thorium-234	EPA 901.1 Modified	2.85E+00	1.93E+00	1.94E+00	3.20E+00	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/3/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.40E+00	2.52E-01	2.62E-01	1.43E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/3/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.24E+00	2.38E-01	2.46E-01	4.66E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/3/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.38E+00	1.94E-01	2.07E-01	2.22E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/3/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.20E+01	2.40E+00	2.65E+00	1.31E+00	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/3/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	1.52E+02	2.10E+01	2.24E+01	1.43E+01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-210	EPA 901.1 Modified	-1.16E+00	1.56E+00	1.56E+00	2.24E+00	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-212	EPA 901.1 Modified	1.19E+00	1.86E-01	1.96E-01	2.15E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-214	EPA 901.1 Modified	1.21E+00	2.08E-01	2.17E-01	2.28E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/3/2017	17-08003	Radium-226	EPA 901.1 Modified	1.38E+00	1.94E-01	2.07E-01	2.22E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/3/2017	17-08003	Thorium-234	EPA 901.1 Modified	6.14E+01	5.40E+00	6.25E+00	4.66E+00	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/3/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.33E+00	2.28E-01	2.38E-01	1.10E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.19E+00	3.51E-01	3.56E-01	4.62E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Bismuth-214	EPA 901.1 Modified	9.77E+00	1.02E+00	1.14E+00	2.68E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.00E+01	2.47E+00	2.68E+00	1.19E+00	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	5.45E+01	1.99E+01	2.01E+01	1.15E+01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-210	EPA 901.1 Modified	5.39E+00	1.53E+00	1.55E+00	2.37E+00	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-212	EPA 901.1 Modified	1.30E+00	4.06E-01	4.11E-01	2.44E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-214	EPA 901.1 Modified	9.50E+00	3.05E+00	3.09E+00	3.21E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Radium-226	EPA 901.1 Modified	9.77E+00	1.02E+00	1.14E+00	2.68E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Thorium-234	EPA 901.1 Modified	6.83E+01	5.49E+00	6.51E+00	3.55E+00	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Thallium-208	EPA 901.1 Modified	9.95E-01	2.25E-01	2.31E-01	8.92E-02	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Actinium-228	EPA 901.1 Modified	6.21E-01	2.09E-01	2.12E-01	4.82E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.58E+01	1.10E+00	1.37E+00	3.84E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Potassium-40	EPA 901.1 Modified	1.80E+01	2.21E+00	2.39E+00	1.99E+00	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	1.39E+01	8.39E+00	8.42E+00	1.35E+01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-210	EPA 901.1 Modified	4.26E+00	1.31E+00	1.33E+00	1.93E+00	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-212	EPA 901.1 Modified	-8.86E-01	2.13E-01	2.18E-01	2.02E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-214	EPA 901.1 Modified	1.47E+01	1.79E+00	1.94E+00	4.17E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Radium-226	EPA 901.1 Modified	1.58E+01	1.10E+00	1.37E+00	3.84E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Thorium-234	EPA 901.1 Modified	2.56E+00	1.50E+00	1.50E+00	2.21E+00	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Thallium-208	EPA 901.1 Modified	8.61E-01	3.03E-01	3.06E-01	3.97E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:

Jeff Wright
Weston Solutions, Inc.
13702 Coursey Blvd, Bldg 7 Suite A
Baton Rouge, LA 70817-1370

Work Order Details:

SDG: **17-08003**
Purchase Order: 0094169
Analysis Category: ENVIRONMENTAL
Sample Matrix: SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.29E+00	2.43E-01	2.52E-01	5.05E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Bismuth-214	EPA 901.1 Modified	2.53E+00	2.64E-01	2.95E-01	2.27E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.32E+01	3.08E+00	3.30E+00	1.23E+00	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	9.84E+00	8.23E+00	8.25E+00	1.35E+01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-210	EPA 901.1 Modified	7.76E-01	5.88E-01	5.89E-01	9.76E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-212	EPA 901.1 Modified	1.31E+00	1.61E-01	1.75E-01	2.42E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-214	EPA 901.1 Modified	2.77E+00	2.55E-01	2.92E-01	2.60E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Radium-226	EPA 901.1 Modified	2.53E+00	2.64E-01	2.95E-01	2.27E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Thorium-234	EPA 901.1 Modified	9.28E+00	1.53E+00	1.60E+00	2.18E+00	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/3/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.05E+00	1.66E-01	1.75E-01	1.75E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/3/2017	17-08003	Actinium-228	EPA 901.1 Modified	9.53E-01	2.52E-01	2.57E-01	1.72E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/3/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.01E+00	1.48E-01	1.57E-01	1.07E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/3/2017	17-08003	Potassium-40	EPA 901.1 Modified	1.87E+01	2.21E+00	2.41E+00	6.92E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/3/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	3.22E+00	2.89E+00	2.89E+00	4.52E+00	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-210	EPA 901.1 Modified	1.07E+00	6.14E-01	6.16E-01	9.98E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-212	EPA 901.1 Modified	1.09E+00	3.22E-01	3.26E-01	1.43E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/3/2017	17-08003	Lead-214	EPA 901.1 Modified	9.74E-01	3.20E-01	3.24E-01	1.12E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/3/2017	17-08003	Radium-226	EPA 901.1 Modified	1.01E+00	1.48E-01	1.57E-01	1.07E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/3/2017	17-08003	Thorium-234	EPA 901.1 Modified	9.52E-01	7.95E-01	7.97E-01	1.32E+00	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/3/2017	17-08003	Thallium-208	EPA 901.1 Modified	9.81E-01	2.02E-01	2.08E-01	5.19E-02	pCi/g
		RUN 2 - 7 Day Count											
17-08003-01	LCS	KNOWN	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Cobalt-60	EPA 901.1 Modified	6.21E+01	2.48E+00			pCi/g
17-08003-01	LCS	KNOWN	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Cesium-137	EPA 901.1 Modified	3.94E+01	1.58E+00			pCi/g
17-08003-01	LCS	SPIKE	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Cobalt-60	EPA 901.1 Modified	5.78E+01	3.48E+00	4.57E+00	4.05E-01	pCi/g
17-08003-01	LCS	SPIKE	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Cesium-137	EPA 901.1 Modified	3.74E+01	3.18E+00	3.72E+00	3.81E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Actinium-228	EPA 901.1 Modified	2.76E-02	5.65E-02	5.65E-02	1.19E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Bismuth-214	EPA 901.1 Modified	4.27E-02	4.20E-02	4.21E-02	7.73E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Potassium-40	EPA 901.1 Modified	1.90E-02	2.42E-01	2.42E-01	4.29E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	-1.15E+00	3.46E+00	3.46E+00	4.43E+00	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-210	EPA 901.1 Modified	1.12E-01	1.29E-01	1.30E-01	2.09E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-212	EPA 901.1 Modified	1.24E-02	2.24E-02	2.24E-02	3.70E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-214	EPA 901.1 Modified	6.37E-02	4.75E-02	4.76E-02	7.58E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Radium-226	EPA 901.1 Modified	4.27E-02	4.20E-02	4.21E-02	7.73E-02	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-08003
Weston Solutions, Inc.	Purchase Order:	0094169
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Thorium-234	EPA 901.1 Modified	2.83E-01	1.53E-01	1.54E-01	2.72E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/9/2017	17-08003	Thallium-208	EPA 901.1 Modified	-1.19E-02	5.22E-02	5.22E-02	8.05E-02	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Actinium-228	EPA 901.1 Modified	2.00E+00	2.58E-01	2.77E-01	7.15E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.90E+00	3.22E-01	3.37E-01	2.12E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.42E+01	2.61E+00	2.89E+00	1.34E+00	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	3.79E+00	5.66E+00	5.67E+00	9.25E+00	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-210	EPA 901.1 Modified	2.01E+00	1.47E+00	1.47E+00	2.41E+00	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-212	EPA 901.1 Modified	2.24E+00	2.09E-01	2.39E-01	2.17E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-214	EPA 901.1 Modified	1.93E+00	5.29E-01	5.38E-01	2.35E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Radium-226	EPA 901.1 Modified	1.90E+00	3.22E-01	3.37E-01	2.12E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Thorium-234	EPA 901.1 Modified	3.08E+00	1.45E+00	1.46E+00	2.37E+00	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.28E+00	2.23E-01	2.32E-01	2.44E-02	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.95E+00	2.85E-01	3.02E-01	4.20E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Bismuth-214	EPA 901.1 Modified	2.03E+00	3.48E-01	3.63E-01	2.33E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.49E+01	2.62E+00	2.92E+00	9.58E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	2.86E+00	6.54E+00	6.54E+00	1.01E+01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-210	EPA 901.1 Modified	1.66E+00	1.68E+00	1.69E+00	2.80E+00	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-212	EPA 901.1 Modified	2.11E+00	2.00E-01	2.28E-01	2.41E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-214	EPA 901.1 Modified	2.02E+00	5.49E-01	5.59E-01	2.36E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Radium-226	EPA 901.1 Modified	2.03E+00	3.48E-01	3.63E-01	2.33E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Thorium-234	EPA 901.1 Modified	2.25E+00	1.44E+00	1.45E+00	2.38E+00	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/9/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.19E+00	2.32E-01	2.39E-01	1.85E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/9/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.17E+00	2.63E-01	2.69E-01	4.06E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/9/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.36E+00	1.83E-01	1.95E-01	2.41E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/9/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.32E+01	2.49E+00	2.76E+00	1.22E+00	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/9/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	1.58E+02	2.14E+01	2.29E+01	1.34E+01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-210	EPA 901.1 Modified	-1.37E+00	1.56E+00	1.56E+00	2.22E+00	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-212	EPA 901.1 Modified	1.67E+00	2.51E-01	2.65E-01	2.14E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-214	EPA 901.1 Modified	1.36E+00	2.27E-01	2.37E-01	2.35E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/9/2017	17-08003	Radium-226	EPA 901.1 Modified	1.36E+00	1.83E-01	1.95E-01	2.41E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/9/2017	17-08003	Thorium-234	EPA 901.1 Modified	9.49E+01	7.64E+00	9.06E+00	5.00E+00	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/9/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.35E+00	2.31E-01	2.41E-01	1.27E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-08003
Weston Solutions, Inc.	Purchase Order:	0094169
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.26E+00	3.63E-01	3.69E-01	4.21E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.15E+01	1.20E+00	1.33E+00	2.79E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.27E+01	2.76E+00	2.99E+00	1.24E+00	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	6.77E+01	2.45E+01	2.47E+01	1.40E+01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-210	EPA 901.1 Modified	5.84E+00	1.47E+00	1.50E+00	2.22E+00	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-212	EPA 901.1 Modified	1.45E+00	4.44E-01	4.50E-01	2.33E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-214	EPA 901.1 Modified	1.12E+01	3.60E+00	3.65E+00	3.24E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Radium-226	EPA 901.1 Modified	1.15E+01	1.20E+00	1.33E+00	2.79E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Thorium-234	EPA 901.1 Modified	7.71E+01	6.13E+00	7.30E+00	3.82E+00	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.08E+00	2.39E-01	2.45E-01	1.55E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Actinium-228	EPA 901.1 Modified	8.99E-01	2.97E-01	3.01E-01	4.51E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.86E+01	1.87E+00	2.10E+00	2.69E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.13E+01	2.54E+00	2.76E+00	1.47E+00	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	1.97E+01	1.07E+01	1.07E+01	1.37E+01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-210	EPA 901.1 Modified	1.36E+01	2.10E+00	2.21E+00	2.75E+00	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-212	EPA 901.1 Modified	6.56E-01	2.16E-01	2.19E-01	2.09E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-214	EPA 901.1 Modified	1.90E+01	6.09E+00	6.17E+00	3.07E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Radium-226	EPA 901.1 Modified	1.86E+01	1.87E+00	2.10E+00	2.69E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Thorium-234	EPA 901.1 Modified	2.01E+01	2.42E+00	2.63E+00	3.08E+00	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Thallium-208	EPA 901.1 Modified	8.07E-01	1.87E-01	1.91E-01	1.68E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Actinium-228	EPA 901.1 Modified	8.69E-01	2.21E-01	2.25E-01	3.51E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Bismuth-214	EPA 901.1 Modified	2.03E+00	2.72E-01	2.92E-01	2.12E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Potassium-40	EPA 901.1 Modified	1.70E+01	1.92E+00	2.11E+00	2.43E+00	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	9.33E+00	4.64E+00	4.67E+00	7.81E+00	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-210	EPA 901.1 Modified	9.88E-01	6.93E-01	6.95E-01	1.07E+00	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-212	EPA 901.1 Modified	1.13E+00	1.73E-01	1.82E-01	1.80E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-214	EPA 901.1 Modified	1.63E+00	3.40E-01	3.50E-01	2.48E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Radium-226	EPA 901.1 Modified	2.03E+00	2.72E-01	2.92E-01	2.12E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Thorium-234	EPA 901.1 Modified	9.39E+00	1.64E+00	1.71E+00	2.37E+00	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/9/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.08E+00	2.01E-01	2.08E-01	2.58E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/9/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.10E+00	2.12E-01	2.19E-01	3.78E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/9/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.16E+00	1.75E-01	1.84E-01	2.17E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/9/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.28E+01	3.00E+00	3.22E+00	1.30E+00	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-08003
Weston Solutions, Inc.	Purchase Order:	0094169
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/9/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	-3.89E+00	7.31E+00	7.31E+00	9.52E+00	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-210	EPA 901.1 Modified	2.16E-02	4.09E-01	4.09E-01	5.88E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-212	EPA 901.1 Modified	1.22E+00	1.42E-01	1.56E-01	1.67E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/9/2017	17-08003	Lead-214	EPA 901.1 Modified	1.06E+00	1.25E-01	1.36E-01	1.70E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/9/2017	17-08003	Radium-226	EPA 901.1 Modified	1.16E+00	1.75E-01	1.84E-01	2.17E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/9/2017	17-08003	Thorium-234	EPA 901.1 Modified	1.12E+00	5.97E-01	6.00E-01	9.76E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/9/2017	17-08003	Thallium-208	EPA 901.1 Modified	9.86E-01	1.72E-01	1.80E-01	2.30E-01	pCi/g
		RUN 3 - 21 Day Count											
17-08003-01	LCS	KNOWN	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Cobalt-60	EPA 901.1 Modified	6.21E+01	2.48E+00			pCi/g
17-08003-01	LCS	KNOWN	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Cesium-137	EPA 901.1 Modified	3.94E+01	1.58E+00			pCi/g
17-08003-01	LCS	SPIKE	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Cobalt-60	EPA 901.1 Modified	5.84E+01	3.51E+00	4.61E+00	3.99E-01	pCi/g
17-08003-01	LCS	SPIKE	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Cesium-137	EPA 901.1 Modified	3.71E+01	3.15E+00	3.69E+00	4.76E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Actinium-228	EPA 901.1 Modified	3.33E-02	4.77E-02	4.77E-02	8.59E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Bismuth-214	EPA 901.1 Modified	2.41E-02	2.46E-02	2.46E-02	4.48E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Potassium-40	EPA 901.1 Modified	5.00E-02	1.64E-01	1.64E-01	2.73E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	-3.24E-01	1.35E+00	1.35E+00	1.98E+00	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-210	EPA 901.1 Modified	3.45E-01	1.62E-01	1.63E-01	3.13E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-212	EPA 901.1 Modified	8.21E-03	1.89E-02	1.89E-02	2.70E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-214	EPA 901.1 Modified	1.53E-02	2.66E-02	2.66E-02	3.83E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Radium-226	EPA 901.1 Modified	2.41E-02	2.46E-02	2.46E-02	4.48E-02	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Thorium-234	EPA 901.1 Modified	1.85E-01	1.68E-01	1.69E-01	2.85E-01	pCi/g
17-08003-02	MBL	BLANK	08/01/17 00:00	8/1/2017	8/24/2017	17-08003	Thallium-208	EPA 901.1 Modified	4.97E-03	2.73E-02	2.73E-02	4.90E-02	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.88E+00	3.37E-01	3.51E-01	5.31E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.90E+00	3.41E-01	3.55E-01	2.33E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.41E+01	2.55E+00	2.83E+00	9.89E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	-1.72E+00	5.87E+00	5.87E+00	8.54E+00	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-210	EPA 901.1 Modified	3.00E+00	1.64E+00	1.65E+00	2.19E+00	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-212	EPA 901.1 Modified	2.25E+00	2.09E-01	2.38E-01	2.77E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-214	EPA 901.1 Modified	1.87E+00	5.10E-01	5.18E-01	2.86E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Radium-226	EPA 901.1 Modified	1.90E+00	3.41E-01	3.55E-01	2.33E-01	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Thorium-234	EPA 901.1 Modified	2.32E+00	1.42E+00	1.42E+00	2.33E+00	pCi/g
17-08003-03	DUP	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.09E+00	2.15E-01	2.23E-01	1.39E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.79E+00	2.80E-01	2.95E-01	4.53E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:

Jeff Wright
Weston Solutions, Inc.
13702 Coursey Blvd, Bldg 7 Suite A
Baton Rouge, LA 70817-1370

Work Order Details:

SDG:	17-08003
Purchase Order:	0094169
Analysis Category:	ENVIRONMENTAL
Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.84E+00	3.25E-01	3.38E-01	2.14E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.43E+01	2.54E+00	2.83E+00	6.93E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	1.68E+00	6.24E+00	6.24E+00	9.61E+00	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-210	EPA 901.1 Modified	2.68E+00	1.65E+00	1.66E+00	2.21E+00	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-212	EPA 901.1 Modified	2.14E+00	2.04E-01	2.32E-01	2.50E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-214	EPA 901.1 Modified	1.91E+00	5.60E-01	5.68E-01	2.74E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Radium-226	EPA 901.1 Modified	1.84E+00	3.25E-01	3.38E-01	2.14E-01	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Thorium-234	EPA 901.1 Modified	2.14E+00	1.26E+00	1.27E+00	2.07E+00	pCi/g
17-08003-04	DO	33-15-2-31-170424	04/24/17 00:00	8/1/2017	8/24/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.40E+00	2.58E-01	2.68E-01	2.08E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/24/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.57E+00	3.25E-01	3.34E-01	5.95E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/24/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.65E+00	2.51E-01	2.65E-01	3.57E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/24/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.67E+01	3.51E+00	3.77E+00	1.47E+00	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/24/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	1.93E+02	2.34E+01	2.55E+01	2.04E+01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-210	EPA 901.1 Modified	-3.70E+00	1.45E+00	1.46E+00	1.94E+00	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-212	EPA 901.1 Modified	1.67E+00	2.11E-01	2.28E-01	2.88E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-214	EPA 901.1 Modified	1.74E+00	2.10E-01	2.28E-01	3.46E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/24/2017	17-08003	Radium-226	EPA 901.1 Modified	1.65E+00	2.51E-01	2.65E-01	3.57E-01	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/24/2017	17-08003	Thorium-234	EPA 901.1 Modified	1.29E+02	1.03E+01	1.22E+01	4.92E+00	pCi/g
17-08003-05	TRG	33-28-2-31-170501	05/01/17 00:00	8/1/2017	8/24/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.41E+00	2.39E-01	2.49E-01	1.68E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.05E+00	3.24E-01	3.28E-01	4.72E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.14E+01	1.18E+00	1.31E+00	2.97E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.32E+01	2.84E+00	3.08E+00	1.40E+00	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	7.65E+01	2.76E+01	2.79E+01	1.57E+01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-210	EPA 901.1 Modified	5.05E+00	1.72E+00	1.74E+00	2.73E+00	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-212	EPA 901.1 Modified	1.51E+00	4.57E-01	4.64E-01	2.48E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-214	EPA 901.1 Modified	1.16E+01	3.72E+00	3.76E+00	3.56E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Radium-226	EPA 901.1 Modified	1.14E+01	1.18E+00	1.31E+00	2.97E-01	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Thorium-234	EPA 901.1 Modified	7.66E+01	6.11E+00	7.27E+00	3.88E+00	pCi/g
17-08003-06	TRG	33-32-2-32-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.19E+00	2.59E-01	2.66E-01	1.20E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Actinium-228	EPA 901.1 Modified	8.01E-01	2.16E-01	2.20E-01	4.72E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Bismuth-214	EPA 901.1 Modified	1.79E+01	1.20E+00	1.51E+00	2.20E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Potassium-40	EPA 901.1 Modified	1.90E+01	2.12E+00	2.34E+00	1.39E+00	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	2.72E+01	1.06E+01	1.07E+01	1.64E+01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-08003
Weston Solutions, Inc.	Purchase Order:	0094169
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-210	EPA 901.1 Modified	1.13E+01	1.82E+00	1.91E+00	2.84E+00	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-212	EPA 901.1 Modified	7.48E-01	1.24E-01	1.30E-01	2.41E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-214	EPA 901.1 Modified	1.79E+01	2.15E+00	2.34E+00	2.42E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Radium-226	EPA 901.1 Modified	1.79E+01	1.20E+00	1.51E+00	2.20E-01	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Thorium-234	EPA 901.1 Modified	1.93E+01	2.42E+00	2.62E+00	3.46E+00	pCi/g
17-08003-07	TRG	33-36-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Thallium-208	EPA 901.1 Modified	8.45E-01	1.52E-01	1.58E-01	1.07E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.56E+00	2.83E-01	2.94E-01	4.44E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Bismuth-214	EPA 901.1 Modified	2.98E+00	2.85E-01	3.23E-01	2.68E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.46E+01	3.31E+00	3.54E+00	1.75E+00	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	1.64E+01	9.52E+00	9.56E+00	1.51E+01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-210	EPA 901.1 Modified	9.22E-01	5.44E-01	5.46E-01	8.96E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-212	EPA 901.1 Modified	1.44E+00	1.73E-01	1.88E-01	2.59E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-214	EPA 901.1 Modified	2.98E+00	2.43E-01	2.87E-01	2.57E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Radium-226	EPA 901.1 Modified	2.98E+00	2.85E-01	3.23E-01	2.68E-01	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Thorium-234	EPA 901.1 Modified	8.10E+00	1.31E+00	1.38E+00	1.84E+00	pCi/g
17-08003-08	TRG	33-37-2-31-170512	05/12/17 00:00	8/1/2017	8/24/2017	17-08003	Thallium-208	EPA 901.1 Modified	1.24E+00	2.08E-01	2.17E-01	1.78E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/24/2017	17-08003	Actinium-228	EPA 901.1 Modified	1.14E+00	3.09E-01	3.15E-01	2.06E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/24/2017	17-08003	Bismuth-214	EPA 901.1 Modified	9.04E-01	1.57E-01	1.64E-01	1.10E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/24/2017	17-08003	Potassium-40	EPA 901.1 Modified	2.07E+01	2.45E+00	2.67E+00	7.34E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/24/2017	17-08003	Protactinium-234m	EPA 901.1 Modified	2.17E+00	3.00E+00	3.00E+00	4.67E+00	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-210	EPA 901.1 Modified	2.71E-01	7.21E-01	7.21E-01	9.17E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-212	EPA 901.1 Modified	1.17E+00	3.45E-01	3.50E-01	1.55E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/24/2017	17-08003	Lead-214	EPA 901.1 Modified	1.01E+00	3.32E-01	3.36E-01	1.55E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/24/2017	17-08003	Radium-226	EPA 901.1 Modified	9.04E-01	1.57E-01	1.64E-01	1.10E-01	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/24/2017	17-08003	Thorium-234	EPA 901.1 Modified	1.74E+00	8.16E-01	8.21E-01	1.08E+00	pCi/g
17-08003-09	TRG	33-48-2-31-170608	06/08/17 00:00	8/1/2017	8/24/2017	17-08003	Thallium-208	EPA 901.1 Modified	9.88E-01	1.99E-01	2.06E-01	1.13E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

MEMO

DATE: June 23, 2019

TO: Keith Delhomme, Robert Sherman

FROM: Rick Haaker RF Haaker

SUBJECT: Review of Gamma Spectroscopy Data Package, 17-08003

File reviewed: SEC33_17-08003.EDD.xls.

This data package has results for more than one run time. Evidently it was done to investigate whether there is any impact of further ingrowth time after receipt of "sealed" samples at Eberline. This review only looks at the final count data from the August 24, 2017 count. It would be helpful to explore the important question of ingrowth behavior. Some samples are listed as "EPA 901.1 modified" while others are identified as "LANL ER-130 Modified," both of which are gamma spectroscopy procedures.

This package consisted of 6 samples (1 of which was a replicate count that was analyzed twice for a total of 7 results), plus method blanks, lab control standards/spikes. The results are considered acceptable for use, except where noted otherwise. The following samples were analyzed by gamma spectroscopy.

SampleID_Table		
ClientID	**LabID**	**Sample Type**
33-15-2-31-170424	17-08003-03	DUP
33-15-2-31-170424	17-08003-04	DO
33-28-2-31-170501	17-08003-05	TRG
33-32-2-32-170512	17-08003-06	TRG
33-36-2-31-170512	17-08003-07	TRG
33-37-2-31-170512	17-08003-08	TRG
33-48-2-31-170608	17-08003-09	TRG

The data was delivered in the usual Microsoft excel data format, except that data for more than one ingrowth time was included. All of the analytical data for 8/24/2017 was reported as EPA Method 901.1 modified.

Lead-210 activity was detected (0.313pCi/g) in the method blank samples at levels that exceeded the minimum detectable activity. Ordinary laboratory proficiency testing does not address nuclides with gamma energy in the range of lead-210 x-rays.

The agreement between duplicate sample results was acceptable for all analytes except protactinium-234m. The lab replicates was reasonably representative background samples in the dataset, being a sample with roughly 1.8pCi/g radium-226, while the radium-226 values for this data package ranged up to nearly 18pCi/g.

Thorium-234 results were considerably more precise than protactinium-234m results. The protactinium-234m results should not by themselves be considered reliable and are not recommended for use. Th-234 was reported as present at levels that exceed the minimum detectable activity in samples as follows. Results are in the units of pCi/g.

DetectedTh234			
ClientID	**Analyte**	**Results**	**MDAC**
33-28-2-31-170501	Thorium-234	128.84	4.92
33-32-2-32-170512	Thorium-234	76.61	3.88
33-36-2-31-170512	Thorium-234	19.33	3.46
33-37-2-31-170512	Thorium-234	8.1	1.84
33-48-2-31-170608	Thorium-234	1.74	1.08

Ignoring protactinium-234m, all other uranium decay chain analytes were detected in all samples, except as follows:

ClientID	Analyte	Method	Results	ReportUnits	Detected
33-28-2-31-170501	Lead-210	EPA 901.1 Modified	-3.7	pCi/g	U
33-48-2-31-170608	Lead-210	EPA 901.1 Modified	0.27	pCi/g	U
33-15-2-31-170424	Thorium-234	EPA 901.1 Modified	2.32	pCi/g	U

This Eberline data package reports radium-226 as equal to bismuth-214, the radium-226 being assigned from the bismuth-214 values.

The degree of agreement between thorium-234 and radium-226 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that the thorium-234 results are not seriously biased by systematic error. The test statistic is the number of standard deviations by which the thorium-234 result exceeds the radium-226 result. If the test statistic is substantially less than zero, it implies that the radium-226 concentration is greater than the thorium-234 concentration. Gamma spectroscopy cannot detect thorium-230, so agreement between thorium-234 and radium-226 doesn't provide information about equilibrium between thorium-230 and radium-226.

Equilibrium		
ClientID	**Test Statistic**	**Disequilibrium Evidence**
33-15-2-31-170424	0.58	Weak or none
33-15-2-31-170424	0.47	Weak or none
33-28-2-31-170501	20.78	Strong
33-32-2-32-170512	17.64	Strong
33-36-2-31-170512	0.91	Weak or none
33-37-2-31-170512	7.25	Strong
33-48-2-31-170608	2.01	Moderate

Twenty-one to twenty-three days elapsed from the date of receipt by Eberline to the date of analysis in their laboratory. Twenty-one days normally occurs between sealing and counting. These samples were collected and analyzed in 2017.

My impression is that the laboratory analyses are acceptable for use.

The maximum concentrations and estimated 99%UCLs for nuisance radionuclides in pCi/g, based on all prior datasets are:

Analyte	Maximum	UCL99%
Actinium-228	1.25	1.42
Lead-212	8.45	3.73
Potassium-40	24.28	28.59
Thallium-208	1.1	1.21

Disequilibrium

The Shapiro-Wilk test failed to provide strong evidence that the differences in pairs were other than normally distributed (p-value = 0.15). So, the paired sample t-test was an appropriate test for significance of continued ingrowth. Most likely the radium results reported for the first count are biased low, since there was marginal evidence that the concentrations for the first count and final count were different according to a paired sample t-test (pvalue = 8.4%).

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-09014
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-09014-01	LCS	KNOWN	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Cobalt-60	EPA 901.1 Modified	6.21E+01	2.48E+00			pCi/g
17-09014-01	LCS	KNOWN	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Cesium-137	EPA 901.1 Modified	3.94E+01	1.58E+00			pCi/g
17-09014-01	LCS	SPIKE	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Cobalt-60	EPA 901.1 Modified	6.93E+01	4.61E+00	5.82E+00	6.10E-01	pCi/g
17-09014-01	LCS	SPIKE	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Cesium-137	EPA 901.1 Modified	4.26E+01	3.85E+00	4.43E+00	6.90E-01	pCi/g
17-09014-02	MBL	BLANK	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Actinium-228	EPA 901.1 Modified	7.11E-02	9.08E-02	9.09E-02	1.64E-01	pCi/g
17-09014-02	MBL	BLANK	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Bismuth-214	EPA 901.1 Modified	1.57E-02	3.53E-02	3.53E-02	6.23E-02	pCi/g
17-09014-02	MBL	BLANK	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Potassium-40	EPA 901.1 Modified	7.62E-03	2.91E-01	2.91E-01	4.98E-01	pCi/g
17-09014-02	MBL	BLANK	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Protactinium-234m	EPA 901.1 Modified	0.00E+00	3.61E+00	3.61E+00	3.61E+00	pCi/g
17-09014-02	MBL	BLANK	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-210	EPA 901.1 Modified	1.79E-01	1.20E-01	1.20E-01	2.08E-01	pCi/g
17-09014-02	MBL	BLANK	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-212	EPA 901.1 Modified	3.50E-02	2.03E-02	2.04E-02	3.88E-02	pCi/g
17-09014-02	MBL	BLANK	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-214	EPA 901.1 Modified	4.11E-02	4.27E-02	4.27E-02	7.04E-02	pCi/g
17-09014-02	MBL	BLANK	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Radium-226	EPA 901.1 Modified	1.57E-02	3.53E-02	3.53E-02	6.23E-02	pCi/g
17-09014-02	MBL	BLANK	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Thorium-234	EPA 901.1 Modified	2.43E-01	1.76E-01	1.76E-01	2.91E-01	pCi/g
17-09014-02	MBL	BLANK	09/05/17 00:00	9/5/2017	9/5/2017	17-09014	Thallium-208	EPA 901.1 Modified	3.02E-03	5.42E-02	5.42E-02	8.88E-02	pCi/g
17-09014-03	DUP	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Actinium-228	EPA 901.1 Modified	1.58E+00	4.16E-01	4.24E-01	2.59E-01	pCi/g
17-09014-03	DUP	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Bismuth-214	EPA 901.1 Modified	1.34E+00	2.32E-01	2.42E-01	1.60E-01	pCi/g
17-09014-03	DUP	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Potassium-40	EPA 901.1 Modified	2.56E+01	3.04E+00	3.32E+00	8.99E-01	pCi/g
17-09014-03	DUP	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Protactinium-234m	EPA 901.1 Modified	2.96E+00	3.93E+00	3.94E+00	6.12E+00	pCi/g
17-09014-03	DUP	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-210	EPA 901.1 Modified	1.34E+00	9.50E-01	9.53E-01	1.57E+00	pCi/g
17-09014-03	DUP	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-212	EPA 901.1 Modified	1.77E+00	5.12E-01	5.20E-01	1.59E-01	pCi/g
17-09014-03	DUP	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-214	EPA 901.1 Modified	1.51E+00	4.93E-01	4.99E-01	1.79E-01	pCi/g
17-09014-03	DUP	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Radium-226	EPA 901.1 Modified	1.34E+00	2.32E-01	2.42E-01	1.60E-01	pCi/g
17-09014-03	DUP	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Thorium-234	EPA 901.1 Modified	2.53E+00	1.51E+00	1.52E+00	2.50E+00	pCi/g
17-09014-03	DUP	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Thallium-208	EPA 901.1 Modified	1.51E+00	3.10E-01	3.20E-01	5.88E-02	pCi/g
17-09014-04	DO	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Actinium-228	EPA 901.1 Modified	1.66E+00	4.36E-01	4.44E-01	3.01E-01	pCi/g
17-09014-04	DO	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Bismuth-214	EPA 901.1 Modified	1.42E+00	2.06E-01	2.19E-01	1.61E-01	pCi/g
17-09014-04	DO	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Potassium-40	EPA 901.1 Modified	2.55E+01	2.99E+00	3.27E+00	8.58E-01	pCi/g
17-09014-04	DO	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Protactinium-234m	EPA 901.1 Modified	-8.59E-01	3.91E+00	3.91E+00	5.64E+00	pCi/g
17-09014-04	DO	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-210	EPA 901.1 Modified	-1.02E-01	9.30E-01	9.30E-01	1.17E+00	pCi/g
17-09014-04	DO	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-212	EPA 901.1 Modified	1.66E+00	4.77E-01	4.85E-01	1.81E-01	pCi/g
17-09014-04	DO	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-214	EPA 901.1 Modified	1.40E+00	4.60E-01	4.65E-01	1.53E-01	pCi/g
17-09014-04	DO	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Radium-226	EPA 901.1 Modified	1.42E+00	2.06E-01	2.19E-01	1.61E-01	pCi/g
17-09014-04	DO	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Thorium-234	EPA 901.1 Modified	2.13E+00	1.17E+00	1.17E+00	1.92E+00	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-09014
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-09014-04	DO	32-03-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Thallium-208	EPA 901.1 Modified	1.60E+00	3.13E-01	3.24E-01	9.91E-02	pCi/g
17-09014-05	TRG	32-10-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Actinium-228	EPA 901.1 Modified	2.18E+00	2.38E-01	2.63E-01	2.85E-01	pCi/g
17-09014-05	TRG	32-10-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Bismuth-214	EPA 901.1 Modified	2.08E+00	2.36E-01	2.59E-01	1.57E-01	pCi/g
17-09014-05	TRG	32-10-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Potassium-40	EPA 901.1 Modified	2.29E+01	2.38E+00	2.66E+00	6.82E-01	pCi/g
17-09014-05	TRG	32-10-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Protactinium-234m	EPA 901.1 Modified	4.69E+00	4.07E+00	4.07E+00	6.62E+00	pCi/g
17-09014-05	TRG	32-10-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-210	EPA 901.1 Modified	1.84E+00	9.29E-01	9.34E-01	1.51E+00	pCi/g
17-09014-05	TRG	32-10-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-212	EPA 901.1 Modified	2.14E+00	2.66E-01	2.87E-01	1.32E-01	pCi/g
17-09014-05	TRG	32-10-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-214	EPA 901.1 Modified	2.08E+00	2.80E-01	3.00E-01	1.73E-01	pCi/g
17-09014-05	TRG	32-10-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Radium-226	EPA 901.1 Modified	2.08E+00	2.36E-01	2.59E-01	1.57E-01	pCi/g
17-09014-05	TRG	32-10-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Thorium-234	EPA 901.1 Modified	3.29E+00	1.18E+00	1.19E+00	1.88E+00	pCi/g
17-09014-05	TRG	32-10-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Thallium-208	EPA 901.1 Modified	2.12E+00	3.00E-01	3.20E-01	1.69E-01	pCi/g
17-09014-06	TRG	32-16-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Actinium-228	EPA 901.1 Modified	2.19E+00	2.88E-01	3.09E-01	4.75E-01	pCi/g
17-09014-06	TRG	32-16-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Bismuth-214	EPA 901.1 Modified	1.61E+00	2.90E-01	3.01E-01	2.02E-01	pCi/g
17-09014-06	TRG	32-16-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Potassium-40	EPA 901.1 Modified	2.02E+01	2.14E+00	2.38E+00	7.82E-01	pCi/g
17-09014-06	TRG	32-16-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Protactinium-234m	EPA 901.1 Modified	3.63E+00	5.10E+00	5.10E+00	8.31E+00	pCi/g
17-09014-06	TRG	32-16-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-210	EPA 901.1 Modified	5.00E-01	1.53E+00	1.53E+00	1.96E+00	pCi/g
17-09014-06	TRG	32-16-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-212	EPA 901.1 Modified	2.31E+00	2.07E-01	2.39E-01	2.45E-01	pCi/g
17-09014-06	TRG	32-16-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-214	EPA 901.1 Modified	1.69E+00	4.65E-01	4.73E-01	2.22E-01	pCi/g
17-09014-06	TRG	32-16-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Radium-226	EPA 901.1 Modified	1.61E+00	2.90E-01	3.01E-01	2.02E-01	pCi/g
17-09014-06	TRG	32-16-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Thorium-234	EPA 901.1 Modified	2.78E+00	1.33E+00	1.34E+00	2.17E+00	pCi/g
17-09014-06	TRG	32-16-2-31-170711	07/11/17 00:00	9/5/2017	9/5/2017	17-09014	Thallium-208	EPA 901.1 Modified	1.45E+00	2.27E-01	2.38E-01	5.32E-02	pCi/g
17-09014-07	TRG	32-23-2-31-170713	07/13/17 00:00	9/5/2017	9/5/2017	17-09014	Actinium-228	EPA 901.1 Modified	1.49E+00	1.81E-01	1.96E-01	2.56E-01	pCi/g
17-09014-07	TRG	32-23-2-31-170713	07/13/17 00:00	9/5/2017	9/5/2017	17-09014	Bismuth-214	EPA 901.1 Modified	1.35E+00	1.73E-01	1.87E-01	1.28E-01	pCi/g
17-09014-07	TRG	32-23-2-31-170713	07/13/17 00:00	9/5/2017	9/5/2017	17-09014	Potassium-40	EPA 901.1 Modified	1.87E+01	1.99E+00	2.21E+00	5.79E-01	pCi/g
17-09014-07	TRG	32-23-2-31-170713	07/13/17 00:00	9/5/2017	9/5/2017	17-09014	Protactinium-234m	EPA 901.1 Modified	1.95E+00	3.62E+00	3.62E+00	5.74E+00	pCi/g
17-09014-07	TRG	32-23-2-31-170713	07/13/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-210	EPA 901.1 Modified	9.15E-01	6.22E-01	6.24E-01	1.02E+00	pCi/g
17-09014-07	TRG	32-23-2-31-170713	07/13/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-212	EPA 901.1 Modified	1.55E+00	1.91E-01	2.07E-01	1.36E-01	pCi/g
17-09014-07	TRG	32-23-2-31-170713	07/13/17 00:00	9/5/2017	9/5/2017	17-09014	Lead-214	EPA 901.1 Modified	1.44E+00	1.92E-01	2.06E-01	1.26E-01	pCi/g
17-09014-07	TRG	32-23-2-31-170713	07/13/17 00:00	9/5/2017	9/5/2017	17-09014	Radium-226	EPA 901.1 Modified	1.35E+00	1.73E-01	1.87E-01	1.28E-01	pCi/g
17-09014-07	TRG	32-23-2-31-170713	07/13/17 00:00	9/5/2017	9/5/2017	17-09014	Thorium-234	EPA 901.1 Modified	2.02E+00	1.19E+00	1.20E+00	1.97E+00	pCi/g
17-09014-07	TRG	32-23-2-31-170713	07/13/17 00:00	9/5/2017	9/5/2017	17-09014	Thallium-208	EPA 901.1 Modified	1.57E+00	2.19E-01	2.33E-01	2.03E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

17-09014

MEMO

DATE: June 23, 2019

TO: Keith Delhomme, Robert Sherman

FROM: Rick Haaker RF Haaker

SUBJECT: Review of Gamma Spectroscopy Data Package, 17-09014

The file evaluated was SEC32_17-09014_EDD.xls.

This package consisted of 4 soil samples (1 of which was a replicate count that was analyzed twice for a total of 5 results), plus method blanks, lab control standards/spikes. All concentration units are in units of pCi/g, unless otherwise noted. The results are considered acceptable for use, except where noted otherwise. The following samples were analyzed by gamma spectroscopy.

SampleID_Table		
ClientID	**LabID**	**Sample Type**
32-03-2-31-170711	17-09014-03	DUP
32-03-2-31-170711	17-09014-04	DO
32-10-2-31-170711	17-09014-05	TRG
32-16-2-31-170711	17-09014-06	TRG
32-23-2-31-170713	17-09014-07	TRG

The data was delivered in the usual Microsoft excel data format.

Thorium-234 activity was detected (0.72 pCi/g) in the method blank samples at levels that exceeded the minimum detectable activity. Consider any thorium-234 values smaller than about 3.6 pCi/g to be more uncertain than usual.

The agreement between duplicate sample results was acceptable for all analytes, except for lead-210, which was more uncertain than usual , which is not an isotope of interest. The lab replicates was reasonably representative background samples in the dataset, being a sample with roughly 1.4 pCi/g radium-226, while the radium-226 values for this data package were all less than 2.1pCi/g.

Thorium-234 results were considerably more precise than protactinium-234m results. The protactinium-234m results should not by themselves be considered reliable. Th-234 was reported as present at levels that exceed the minimum detectable activity in samples as follows. Results are in the units of pCi/g.

Detected_Pa234m_Th234			
ClientID	**Analyte**	**Results**	**MDAC**
32-03-2-31-170711	Thorium-234	2.53	2.5
32-10-2-31-170711	Thorium-234	3.29	1.88
32-16-2-31-170711	Thorium-234	2.78	2.17
32-23-2-31-170713	Thorium-234	2.02	1.97

Ignoring protactinium-234m, all other uranium decay chain analytes were detected in all samples except as follows:

NonDetects6				
ClientID	Analyte	Result	MDAC	ReportUnits
32-03-2-31-170711	Lead-210	1.34	1.5662	pCi/g
32-16-2-31-170711	Lead-210	0.5	1.9612	pCi/g
32-23-2-31-170713	Lead-210	0.91	1.0212	pCi/g

This Eberline data package reports radium-226 as equal to bismuth-214, the radium-226 being assigned from the bismuth-214 values.

The degree of agreement between thorium-234 and radium-226 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that the thorium-234 results might be seriously biased by systematic error. The test statistic is the number of standard deviations by which the thorium-234 result exceeds the radium-226 result. If the test statistic is substantially less than zero, it implies that the radium-226 concentration is greater than the thorium-234 concentration. Gamma spectroscopy cannot detect thorium-230, so agreement between thorium-234 and radium-226 doesn't provide ***any*** information about equilibrium between thorium-230 and radium-226.

Equilibrium		
ClientID	Test Statistic	Disequilibrium Evidence
32-03-2-31-170711	1.56	Weak or none
32-03-2-31-170711	1.19	Weak or none
32-10-2-31-170711	1.99	Moderate
32-16-2-31-170711	1.72	Weak or none
32-23-2-31-170713	1.1	Weak or none

Zero days elapsed from the date of receipt by Eberline to the date of analysis in their laboratory, which is satisfactory. Twenty-one days normally occurs between sealing and counting. The radium-226, lead-214, and bismuth-210 reported results could have a negative bias (i.e. they may have a strong tendency to be reported somewhat below their true value).

My impression is that the laboratory analyses are acceptable for use subject to the caveat that the reported radium-226, lead-214, and bismuth-210 values may tend to be somewhat lower than the true values. These values should be considered more uncertain than usual.

The maximum and estimated 99%UCLs (assuming normal statistics) for nuisance radionuclides in pCi/g, based on all prior datasets are:

Analyte	Maximum	UCL99%
Actinium-228	1.88	1.9
Lead-212	8.45	3.49
Potassium-40	26.79	31.7

17-09014

Analyte	Maximum	UCL99%
Thallium-208	1.89	1.78

For this dataset(data package), the following matrix of linear correlation coefficients was obtained for samples having a radium-226 concentration below 10pCi/g. Correlation coefficients can have a range between 1 and -1, and are a measure of tendency of pairs of ***reported*** isotopic concentrations to go up and down together in a linear fashion. These correlation coefficients are based on twelve observations in the concentration range of interest to project engineers.

	Ac-228	Bi-214	Pb-210	Pb-212	Pb-214	K-40	Pa-234m	Ra-226	Tl-208	Th-234
Ac-228	1.00	0.83	0.23	0.96	0.83	-0.16	0.63	0.83	0.45	0.86
Bi-214	0.83	1.00	0.55	0.69	0.97	-0.06	0.64	1.00	0.87	0.89
Pb-210	0.23	0.55	1.00	0.25	0.68	-0.04	0.82	0.55	0.63	0.65
Pb-212	0.96	0.69	0.25	1.00	0.74	-0.16	0.70	0.69	0.25	0.84
Pb-214	0.83	0.97	0.68	0.74	1.00	-0.08	0.79	0.97	0.81	0.95
K-40	-0.16	-0.06	-0.04	-0.16	-0.08	1.00	-0.32	-0.06	0.11	0.07
Pa-234m	0.63	0.64	0.82	0.70	0.79	-0.32	1.00	0.64	0.41	0.82
Ra-226	0.83	1.00	0.55	0.69	0.97	-0.06	0.64	1.00	0.87	0.89
Tl-208	0.45	0.87	0.63	0.25	0.81	0.11	0.41	0.87	1.00	0.66
Th-234	0.86	0.89	0.65	0.84	0.95	0.07	0.82	0.89	0.66	1.00

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-06112
Weston Solutions, Inc.	Purchase Order:	0094169
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-06112-01	LCS	KNOWN	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Cobalt-60	EPA 901.1 Modified	6.21E+01	2.48E+00			pCi/g
17-06112-01	LCS	KNOWN	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Cesium-137	EPA 901.1 Modified	3.94E+01	1.58E+00			pCi/g
17-06112-01	LCS	SPIKE	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Cobalt-60	EPA 901.1 Modified	7.14E+01	4.74E+00	5.99E+00	6.95E-01	pCi/g
17-06112-01	LCS	SPIKE	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Cesium-137	EPA 901.1 Modified	4.30E+01	3.89E+00	4.47E+00	6.17E-01	pCi/g
17-06112-02	MBL	BLANK	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Actinium-228	EPA 901.1 Modified	4.83E-02	8.74E-02	8.75E-02	1.53E-01	pCi/g
17-06112-02	MBL	BLANK	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Bismuth-214	EPA 901.1 Modified	-6.48E-03	4.44E-02	4.45E-02	6.22E-02	pCi/g
17-06112-02	MBL	BLANK	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Potassium-40	EPA 901.1 Modified	6.12E-02	2.39E-01	2.39E-01	4.29E-01	pCi/g
17-06112-02	MBL	BLANK	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Protactinium-234m	EPA 901.1 Modified	-2.71E+00	3.47E+00	3.47E+00	3.96E+00	pCi/g
17-06112-02	MBL	BLANK	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-212	EPA 901.1 Modified	1.06E-04	2.58E-02	2.58E-02	3.88E-02	pCi/g
17-06112-02	MBL	BLANK	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-214	EPA 901.1 Modified	2.17E-02	2.33E-02	2.33E-02	5.23E-02	pCi/g
17-06112-02	MBL	BLANK	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Radium-226	EPA 901.1 Modified	-6.48E-03	4.44E-02	4.45E-02	6.22E-02	pCi/g
17-06112-02	MBL	BLANK	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Thorium-234	EPA 901.1 Modified	2.37E-01	1.63E-01	1.64E-01	2.79E-01	pCi/g
17-06112-02	MBL	BLANK	06/23/17 00:00	6/23/2017	6/23/2017	17-06112	Thallium-208	EPA 901.1 Modified	5.96E-02	5.23E-02	5.24E-02	9.25E-02	pCi/g
17-06112-03	DUP	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Actinium-228	EPA 901.1 Modified	1.62E+00	4.22E-01	4.30E-01	2.93E-01	pCi/g
17-06112-03	DUP	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Bismuth-214	EPA 901.1 Modified	5.61E+00	6.09E-01	6.74E-01	1.62E-01	pCi/g
17-06112-03	DUP	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Potassium-40	EPA 901.1 Modified	2.19E+01	2.54E+00	2.78E+00	1.06E+00	pCi/g
17-06112-03	DUP	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Protactinium-234m	EPA 901.1 Modified	6.08E+01	2.12E+01	2.14E+01	7.99E+00	pCi/g
17-06112-03	DUP	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-212	EPA 901.1 Modified	1.88E+00	5.47E-01	5.56E-01	1.96E-01	pCi/g
17-06112-03	DUP	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-214	EPA 901.1 Modified	5.56E+00	1.79E+00	1.81E+00	2.62E-01	pCi/g
17-06112-03	DUP	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Radium-226	EPA 901.1 Modified	5.61E+00	6.09E-01	6.74E-01	1.62E-01	pCi/g
17-06112-03	DUP	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Thorium-234	EPA 901.1 Modified	6.01E+01	4.86E+00	5.75E+00	3.32E+00	pCi/g
17-06112-03	DUP	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Thallium-208	EPA 901.1 Modified	1.52E+00	2.95E-01	3.05E-01	5.51E-02	pCi/g
17-06112-04	DO	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Actinium-228	EPA 901.1 Modified	1.61E+00	4.24E-01	4.32E-01	3.37E-01	pCi/g
17-06112-04	DO	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Bismuth-214	EPA 901.1 Modified	5.72E+00	6.07E-01	6.75E-01	2.59E-01	pCi/g
17-06112-04	DO	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Potassium-40	EPA 901.1 Modified	2.28E+01	2.63E+00	2.88E+00	1.33E+00	pCi/g
17-06112-04	DO	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Protactinium-234m	EPA 901.1 Modified	6.02E+01	2.13E+01	2.15E+01	9.95E+00	pCi/g
17-06112-04	DO	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-212	EPA 901.1 Modified	1.86E+00	5.35E-01	5.44E-01	1.99E-01	pCi/g
17-06112-04	DO	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-214	EPA 901.1 Modified	5.65E+00	1.82E+00	1.84E+00	2.36E-01	pCi/g
17-06112-04	DO	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Radium-226	EPA 901.1 Modified	5.72E+00	6.07E-01	6.75E-01	2.59E-01	pCi/g
17-06112-04	DO	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Thorium-234	EPA 901.1 Modified	6.29E+01	5.04E+00	5.98E+00	3.31E+00	pCi/g
17-06112-04	DO	30-11-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Thallium-208	EPA 901.1 Modified	1.48E+00	2.97E-01	3.07E-01	6.02E-02	pCi/g
17-06112-05	TRG	30-12-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Actinium-228	EPA 901.1 Modified	1.30E+00	1.97E-01	2.08E-01	3.83E-01	pCi/g
17-06112-05	TRG	30-12-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Bismuth-214	EPA 901.1 Modified	1.16E+01	7.98E-01	9.96E-01	1.71E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical Final Report of Analysis	Report To:	Work Order Details:	
	Jeff Wright	SDG:	17-06112
	Weston Solutions, Inc.	Purchase Order:	0094169
	13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
	Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-06112-05	TRG	30-12-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Potassium-40	EPA 901.1 Modified	2.08E+01	2.14E+00	2.39E+00	1.35E+00	pCi/g
17-06112-05	TRG	30-12-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Protactinium-234m	EPA 901.1 Modified	5.03E+01	9.19E+00	9.54E+00	9.96E+00	pCi/g
17-06112-05	TRG	30-12-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-212	EPA 901.1 Modified	1.04E+00	1.46E-01	1.55E-01	2.44E-01	pCi/g
17-06112-05	TRG	30-12-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-214	EPA 901.1 Modified	1.08E+01	1.32E+00	1.43E+00	2.07E-01	pCi/g
17-06112-05	TRG	30-12-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Radium-226	EPA 901.1 Modified	1.16E+01	7.98E-01	9.96E-01	1.71E-01	pCi/g
17-06112-05	TRG	30-12-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Thorium-234	EPA 901.1 Modified	2.89E+01	2.70E+00	3.08E+00	3.00E+00	pCi/g
17-06112-05	TRG	30-12-2-31-170322	03/22/17 00:00	6/23/2017	6/23/2017	17-06112	Thallium-208	EPA 901.1 Modified	1.04E+00	1.67E-01	1.76E-01	1.51E-01	pCi/g
17-06112-06	TRG	30-20-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Actinium-228	EPA 901.1 Modified	1.37E+00	1.73E-01	1.87E-01	2.51E-01	pCi/g
17-06112-06	TRG	30-20-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Bismuth-214	EPA 901.1 Modified	3.53E+00	3.09E-01	3.58E-01	1.33E-01	pCi/g
17-06112-06	TRG	30-20-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Potassium-40	EPA 901.1 Modified	2.24E+01	2.29E+00	2.56E+00	7.45E-01	pCi/g
17-06112-06	TRG	30-20-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Protactinium-234m	EPA 901.1 Modified	3.97E+01	7.63E+00	7.90E+00	8.47E+00	pCi/g
17-06112-06	TRG	30-20-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-212	EPA 901.1 Modified	1.31E+00	1.68E-01	1.81E-01	1.27E-01	pCi/g
17-06112-06	TRG	30-20-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-214	EPA 901.1 Modified	3.38E+00	4.18E-01	4.53E-01	1.40E-01	pCi/g
17-06112-06	TRG	30-20-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Radium-226	EPA 901.1 Modified	3.53E+00	3.09E-01	3.58E-01	1.33E-01	pCi/g
17-06112-06	TRG	30-20-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Thorium-234	EPA 901.1 Modified	4.06E+01	3.54E+00	4.11E+00	2.71E+00	pCi/g
17-06112-06	TRG	30-20-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Thallium-208	EPA 901.1 Modified	1.30E+00	1.98E-01	2.09E-01	7.77E-02	pCi/g
17-06112-07	TRG	30-21-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Actinium-228	EPA 901.1 Modified	1.23E+00	3.02E-01	3.09E-01	5.63E-01	pCi/g
17-06112-07	TRG	30-21-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Bismuth-214	EPA 901.1 Modified	6.47E+00	4.68E-01	5.73E-01	2.83E-01	pCi/g
17-06112-07	TRG	30-21-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Potassium-40	EPA 901.1 Modified	2.34E+01	3.15E+00	3.37E+00	2.05E+00	pCi/g
17-06112-07	TRG	30-21-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Protactinium-234m	EPA 901.1 Modified	1.04E+01	8.80E+00	8.82E+00	1.45E+01	pCi/g
17-06112-07	TRG	30-21-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-212	EPA 901.1 Modified	1.27E+00	1.65E-01	1.77E-01	2.66E-01	pCi/g
17-06112-07	TRG	30-21-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-214	EPA 901.1 Modified	5.99E+00	4.21E-01	5.21E-01	2.65E-01	pCi/g
17-06112-07	TRG	30-21-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Radium-226	EPA 901.1 Modified	6.47E+00	4.68E-01	5.73E-01	2.83E-01	pCi/g
17-06112-07	TRG	30-21-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Thorium-234	EPA 901.1 Modified	5.74E+00	1.28E+00	1.31E+00	1.97E+00	pCi/g
17-06112-07	TRG	30-21-2-31-170327	03/27/17 00:00	6/23/2017	6/23/2017	17-06112	Thallium-208	EPA 901.1 Modified	1.16E+00	3.07E-01	3.13E-01	4.43E-01	pCi/g
17-06112-08	TRG	30-30-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Actinium-228	EPA 901.1 Modified	1.88E+00	4.99E-01	5.08E-01	3.38E-01	pCi/g
17-06112-08	TRG	30-30-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Bismuth-214	EPA 901.1 Modified	7.01E+00	7.58E-01	8.39E-01	2.34E-01	pCi/g
17-06112-08	TRG	30-30-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Potassium-40	EPA 901.1 Modified	2.44E+01	2.88E+00	3.14E+00	1.20E+00	pCi/g
17-06112-08	TRG	30-30-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Protactinium-234m	EPA 901.1 Modified	2.04E+01	9.76E+00	9.82E+00	1.10E+01	pCi/g
17-06112-08	TRG	30-30-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-212	EPA 901.1 Modified	2.20E+00	6.46E-01	6.55E-01	3.24E-01	pCi/g
17-06112-08	TRG	30-30-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-214	EPA 901.1 Modified	7.51E+00	2.41E+00	2.44E+00	2.65E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-06112
Weston Solutions, Inc.	Purchase Order:	0094169
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-06112-08	TRG	30-30-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Radium-226	EPA 901.1 Modified	7.01E+00	7.58E-01	8.39E-01	2.34E-01	pCi/g
17-06112-08	TRG	30-30-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Thorium-234	EPA 901.1 Modified	1.21E+01	1.74E+00	1.84E+00	2.36E+00	pCi/g
17-06112-08	TRG	30-30-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Thallium-208	EPA 901.1 Modified	1.78E+00	3.48E-01	3.60E-01	1.53E-02	pCi/g
17-06112-09	TRG	30-32-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Actinium-228	EPA 901.1 Modified	8.97E-01	1.42E-01	1.50E-01	2.87E-01	pCi/g
17-06112-09	TRG	30-32-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Bismuth-214	EPA 901.1 Modified	4.67E+00	3.74E-01	4.44E-01	1.43E-01	pCi/g
17-06112-09	TRG	30-32-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Potassium-40	EPA 901.1 Modified	1.85E+01	1.94E+00	2.16E+00	7.04E-01	pCi/g
17-06112-09	TRG	30-32-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Protactinium-234m	EPA 901.1 Modified	7.61E+00	5.24E+00	5.25E+00	8.46E+00	pCi/g
17-06112-09	TRG	30-32-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-212	EPA 901.1 Modified	8.70E-01	1.20E-01	1.28E-01	1.35E-01	pCi/g
17-06112-09	TRG	30-32-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-214	EPA 901.1 Modified	4.38E+00	5.43E-01	5.88E-01	1.29E-01	pCi/g
17-06112-09	TRG	30-32-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Radium-226	EPA 901.1 Modified	4.67E+00	3.74E-01	4.44E-01	1.43E-01	pCi/g
17-06112-09	TRG	30-32-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Thorium-234	EPA 901.1 Modified	4.09E+00	1.37E+00	1.38E+00	2.20E+00	pCi/g
17-06112-09	TRG	30-32-2-31-170331	03/31/17 00:00	6/23/2017	6/23/2017	17-06112	Thallium-208	EPA 901.1 Modified	8.71E-01	1.40E-01	1.47E-01	1.67E-02	pCi/g
17-06112-10	TRG	33-08-2-31-170424	04/24/17 00:00	6/23/2017	6/23/2017	17-06112	Actinium-228	EPA 901.1 Modified	2.04E+00	2.70E-01	2.90E-01	6.69E-01	pCi/g
17-06112-10	TRG	33-08-2-31-170424	04/24/17 00:00	6/23/2017	6/23/2017	17-06112	Bismuth-214	EPA 901.1 Modified	2.41E+00	2.79E-01	3.05E-01	3.52E-01	pCi/g
17-06112-10	TRG	33-08-2-31-170424	04/24/17 00:00	6/23/2017	6/23/2017	17-06112	Potassium-40	EPA 901.1 Modified	2.82E+01	3.67E+00	3.94E+00	1.26E+00	pCi/g
17-06112-10	TRG	33-08-2-31-170424	04/24/17 00:00	6/23/2017	6/23/2017	17-06112	Protactinium-234m	EPA 901.1 Modified	1.90E+01	9.79E+00	9.84E+00	3.07E+01	pCi/g
17-06112-10	TRG	33-08-2-31-170424	04/24/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-212	EPA 901.1 Modified	2.08E+00	2.32E-01	2.55E-01	2.67E-01	pCi/g
17-06112-10	TRG	33-08-2-31-170424	04/24/17 00:00	6/23/2017	6/23/2017	17-06112	Lead-214	EPA 901.1 Modified	2.29E+00	2.40E-01	2.67E-01	2.67E-01	pCi/g
17-06112-10	TRG	33-08-2-31-170424	04/24/17 00:00	6/23/2017	6/23/2017	17-06112	Radium-226	EPA 901.1 Modified	2.41E+00	2.79E-01	3.05E-01	3.52E-01	pCi/g
17-06112-10	TRG	33-08-2-31-170424	04/24/17 00:00	6/23/2017	6/23/2017	17-06112	Thorium-234	EPA 901.1 Modified	1.64E+01	2.10E+00	2.26E+00	2.67E+00	pCi/g
17-06112-10	TRG	33-08-2-31-170424	04/24/17 00:00	6/23/2017	6/23/2017	17-06112	Thallium-208	EPA 901.1 Modified	1.60E+00	2.29E-01	2.43E-01	3.79E-02	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

MEMO

DATE: June 25, 2019

TO: Keith Delhomme, Robert Sherman

FROM: Rick Haaker RF Haaker

SUBJECT: Review of Gamma Spectroscopy Data Package, 17-06112

The file evaluated was SEC30_SEC33_17-06112_EDD.xlsx.

This package consisted of 7 soil samples (1 of which was a replicate count that was analyzed twice for a total of 8 results), plus method blanks, lab control standards/spikes. All concentration units are in units of pCi/g, unless otherwise noted. The results are considered acceptable for use, except where noted otherwise. The following samples were analyzed by gamma spectroscopy.

SampleID_Table		
ClientID	**LabID**	**Sample Type**
30-11-2-31-170322	17-06112-03	DUP
30-11-2-31-170322	17-06112-04	DO
30-12-2-31-170322	17-06112-05	TRG
30-20-2-31-170327	17-06112-06	TRG
30-21-2-31-170327	17-06112-07	TRG
30-30-2-31-170331	17-06112-08	TRG
30-32-2-31-170331	17-06112-09	TRG
33-08-2-31-170424	17-06112-10	TRG

The data was delivered in the usual Microsoft excel data format.

No isotopes were detected in the method blank samples at levels that exceeded the minimum detectable activity.

The agreement between duplicate sample results was acceptable.

Thorium-234 results were considerably more precise than protactinium-234m results. The protactinium-234m results should not by themselves be considered reliable. Th-234 was reported as present at levels that exceed the minimum detectable activity in samples as follows. Results are in the units of pCi/g.

Detected Th234			
ClientID	**Analyte**	**Results**	**MDAC**
30-11-2-31-170322	Thorium-234	60.09	3.32
30-12-2-31-170322	Thorium-234	28.87	3
30-20-2-31-170327	Thorium-234	40.61	2.71
30-21-2-31-170327	Thorium-234	5.74	1.97
30-30-2-31-170331	Thorium-234	12.11	2.36

Detected Th234			
ClientID	Analyte	Results	MDAC
30-32-2-31-170331	Thorium-234	4.09	2.2
33-08-2-31-170424	Thorium-234	16.43	2.67

Ignoring protactinium-234m, all other uranium decay chain analytes were detected in all samples except as follows:

None

This Eberline data package reports radium-226 as equal to bismuth-214, the radium-226 being assigned from the bismuth-214 values.

The degree of agreement between thorium-234 and radium-226 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that the thorium-234 results might be seriously biased by systematic error. The test statistic is the number of standard deviations by which the thorium-234 result exceeds the radium-226 result. If the test statistic is substantially less than zero, it implies that the reported radium-226 concentration is greater than the thorium-234 concentration. Gamma spectroscopy cannot detect thorium-230, **so agreement between thorium-234 and radium-226 doesn't provide *any* information about equilibrium between thorium-230 and radium-226.**

Equilibrium Th234 -> Ra-226		
ClientID	Test Statistic	Disequilibrium Evidence
30-11-2-31-170322	18.81	Strong
30-11-2-31-170322	18.99	Strong
30-12-2-31-170322	10.66	Strong
30-20-2-31-170327	17.97	Strong
30-21-2-31-170327	-1.02	Weak or none
30-30-2-31-170331	5.03	Strong
30-32-2-31-170331	-0.8	Weak or none
33-08-2-31-170424	12.3	Strong

The degree of agreement between radium-226 and lead-210 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that there is no proficiency testing of radiochemistry laboratories for isotopes having gamma energies similar to those for lead-210. The test statistic is the number of standard deviations by which the radium-226 result exceeds the lead-210 result. If the test statistic is substantially less than zero, it implies that the reported lead-210 concentration is greater than the radium-226 concentration. Agreement between radium-226 and lead-210 doesn't provide ***any*** information about equilibrium between thorium-230 and radium-226.

No Lead-210 results were reported for this data package.

Zero days elapsed from the date of receipt by Eberline to the date of analysis in their laboratory. Twenty-one days normally occurs between sealing and counting. The radium-226, lead-214, and bismuth-210 reported results <u>may</u> have a negative bias (i.e. they may have a tendency to be reported somewhat below their true value).

My impression is that the laboratory analyses are acceptable for use subject to the caveat that the radium-226, lead-214, and bismuth-210 reported results <u>may</u> have a negative bias.

The maximum and estimated 99%UCLs (assuming normal statistics) for nuisance radionuclides in pCi/g, based on all prior datasets are:

Analyte	Maximum	UCL99%
Actinium-228	2.19	2.03
Lead-212	8.45	3.38
Potassium-40	26.79	32.01
Thallium-208	2.12	1.9

For this dataset(data package), the following matrix of linear correlation coefficients was obtained for samples having a radium-226 concentration below 10pCi/g. Correlation coefficients can have a range between 1 and -1, and are a measure of tendency of pairs of ***reported*** isotopic concentrations to go up and down together in a linear fashion. These correlation coefficients are based on observations in the concentration range of interest to project engineers.

	Ac-228	Bi-214	Pb-212	Pb-214	K-40	Pa-234m	Ra-226	Tl-208	Th-234
Ac-228	1.00	-0.13	0.97	-0.01	0.86	0.28	-0.13	0.95	0.23
Bi-214	-0.13	1.00	0.10	0.99	-0.30	0.06	1.00	0.12	0.00
Pb-212	0.97	0.10	1.00	0.22	0.73	0.37	0.10	0.98	0.32
Pb-214	-0.01	0.99	0.22	1.00	-0.24	0.09	0.99	0.24	0.02
K-40	0.86	-0.30	0.73	-0.24	1.00	-0.06	-0.30	0.71	-0.08
Pa-234m	0.28	0.06	0.37	0.09	-0.06	1.00	0.06	0.39	1.00
Ra-226	-0.13	1.00	0.10	0.99	-0.30	0.06	1.00	0.12	0.00
Tl-208	0.95	0.12	0.98	0.24	0.71	0.39	0.12	1.00	0.33
Th-234	0.23	0.00	0.32	0.02	-0.08	1.00	0.00	0.33	1.00

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	18-08148
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
18-08148-01	LCS	KNOWN	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Cobalt-60	EPA 901.1 Modified	6.21E+01	2.48E+00			pCi/g
18-08148-01	LCS	KNOWN	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Cesium-137	EPA 901.1 Modified	3.94E+01	1.58E+00			pCi/g
18-08148-01	LCS	SPIKE	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Cobalt-60	EPA 901.1 Modified	6.01E+01	3.42E+00	4.61E+00	5.48E-01	pCi/g
18-08148-01	LCS	SPIKE	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Cesium-137	EPA 901.1 Modified	3.82E+01	3.32E+00	3.86E+00	4.39E-01	pCi/g
18-08148-02	MBL	BLANK	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Actinium-228	EPA 901.1 Modified	8.36E-03	3.20E-02	3.20E-02	5.83E-02	pCi/g
18-08148-02	MBL	BLANK	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Bismuth-214	EPA 901.1 Modified	3.68E-03	2.87E-02	2.87E-02	4.42E-02	pCi/g
18-08148-02	MBL	BLANK	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Potassium-40	EPA 901.1 Modified	1.64E-01	1.15E-01	1.15E-01	2.73E-01	pCi/g
18-08148-02	MBL	BLANK	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Protactinium-234m	EPA 901.1 Modified	-3.41E-01	1.35E+00	1.35E+00	2.06E+00	pCi/g
18-08148-02	MBL	BLANK	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-210	EPA 901.1 Modified	5.98E-02	1.66E-01	1.66E-01	2.67E-01	pCi/g
18-08148-02	MBL	BLANK	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-212	EPA 901.1 Modified	1.05E-02	1.53E-02	1.53E-02	2.35E-02	pCi/g
18-08148-02	MBL	BLANK	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-214	EPA 901.1 Modified	1.71E-02	2.40E-02	2.40E-02	3.71E-02	pCi/g
18-08148-02	MBL	BLANK	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Radium-226	EPA 901.1 Modified	3.68E-03	2.87E-02	2.87E-02	4.42E-02	pCi/g
18-08148-02	MBL	BLANK	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Thorium-234	EPA 901.1 Modified	1.28E-01	2.47E-01	2.47E-01	3.49E-01	pCi/g
18-08148-02	MBL	BLANK	08/28/18 00:00	8/28/2018	8/28/2018	18-08148	Thallium-208	EPA 901.1 Modified	7.98E-03	2.94E-02	2.94E-02	5.35E-02	pCi/g
18-08148-03	DUP	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Actinium-228	EPA 901.1 Modified	9.65E-01	1.83E-01	1.90E-01	2.63E-01	pCi/g
18-08148-03	DUP	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Bismuth-214	EPA 901.1 Modified	3.94E+00	3.36E-01	3.92E-01	1.29E-01	pCi/g
18-08148-03	DUP	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Potassium-40	EPA 901.1 Modified	1.71E+01	1.75E+00	1.96E+00	6.12E-01	pCi/g
18-08148-03	DUP	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Protactinium-234m	EPA 901.1 Modified	3.10E+01	7.23E+00	7.40E+00	9.32E+00	pCi/g
18-08148-03	DUP	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-210	EPA 901.1 Modified	1.69E+00	7.83E-01	7.88E-01	1.46E+00	pCi/g
18-08148-03	DUP	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-212	EPA 901.1 Modified	3.27E-01	7.29E-02	7.48E-02	1.44E-01	pCi/g
18-08148-03	DUP	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-214	EPA 901.1 Modified	3.90E+00	4.80E-01	5.20E-01	1.54E-01	pCi/g
18-08148-03	DUP	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Radium-226	EPA 901.1 Modified	3.94E+00	3.36E-01	3.92E-01	1.29E-01	pCi/g
18-08148-03	DUP	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Thorium-234	EPA 901.1 Modified	3.08E+01	2.78E+00	3.19E+00	2.54E+00	pCi/g
18-08148-03	DUP	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Thallium-208	EPA 901.1 Modified	9.55E-01	1.54E-01	1.61E-01	6.29E-02	pCi/g
18-08148-04	DO	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Actinium-228	EPA 901.1 Modified	9.11E-01	1.43E-01	1.50E-01	2.96E-01	pCi/g
18-08148-04	DO	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Bismuth-214	EPA 901.1 Modified	3.80E+00	3.19E-01	3.74E-01	1.27E-01	pCi/g
18-08148-04	DO	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Potassium-40	EPA 901.1 Modified	1.75E+01	1.81E+00	2.02E+00	7.95E-01	pCi/g
18-08148-04	DO	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Protactinium-234m	EPA 901.1 Modified	2.76E+01	6.27E+00	6.43E+00	7.78E+00	pCi/g
18-08148-04	DO	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-210	EPA 901.1 Modified	1.82E+00	1.04E+00	1.05E+00	1.72E+00	pCi/g
18-08148-04	DO	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-212	EPA 901.1 Modified	3.89E-01	8.15E-02	8.39E-02	1.44E-01	pCi/g
18-08148-04	DO	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-214	EPA 901.1 Modified	4.09E+00	5.06E-01	5.48E-01	1.56E-01	pCi/g
18-08148-04	DO	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Radium-226	EPA 901.1 Modified	3.80E+00	3.19E-01	3.74E-01	1.27E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:

Jeff Wright
Weston Solutions, Inc.
13702 Coursey Blvd, Bldg 7 Suite A
Baton Rouge, LA 70817-1370

Work Order Details:

SDG:	**18-08148**
Purchase Order:	0095131
Analysis Category:	ENVIRONMENTAL
Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
18-08148-04	DO	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Thorium-234	EPA 901.1 Modified	3.26E+01	2.95E+00	3.39E+00	2.50E+00	pCi/g
18-08148-04	DO	20-01-2-31-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Thallium-208	EPA 901.1 Modified	9.17E-01	2.04E-01	2.09E-01	2.10E-01	pCi/g
18-08148-05	TRG	20-01-2-32-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Actinium-228	EPA 901.1 Modified	9.53E-01	1.61E-01	1.68E-01	2.91E-01	pCi/g
18-08148-05	TRG	20-01-2-32-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Bismuth-214	EPA 901.1 Modified	7.12E+00	5.10E-01	6.28E-01	1.43E-01	pCi/g
18-08148-05	TRG	20-01-2-32-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Potassium-40	EPA 901.1 Modified	1.86E+01	1.92E+00	2.14E+00	8.91E-01	pCi/g
18-08148-05	TRG	20-01-2-32-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Protactinium-234m	EPA 901.1 Modified	3.70E+01	7.65E+00	7.88E+00	9.15E+00	pCi/g
18-08148-05	TRG	20-01-2-32-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-210	EPA 901.1 Modified	3.45E+00	9.52E-01	9.68E-01	1.70E+00	pCi/g
18-08148-05	TRG	20-01-2-32-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-212	EPA 901.1 Modified	6.46E-01	1.06E-01	1.11E-01	1.81E-01	pCi/g
18-08148-05	TRG	20-01-2-32-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-214	EPA 901.1 Modified	7.07E+00	8.64E-01	9.37E-01	1.89E-01	pCi/g
18-08148-05	TRG	20-01-2-32-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Radium-226	EPA 901.1 Modified	7.12E+00	5.10E-01	6.28E-01	1.43E-01	pCi/g
18-08148-05	TRG	20-01-2-32-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Thorium-234	EPA 901.1 Modified	3.34E+01	3.05E+00	3.49E+00	2.95E+00	pCi/g
18-08148-05	TRG	20-01-2-32-180213	02/23/18 00:00	8/28/2018	8/28/2018	18-08148	Thallium-208	EPA 901.1 Modified	1.06E+00	2.34E-01	2.40E-01	2.45E-01	pCi/g
18-08148-06	TRG	20-08-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Actinium-228	EPA 901.1 Modified	1.58E+00	4.15E-01	4.23E-01	2.78E-01	pCi/g
18-08148-06	TRG	20-08-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Bismuth-214	EPA 901.1 Modified	2.34E+00	2.96E-01	3.19E-01	2.03E-01	pCi/g
18-08148-06	TRG	20-08-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Potassium-40	EPA 901.1 Modified	2.26E+01	2.63E+00	2.87E+00	1.05E+00	pCi/g
18-08148-06	TRG	20-08-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Protactinium-234m	EPA 901.1 Modified	1.35E+01	6.05E+00	6.09E+00	8.70E+00	pCi/g
18-08148-06	TRG	20-08-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-210	EPA 901.1 Modified	1.23E+00	1.19E+00	1.19E+00	1.98E+00	pCi/g
18-08148-06	TRG	20-08-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-212	EPA 901.1 Modified	1.76E+00	5.12E-01	5.20E-01	1.92E-01	pCi/g
18-08148-06	TRG	20-08-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-214	EPA 901.1 Modified	2.27E+00	7.35E-01	7.45E-01	1.55E-01	pCi/g
18-08148-06	TRG	20-08-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Radium-226	EPA 901.1 Modified	2.34E+00	2.96E-01	3.19E-01	2.03E-01	pCi/g
18-08148-06	TRG	20-08-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Thorium-234	EPA 901.1 Modified	1.08E+01	1.49E+00	1.59E+00	1.98E+00	pCi/g
18-08148-06	TRG	20-08-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Thallium-208	EPA 901.1 Modified	1.65E+00	4.49E-01	4.57E-01	2.22E-01	pCi/g
18-08148-07	TRG	20-11-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Actinium-228	EPA 901.1 Modified	1.20E+00	1.97E-01	2.06E-01	2.20E-01	pCi/g
18-08148-07	TRG	20-11-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Bismuth-214	EPA 901.1 Modified	8.89E-01	5.18E-01	5.20E-01	1.42E-01	pCi/g
18-08148-07	TRG	20-11-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Potassium-40	EPA 901.1 Modified	1.83E+01	1.79E+00	2.02E+00	4.68E-01	pCi/g
18-08148-07	TRG	20-11-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Protactinium-234m	EPA 901.1 Modified	-7.84E-01	1.73E+00	1.73E+00	6.19E+00	pCi/g
18-08148-07	TRG	20-11-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-210	EPA 901.1 Modified	8.93E-01	1.03E+00	1.03E+00	1.71E+00	pCi/g
18-08148-07	TRG	20-11-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-212	EPA 901.1 Modified	1.22E+00	1.19E-01	1.35E-01	1.05E-01	pCi/g
18-08148-07	TRG	20-11-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Lead-214	EPA 901.1 Modified	8.90E-01	2.64E-01	2.68E-01	1.37E-01	pCi/g
18-08148-07	TRG	20-11-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Radium-226	EPA 901.1 Modified	8.89E-01	5.18E-01	5.20E-01	1.42E-01	pCi/g
18-08148-07	TRG	20-11-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Thorium-234	EPA 901.1 Modified	3.09E+00	1.12E+00	1.13E+00	1.81E+00	pCi/g
18-08148-07	TRG	20-11-2-31-180307	03/07/18 00:00	8/28/2018	8/28/2018	18-08148	Thallium-208	EPA 901.1 Modified	1.20E+00	6.77E-01	6.80E-01	2.40E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

MEMO

DATE: June 25, 2019

TO: Keith Delhomme, Robert Sherman

FROM: Rick Haaker RF Haaker

SUBJECT: Review of Gamma Spectroscopy Data Package, 18-08148

The file evaluated was SEC20_18-08148.EDD.xlsx.

This package consisted of 4 soil samples (1 of which was a replicate count that was analyzed twice for a total of 5 results), plus method blanks, lab control standards/spikes. All concentration units are in units of pCi/g, unless otherwise noted. The results are considered acceptable for use, except where noted otherwise. The following samples were analyzed by gamma spectroscopy.

SampleID_Table		
ClientID	LabID	Sample Type
20-01-2-31-180213	18-08148-03	DUP
20-01-2-31-180213	18-08148-04	DO
20-01-2-32-180213	18-08148-05	TRG
20-08-2-31-180307	18-08148-06	TRG
20-11-2-31-180307	18-08148-07	TRG

The data was delivered in the usual Microsoft excel data format.

No isotopes were detected in the method blank samples at levels that exceeded the minimum detectable activity.

The agreement between duplicate sample results was acceptable. The duplicate sample had approximately 4pCi/g radium-226 (a reasonable value considering the the cleanup level is about 6 pCi/g). The concentration of radium-226 in other samples ranged up to more than 7pCi/g.

Thorium-234 results were considerably more precise than protactinium-234m results. The protactinium-234m results should not by themselves be considered reliable. Th-234 was reported as present at levels that exceed the minimum detectable activity in samples as follows. Results are in the units of pCi/g.

Detected Th234			
ClientID	Analyte	Results	MDAC
20-01-2-31-180213	Thorium-234	30.8	2.54
20-01-2-32-180213	Thorium-234	33.37	2.95
20-08-2-31-180307	Thorium-234	10.83	1.98
20-11-2-31-180307	Thorium-234	3.09	1.81

Ignoring protactinium-234m, all other uranium decay chain analytes were detected in all samples except as follows:

NonDetects				
ClientID	**Analyte**	**Result**	**MDAC**	**ReportUnits**
20-08-2-31-180307	Lead-210	1.23	1.9837	pCi/g
20-11-2-31-180307	Lead-210	0.89	1.7144	pCi/g

This Eberline data package reports radium-226 as equal to bismuth-214, the radium-226 being assigned from the bismuth-214 values.

The degree of agreement between thorium-234 and radium-226 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that the thorium-234 results might be seriously biased by systematic error. The test statistic is the number of standard deviations by which the thorium-234 result exceeds the radium-226 result. If the test statistic is substantially less than zero, it implies that the reported radium-226 concentration is greater than the thorium-234 concentration. Gamma spectroscopy cannot detect thorium-230, **so agreement between thorium-234 and radium-226 doesn't provide *any* information about equilibrium between thorium-230 and radium-226.**

Equilibrium Th234 → Ra226		
ClientID	**Test Statistic**	**Disequilibrium Evidence**
20-01-2-31-180213	16.69	Strong
20-01-2-31-180213	16.84	Strong
20-01-2-32-180213	14.78	Strong
20-08-2-31-180307	10.47	Strong
20-11-2-31-180307	3.53	Strong

The degree of agreement between radium-226 and lead-210 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that there is no proficiency testing of radiochemistry laboratories for isotopes having gamma energies similar to those for lead-210. The test statistic is the number of standard deviations by which the radium-226 result exceeds the lead-210 result. If the test statistic is substantially less than zero, it implies that the reported lead-210 concentration is greater than the radium-226 concentration. Agreement between radium-226 and lead-210 doesn't provide ***any*** information about equilibrium between thorium-230 and radium-226.

Equilibrium Ra226 → Pb210		
ClientID	**Test Statistic**	**Disequilibrium Evidence**
20-01-2-31-180213	5.12	Strong
20-01-2-31-180213	3.58	Strong
20-01-2-32-180213	6.37	Strong
20-08-2-31-180307	1.8	Weak or none
20-11-2-31-180307	-0.01	Weak or none

Zero days elapsed from the date of receipt by Eberline to the date of analysis in their laboratory. Twenty-one days normally occurs between sealing and counting. The radium-226, lead-214, and bismuth-210 reported results may have a negative bias (i.e. they may have a tendency to be reported somewhat below their true value).

My impression is that the laboratory analyses are acceptable for use subject to the caveat that the radium-226, lead-214, and bismuth-210 reported results may have a negative bias.

The maximum and estimated 99%UCLs (assuming normal statistics) for nuisance radionuclides in pCi/g, based on all prior datasets are:

Analyte	Maximum	UCL99%
Actinium-228	2.19	2.14
Lead-212	8.45	3.4
Potassium-40	28.22	32.65
Thallium-208	2.12	1.97

For this dataset (data package), the following matrix of linear correlation coefficients was obtained for samples having a radium-226 concentration below 10pCi/g. Correlation coefficients can have a range between 1 and -1, and are a measure of tendency of pairs of ***reported*** isotopic concentrations to go up and down together in a linear fashion. These correlation coefficients are based on observations in the concentration range of interest to project engineers.

	Ac_228	Bi_214	Pb_210	Pb_212	Pb_214	K_40	Pa_234m	Ra_226	Tl_208	Th_234
Ac_228	1.00	-0.57	-0.54	0.96	-0.59	0.93	-0.63	-0.57	0.99	-0.76
Bi_214	-0.57	1.00	0.98	-0.56	1.00	-0.26	0.92	1.00	-0.44	0.84
Pb_210	-0.54	0.98	1.00	-0.48	0.98	-0.23	0.82	0.98	-0.40	0.74
Pb_212	0.96	-0.56	-0.48	1.00	-0.58	0.90	-0.71	-0.56	0.97	-0.84
Pb_214	-0.59	1.00	0.98	-0.58	1.00	-0.28	0.93	1.00	-0.47	0.86
K_40	0.93	-0.26	-0.23	0.90	-0.28	1.00	-0.36	-0.26	0.97	-0.53
Pa_234m	-0.63	0.92	0.82	-0.71	0.93	-0.36	1.00	0.92	-0.54	0.97
Ra_226	-0.57	1.00	0.98	-0.56	1.00	-0.26	0.92	1.00	-0.44	0.84
Tl_208	0.99	-0.44	-0.40	0.97	-0.47	0.97	-0.54	-0.44	1.00	-0.70
Th_234	-0.76	0.84	0.74	-0.84	0.86	-0.53	0.97	0.84	-0.70	1.00

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	**18-03095**
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
18-03095-01	LCS	KNOWN	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Cobalt-60	EPA 901.1 Modified	6.21E+01	2.48E+00			pCi/g
18-03095-01	LCS	KNOWN	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Cesium-137	EPA 901.1 Modified	3.94E+01	1.58E+00			pCi/g
18-03095-01	LCS	SPIKE	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Cobalt-60	EPA 901.1 Modified	7.35E+01	4.89E+00	6.18E+00	6.66E-01	pCi/g
18-03095-01	LCS	SPIKE	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Cesium-137	EPA 901.1 Modified	4.39E+01	3.96E+00	4.56E+00	6.31E-01	pCi/g
18-03095-02	MBL	BLANK	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Actinium-228	EPA 901.1 Modified	2.56E-03	5.97E-02	5.97E-02	1.08E-01	pCi/g
18-03095-02	MBL	BLANK	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Bismuth-214	EPA 901.1 Modified	2.16E-02	4.08E-02	4.08E-02	6.73E-02	pCi/g
18-03095-02	MBL	BLANK	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Potassium-40	EPA 901.1 Modified	-1.81E-01	3.03E-01	3.03E-01	3.75E-01	pCi/g
18-03095-02	MBL	BLANK	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Protactinium-234m	EPA 901.1 Modified	7.58E-02	9.68E-01	9.68E-01	3.79E+00	pCi/g
18-03095-02	MBL	BLANK	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Lead-212	EPA 901.1 Modified	2.05E-02	2.31E-02	2.31E-02	3.91E-02	pCi/g
18-03095-02	MBL	BLANK	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Lead-214	EPA 901.1 Modified	3.09E-02	2.93E-02	2.93E-02	5.44E-02	pCi/g
18-03095-02	MBL	BLANK	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Radium-226	EPA 901.1 Modified	2.16E-02	4.08E-02	4.08E-02	6.73E-02	pCi/g
18-03095-02	MBL	BLANK	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Thorium-234	EPA 901.1 Modified	2.18E-01	1.62E-01	1.63E-01	2.74E-01	pCi/g
18-03095-02	MBL	BLANK	03/20/18 00:00	3/20/2018	3/21/2018	18-03095	Thallium-208	EPA 901.1 Modified	-2.99E-03	6.62E-02	6.62E-02	9.62E-02	pCi/g
18-03095-03	DUP	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Actinium-228	EPA 901.1 Modified	9.94E-01	3.37E-01	3.40E-01	7.12E-01	pCi/g
18-03095-03	DUP	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Bismuth-214	EPA 901.1 Modified	1.06E+01	6.89E-01	8.77E-01	2.73E-01	pCi/g
18-03095-03	DUP	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Potassium-40	EPA 901.1 Modified	2.31E+01	3.15E+00	3.37E+00	2.39E+00	pCi/g
18-03095-03	DUP	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Protactinium-234m	EPA 901.1 Modified	1.31E+01	8.95E+00	8.97E+00	1.48E+01	pCi/g
18-03095-03	DUP	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-212	EPA 901.1 Modified	1.18E+00	1.64E-01	1.74E-01	3.23E-01	pCi/g
18-03095-03	DUP	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-214	EPA 901.1 Modified	9.90E+00	6.60E-01	8.33E-01	3.28E-01	pCi/g
18-03095-03	DUP	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Radium-226	EPA 901.1 Modified	1.06E+01	6.89E-01	8.77E-01	2.73E-01	pCi/g
18-03095-03	DUP	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Thorium-234	EPA 901.1 Modified	5.56E+00	1.14E+00	1.17E+00	1.61E+00	pCi/g
18-03095-03	DUP	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Thallium-208	EPA 901.1 Modified	9.76E-01	1.68E-01	1.75E-01	2.54E-02	pCi/g
18-03095-04	DO	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Actinium-228	EPA 901.1 Modified	1.25E+00	2.46E-01	2.54E-01	7.59E-01	pCi/g
18-03095-04	DO	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Bismuth-214	EPA 901.1 Modified	1.01E+01	6.56E-01	8.38E-01	2.78E-01	pCi/g
18-03095-04	DO	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Potassium-40	EPA 901.1 Modified	1.92E+01	2.84E+00	3.00E+00	2.55E+00	pCi/g
18-03095-04	DO	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Protactinium-234m	EPA 901.1 Modified	3.98E+00	9.32E+00	9.33E+00	1.47E+01	pCi/g
18-03095-04	DO	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-212	EPA 901.1 Modified	1.01E+00	1.45E-01	1.54E-01	2.67E-01	pCi/g
18-03095-04	DO	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-214	EPA 901.1 Modified	9.77E+00	6.68E-01	8.35E-01	3.33E-01	pCi/g
18-03095-04	DO	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Radium-226	EPA 901.1 Modified	1.01E+01	6.56E-01	8.38E-01	2.78E-01	pCi/g
18-03095-04	DO	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Thorium-234	EPA 901.1 Modified	3.95E+00	9.93E-01	1.01E+00	1.55E+00	pCi/g
18-03095-04	DO	17-11-2-31-170909	09/09/17 00:00	3/20/2018	3/21/2018	18-03095	Thallium-208	EPA 901.1 Modified	1.03E+00	1.81E-01	1.88E-01	1.25E-01	pCi/g
18-03095-05	TRG	17-14-2-31-170904	09/04/17 00:00	3/20/2018	3/21/2018	18-03095	Actinium-228	EPA 901.1 Modified	1.91E+00	3.06E-01	3.21E-01	3.65E-01	pCi/g
18-03095-05	TRG	17-14-2-31-170904	09/04/17 00:00	3/20/2018	3/21/2018	18-03095	Bismuth-214	EPA 901.1 Modified	3.07E+00	3.79E-01	4.11E-01	3.39E-01	pCi/g
18-03095-05	TRG	17-14-2-31-170904	09/04/17 00:00	3/20/2018	3/21/2018	18-03095	Potassium-40	EPA 901.1 Modified	1.72E+01	1.80E+00	2.00E+00	9.34E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	**18-03095**
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
18-03095-05	TRG	17-14-2-31-170904	09/04/17 00:00	3/20/2018	3/21/2018	18-03095	Protactinium-234m	EPA 901.1 Modified	5.40E+00	5.62E+00	5.62E+00	9.48E+00	pCi/g
18-03095-05	TRG	17-14-2-31-170904	09/04/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-212	EPA 901.1 Modified	2.98E+00	2.91E-01	3.29E-01	2.71E-01	pCi/g
18-03095-05	TRG	17-14-2-31-170904	09/04/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-214	EPA 901.1 Modified	3.58E+00	1.05E+00	1.07E+00	2.36E-01	pCi/g
18-03095-05	TRG	17-14-2-31-170904	09/04/17 00:00	3/20/2018	3/21/2018	18-03095	Radium-226	EPA 901.1 Modified	3.07E+00	3.79E-01	4.11E-01	3.39E-01	pCi/g
18-03095-05	TRG	17-14-2-31-170904	09/04/17 00:00	3/20/2018	3/21/2018	18-03095	Thorium-234	EPA 901.1 Modified	1.99E+01	2.26E+00	2.48E+00	1.08E+01	pCi/g
18-03095-05	TRG	17-14-2-31-170904	09/04/17 00:00	3/20/2018	3/21/2018	18-03095	Thallium-208	EPA 901.1 Modified	1.32E+00	1.97E-01	2.08E-01	7.70E-02	pCi/g
18-03095-06	TRG	17-19-2-31-170906	09/06/17 00:00	3/20/2018	3/21/2018	18-03095	Actinium-228	EPA 901.1 Modified	1.98E+00	3.92E-01	4.05E-01	6.65E-01	pCi/g
18-03095-06	TRG	17-19-2-31-170906	09/06/17 00:00	3/20/2018	3/21/2018	18-03095	Bismuth-214	EPA 901.1 Modified	1.15E+01	7.08E-01	9.21E-01	3.59E-01	pCi/g
18-03095-06	TRG	17-19-2-31-170906	09/06/17 00:00	3/20/2018	3/21/2018	18-03095	Potassium-40	EPA 901.1 Modified	1.91E+01	2.71E+00	2.88E+00	2.16E+00	pCi/g
18-03095-06	TRG	17-19-2-31-170906	09/06/17 00:00	3/20/2018	3/21/2018	18-03095	Protactinium-234m	EPA 901.1 Modified	1.63E+01	1.01E+01	1.01E+01	1.66E+01	pCi/g
18-03095-06	TRG	17-19-2-31-170906	09/06/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-212	EPA 901.1 Modified	1.93E+00	2.25E-01	2.45E-01	3.85E-01	pCi/g
18-03095-06	TRG	17-19-2-31-170906	09/06/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-214	EPA 901.1 Modified	1.09E+01	7.01E-01	8.95E-01	3.50E-01	pCi/g
18-03095-06	TRG	17-19-2-31-170906	09/06/17 00:00	3/20/2018	3/21/2018	18-03095	Radium-226	EPA 901.1 Modified	1.15E+01	7.08E-01	9.21E-01	3.59E-01	pCi/g
18-03095-06	TRG	17-19-2-31-170906	09/06/17 00:00	3/20/2018	3/21/2018	18-03095	Thorium-234	EPA 901.1 Modified	1.86E+01	2.16E+00	2.36E+00	5.48E+00	pCi/g
18-03095-06	TRG	17-19-2-31-170906	09/06/17 00:00	3/20/2018	3/21/2018	18-03095	Thallium-208	EPA 901.1 Modified	1.58E+00	2.25E-01	2.40E-01	2.50E-02	pCi/g
18-03095-07	TRG	17-32-2-31-170912	09/12/17 00:00	3/20/2018	3/21/2018	18-03095	Actinium-228	EPA 901.1 Modified	1.76E+00	2.48E-01	2.64E-01	4.31E-01	pCi/g
18-03095-07	TRG	17-32-2-31-170912	09/12/17 00:00	3/20/2018	3/21/2018	18-03095	Bismuth-214	EPA 901.1 Modified	3.35E+00	3.04E-01	3.49E-01	2.53E-01	pCi/g
18-03095-07	TRG	17-32-2-31-170912	09/12/17 00:00	3/20/2018	3/21/2018	18-03095	Potassium-40	EPA 901.1 Modified	2.36E+01	3.05E+00	3.28E+00	1.59E+00	pCi/g
18-03095-07	TRG	17-32-2-31-170912	09/12/17 00:00	3/20/2018	3/21/2018	18-03095	Protactinium-234m	EPA 901.1 Modified	4.14E+01	1.01E+01	1.03E+01	1.38E+01	pCi/g
18-03095-07	TRG	17-32-2-31-170912	09/12/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-212	EPA 901.1 Modified	1.83E+00	2.00E-01	2.21E-01	2.26E-01	pCi/g
18-03095-07	TRG	17-32-2-31-170912	09/12/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-214	EPA 901.1 Modified	3.09E+00	2.40E-01	2.88E-01	2.56E-01	pCi/g
18-03095-07	TRG	17-32-2-31-170912	09/12/17 00:00	3/20/2018	3/21/2018	18-03095	Radium-226	EPA 901.1 Modified	3.35E+00	3.04E-01	3.49E-01	2.53E-01	pCi/g
18-03095-07	TRG	17-32-2-31-170912	09/12/17 00:00	3/20/2018	3/21/2018	18-03095	Thorium-234	EPA 901.1 Modified	3.47E+01	3.10E+00	3.57E+00	2.48E+00	pCi/g
18-03095-07	TRG	17-32-2-31-170912	09/12/17 00:00	3/20/2018	3/21/2018	18-03095	Thallium-208	EPA 901.1 Modified	1.38E+00	1.78E-01	1.92E-01	2.73E-02	pCi/g
18-03095-08	TRG	17-40-2-31-170915	09/15/17 00:00	3/20/2018	3/21/2018	18-03095	Actinium-228	EPA 901.1 Modified	2.09E+00	2.62E-01	2.83E-01	5.44E-01	pCi/g
18-03095-08	TRG	17-40-2-31-170915	09/15/17 00:00	3/20/2018	3/21/2018	18-03095	Bismuth-214	EPA 901.1 Modified	2.24E+00	2.44E-01	2.69E-01	2.24E-01	pCi/g
18-03095-08	TRG	17-40-2-31-170915	09/15/17 00:00	3/20/2018	3/21/2018	18-03095	Potassium-40	EPA 901.1 Modified	2.71E+01	3.40E+00	3.67E+00	1.35E+00	pCi/g
18-03095-08	TRG	17-40-2-31-170915	09/15/17 00:00	3/20/2018	3/21/2018	18-03095	Protactinium-234m	EPA 901.1 Modified	4.99E+00	6.59E+00	6.59E+00	1.09E+01	pCi/g
18-03095-08	TRG	17-40-2-31-170915	09/15/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-212	EPA 901.1 Modified	2.28E+00	2.33E-01	2.61E-01	2.22E-01	pCi/g
18-03095-08	TRG	17-40-2-31-170915	09/15/17 00:00	3/20/2018	3/21/2018	18-03095	Lead-214	EPA 901.1 Modified	2.24E+00	1.92E-01	2.24E-01	2.14E-01	pCi/g
18-03095-08	TRG	17-40-2-31-170915	09/15/17 00:00	3/20/2018	3/21/2018	18-03095	Radium-226	EPA 901.1 Modified	2.24E+00	2.44E-01	2.69E-01	2.24E-01	pCi/g
18-03095-08	TRG	17-40-2-31-170915	09/15/17 00:00	3/20/2018	3/21/2018	18-03095	Thorium-234	EPA 901.1 Modified	1.89E+00	9.46E-01	9.51E-01	1.55E+00	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical Final Report of Analysis	Report To:	Work Order Details:	
	Jeff Wright	SDG:	18-03095
	Weston Solutions, Inc.	Purchase Order:	0095131
	13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
	Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
18-03095-08	TRG	17-40-2-31-170915	09/15/17 00:00	3/20/2018	3/21/2018	18-03095	Thallium-208	EPA 901.1 Modified	1.92E+00	2.29E-01	2.50E-01	1.47E-01	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (1-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

MEMO

DATE: June 25, 2019

TO: Keith Delhomme, Robert Sherman

FROM: Rick Haaker RF Haaker

SUBJECT: Review of Gamma Spectroscopy Data Package, 18-03095

The file evaluated was SEC17_18-03095.EDD.xlsx.

This package consisted of 5 soil samples (1 of which was a replicate count that was analyzed twice for a total of 6 results), plus method blanks, lab control standards/spikes. All concentration units are in units of pCi/g, unless otherwise noted. The results are considered acceptable for use, except where noted otherwise. The following samples were analyzed by gamma spectroscopy.

SampleID_Table		
ClientID	LabID	Sample Type
17-11-2-31-170909	18-03095-03	DUP
17-11-2-31-170909	18-03095-04	DO
17-14-2-31-170904	18-03095-05	TRG
17-19-2-31-170906	18-03095-06	TRG
17-32-2-31-170912	18-03095-07	TRG
17-40-2-31-170915	18-03095-08	TRG

The data was delivered in the usual Microsoft excel data format.

No isotopes were detected in the method blank samples at levels that exceeded the minimum detectable activity.

The agreement between duplicate sample results was acceptable, with the exception that thorium-234 should be considered more uncertain than usual. The duplicate sample had approximately 10pCi/g radium-226 (a reasonable value) while the concentration of radium-226 in other samples ranged up to more than 11 pCi/g.

Thorium-234 results were considerably more precise than protactinium-234m results. The protactinium-234m results should not by themselves be considered reliable. Th-234 was reported as present at levels that exceed the minimum detectable activity in samples as follows. Results are in the units of pCi/g.

Detected Th234			
ClientID	Analyte	Results	MDAC
17-11-2-31-170909	Thorium-234	5.56	1.61
17-14-2-31-170904	Thorium-234	19.93	10.76
17-19-2-31-170906	Thorium-234	18.64	5.48
17-32-2-31-170912	Thorium-234	34.65	2.48
17-40-2-31-170915	Thorium-234	1.89	1.55

Ignoring protactinium-234m, all other uranium decay chain analytes were detected in all samples except as follows:

None

This Eberline data package reports radium-226 as equal to bismuth-214, the radium-226 being assigned from the bismuth-214 values.

The degree of agreement between thorium-234 and radium-226 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that the thorium-234 results might be seriously biased by systematic error. The test statistic is the number of standard deviations by which the thorium-234 result exceeds the radium-226 result. If the test statistic is substantially less than zero, it implies that the reported radium-226 concentration is greater than the thorium-234 concentration. Gamma spectroscopy cannot detect thorium-230, **so agreement between thorium-234 and radium-226 doesn't provide *any* information about equilibrium between thorium-230 and radium-226.**

Equilibrium Th234 ->		
ClientID	**Test Statistic**	**Disequilibrium Evidence**
17-11-2-31-170909	-6.85	Strong
17-11-2-31-170909	-9.42	Strong
17-14-2-31-170904	13.41	Strong
17-19-2-31-170906	5.66	Strong
17-32-2-31-170912	17.44	Strong
17-40-2-31-170915	-0.7	Weak or none

The degree of agreement between radium-226 and lead-210 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that there is no proficiency testing of radiochemistry laboratories for isotopes having gamma energies similar to those for lead-210. The test statistic is the number of standard deviations by which the radium-226 result exceeds the lead-210 result. If the test statistic is substantially less than zero, it implies that the reported lead-210 concentration is greater than the radium-226 concentration. Agreement between radium-226 and lead-210 doesn't provide ***any*** information about equilibrium between thorium-230 and radium-226.

No Lead-210 results were reported for this data package.

One days elapsed from the date of receipt by Eberline to the date of analysis in their laboratory. Twenty-one days normally occurs between sealing and counting. The radium-226, lead-214, and bismuth-210 reported results <u>may</u> have a negative bias (i.e. they may have a tendency to be reported somewhat below their true value).

My impression is that the laboratory analyses are acceptable for use subject to the caveat that the radium-226, lead-214, and bismuth-210 reported results <u>may</u> have a negative bias and thorium-234 results appear to be more uncertain than usual.

The maximum and estimated 99%UCLs (assuming normal statistics) for nuisance radionuclides in pCi/g, based on all prior datasets are:

Analyte	Maximum	UCL99%
Actinium-228	2.19	2.08
Lead-212	8.45	3.38
Potassium-40	28.22	32.42
Thallium-208	2.12	1.94

For this dataset (data package), the following matrix of linear correlation coefficients was obtained for samples having a radium-226 concentration below 10pCi/g. Correlation coefficients can have a range between 1 and -1, and are a measure of tendency of pairs of ***reported*** isotopic concentrations to go up and down together in a linear fashion. These correlation coefficients are based on observations in the concentration range of interest to project engineers.

	Ac_228	Bi_214	Pb_212	Pb_214	K_40	Pa_234m	Ra_226	Tl_208	Th_234
Ac_228	1.00	-0.98	0.32	-0.68	0.42	-0.83	-0.98	0.85	-1.00
Bi_214	-0.98	1.00	-0.12	0.82	-0.60	0.70	1.00	-0.94	0.98
Pb_212	0.32	-0.12	1.00	0.47	-0.72	-0.79	-0.12	-0.22	-0.34
Pb_214	-0.68	0.82	0.47	1.00	-0.95	0.16	0.82	-0.96	0.67
K_40	0.42	-0.60	-0.72	-0.95	1.00	0.15	-0.60	0.83	-0.41
Pa_234m	-0.83	0.70	-0.79	0.16	0.15	1.00	0.70	-0.42	0.84
Ra_226	-0.98	1.00	-0.12	0.82	-0.60	0.70	1.00	-0.94	0.98
Tl_208	0.85	-0.94	-0.22	-0.96	0.83	-0.42	-0.94	1.00	-0.85
Th_234	-1.00	0.98	-0.34	0.67	-0.41	0.84	0.98	-0.85	1.00

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-10097
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-10097-01	LCS	KNOWN	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Cobalt-60	EPA 901.1 Modified	6.21E+01	2.48E+00			pCi/g
17-10097-01	LCS	KNOWN	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Cesium-137	EPA 901.1 Modified	3.94E+01	1.58E+00			pCi/g
17-10097-01	LCS	SPIKE	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Cobalt-60	EPA 901.1 Modified	7.05E+01	4.69E+00	5.92E+00	6.20E-01	pCi/g
17-10097-01	LCS	SPIKE	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Cesium-137	EPA 901.1 Modified	4.28E+01	3.88E+00	4.46E+00	6.69E-01	pCi/g
17-10097-02	MBL	BLANK	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Actinium-228	EPA 901.1 Modified	1.66E-02	3.94E-02	3.94E-02	7.67E-02	pCi/g
17-10097-02	MBL	BLANK	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Bismuth-214	EPA 901.1 Modified	3.06E-02	3.20E-02	3.20E-02	5.20E-02	pCi/g
17-10097-02	MBL	BLANK	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Potassium-40	EPA 901.1 Modified	1.43E-01	9.98E-02	1.00E-01	4.84E-02	pCi/g
17-10097-02	MBL	BLANK	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Protactinium-234m	EPA 901.1 Modified	-9.07E-01	1.69E+00	1.69E+00	2.40E+00	pCi/g
17-10097-02	MBL	BLANK	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-212	EPA 901.1 Modified	1.69E-02	1.90E-02	1.90E-02	3.24E-02	pCi/g
17-10097-02	MBL	BLANK	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-214	EPA 901.1 Modified	-8.04E-03	2.74E-02	2.74E-02	3.88E-02	pCi/g
17-10097-02	MBL	BLANK	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Radium-226	EPA 901.1 Modified	3.06E-02	3.20E-02	3.20E-02	5.20E-02	pCi/g
17-10097-02	MBL	BLANK	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Thorium-234	EPA 901.1 Modified	4.15E-01	3.15E-01	3.16E-01	4.63E-01	pCi/g
17-10097-02	MBL	BLANK	10/20/17 00:00	10/20/2017	10/23/2017	17-10097	Thallium-208	EPA 901.1 Modified	-3.93E-03	2.53E-02	2.53E-02	4.59E-02	pCi/g
17-10097-03	DUP	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Actinium-228	EPA 901.1 Modified	7.67E-01	2.04E-01	2.08E-01	4.63E-01	pCi/g
17-10097-03	DUP	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Bismuth-214	EPA 901.1 Modified	8.05E+00	5.97E-01	7.26E-01	1.77E-01	pCi/g
17-10097-03	DUP	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Potassium-40	EPA 901.1 Modified	1.19E+01	1.46E+00	1.58E+00	1.24E+00	pCi/g
17-10097-03	DUP	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Protactinium-234m	EPA 901.1 Modified	6.28E+00	6.11E+00	6.12E+00	1.01E+01	pCi/g
17-10097-03	DUP	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-212	EPA 901.1 Modified	-9.56E-02	6.78E-02	6.80E-02	2.00E-01	pCi/g
17-10097-03	DUP	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-214	EPA 901.1 Modified	8.18E+00	2.05E+00	2.10E+00	2.85E-01	pCi/g
17-10097-03	DUP	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Radium-226	EPA 901.1 Modified	8.05E+00	5.97E-01	7.26E-01	1.77E-01	pCi/g
17-10097-03	DUP	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Thorium-234	EPA 901.1 Modified	1.03E+01	2.06E+00	2.12E+00	3.10E+00	pCi/g
17-10097-03	DUP	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Thallium-208	EPA 901.1 Modified	4.52E-01	9.85E-02	1.01E-01	1.42E-02	pCi/g
17-10097-04	DO	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Actinium-228	EPA 901.1 Modified	4.86E-01	1.90E-01	1.92E-01	4.07E-01	pCi/g
17-10097-04	DO	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Bismuth-214	EPA 901.1 Modified	7.19E+00	5.57E-01	6.68E-01	2.03E-01	pCi/g
17-10097-04	DO	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Potassium-40	EPA 901.1 Modified	1.34E+01	1.55E+00	1.69E+00	1.15E+00	pCi/g
17-10097-04	DO	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Protactinium-234m	EPA 901.1 Modified	8.63E+00	6.60E+00	6.62E+00	1.08E+01	pCi/g
17-10097-04	DO	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-212	EPA 901.1 Modified	1.99E-01	8.12E-02	8.18E-02	2.02E-01	pCi/g
17-10097-04	DO	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-214	EPA 901.1 Modified	8.33E+00	2.09E+00	2.13E+00	2.68E-01	pCi/g
17-10097-04	DO	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Radium-226	EPA 901.1 Modified	7.19E+00	5.57E-01	6.68E-01	2.03E-01	pCi/g
17-10097-04	DO	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Thorium-234	EPA 901.1 Modified	6.49E+00	1.51E+00	1.55E+00	2.33E+00	pCi/g
17-10097-04	DO	17-09-2-31-170818	08/18/17 00:00	10/20/2017	10/23/2017	17-10097	Thallium-208	EPA 901.1 Modified	3.76E-01	9.34E-02	9.54E-02	5.97E-02	pCi/g
17-10097-05	TRG	29-02-2-31-170713	07/13/17 00:00	10/20/2017	10/23/2017	17-10097	Actinium-228	EPA 901.1 Modified	1.91E+00	2.69E-01	2.86E-01	5.41E-01	pCi/g
17-10097-05	TRG	29-02-2-31-170713	07/13/17 00:00	10/20/2017	10/23/2017	17-10097	Bismuth-214	EPA 901.1 Modified	1.47E+00	1.96E-01	2.10E-01	2.01E-01	pCi/g
17-10097-05	TRG	29-02-2-31-170713	07/13/17 00:00	10/20/2017	10/23/2017	17-10097	Potassium-40	EPA 901.1 Modified	2.30E+01	3.07E+00	3.29E+00	1.38E+00	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:

Jeff Wright
Weston Solutions, Inc.
13702 Coursey Blvd, Bldg 7 Suite A
Baton Rouge, LA 70817-1370

Work Order Details:

SDG:	**17-10097**
Purchase Order:	0095131
Analysis Category:	ENVIRONMENTAL
Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-10097-05	TRG	29-02-2-31-170713	07/13/17 00:00	10/20/2017	10/23/2017	17-10097	Protactinium-234m	EPA 901.1 Modified	3.74E+00	7.63E+00	7.63E+00	1.13E+01	pCi/g
17-10097-05	TRG	29-02-2-31-170713	07/13/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-212	EPA 901.1 Modified	1.70E+00	1.88E-01	2.07E-01	2.05E-01	pCi/g
17-10097-05	TRG	29-02-2-31-170713	07/13/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-214	EPA 901.1 Modified	1.52E+00	1.53E-01	1.72E-01	2.38E-01	pCi/g
17-10097-05	TRG	29-02-2-31-170713	07/13/17 00:00	10/20/2017	10/23/2017	17-10097	Radium-226	EPA 901.1 Modified	1.47E+00	1.96E-01	2.10E-01	2.01E-01	pCi/g
17-10097-05	TRG	29-02-2-31-170713	07/13/17 00:00	10/20/2017	10/23/2017	17-10097	Thorium-234	EPA 901.1 Modified	2.66E+00	1.01E+00	1.02E+00	3.34E+00	pCi/g
17-10097-05	TRG	29-02-2-31-170713	07/13/17 00:00	10/20/2017	10/23/2017	17-10097	Thallium-208	EPA 901.1 Modified	1.48E+00	1.97E-01	2.11E-01	1.88E-01	pCi/g
17-10097-06	TRG	29-18-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Actinium-228	EPA 901.1 Modified	1.64E+00	1.84E-01	2.03E-01	2.34E-01	pCi/g
17-10097-06	TRG	29-18-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Bismuth-214	EPA 901.1 Modified	1.17E+00	1.43E-01	1.55E-01	1.18E-01	pCi/g
17-10097-06	TRG	29-18-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Potassium-40	EPA 901.1 Modified	1.91E+01	1.98E+00	2.21E+00	4.92E-01	pCi/g
17-10097-06	TRG	29-18-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Protactinium-234m	EPA 901.1 Modified	1.95E+00	3.28E+00	3.28E+00	5.21E+00	pCi/g
17-10097-06	TRG	29-18-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-212	EPA 901.1 Modified	1.85E+00	2.29E-01	2.48E-01	1.09E-01	pCi/g
17-10097-06	TRG	29-18-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-214	EPA 901.1 Modified	1.33E+00	1.75E-01	1.88E-01	1.12E-01	pCi/g
17-10097-06	TRG	29-18-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Radium-226	EPA 901.1 Modified	1.17E+00	1.43E-01	1.55E-01	1.18E-01	pCi/g
17-10097-06	TRG	29-18-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Thorium-234	EPA 901.1 Modified	2.16E+00	8.44E-01	8.52E-01	1.36E+00	pCi/g
17-10097-06	TRG	29-18-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Thallium-208	EPA 901.1 Modified	1.69E+00	2.28E-01	2.44E-01	6.74E-02	pCi/g
17-10097-07	TRG	29-19-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Actinium-228	EPA 901.1 Modified	1.63E+00	2.33E-01	2.47E-01	4.16E-01	pCi/g
17-10097-07	TRG	29-19-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Bismuth-214	EPA 901.1 Modified	1.51E+00	1.88E-01	2.03E-01	2.07E-01	pCi/g
17-10097-07	TRG	29-19-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Potassium-40	EPA 901.1 Modified	2.32E+01	3.01E+00	3.23E+00	1.27E+00	pCi/g
17-10097-07	TRG	29-19-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Protactinium-234m	EPA 901.1 Modified	7.23E+00	6.53E+00	6.54E+00	1.51E+01	pCi/g
17-10097-07	TRG	29-19-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-212	EPA 901.1 Modified	1.60E+00	1.71E-01	1.90E-01	1.66E-01	pCi/g
17-10097-07	TRG	29-19-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-214	EPA 901.1 Modified	1.60E+00	1.54E-01	1.74E-01	2.09E-01	pCi/g
17-10097-07	TRG	29-19-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Radium-226	EPA 901.1 Modified	1.51E+00	1.88E-01	2.03E-01	2.07E-01	pCi/g
17-10097-07	TRG	29-19-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Thorium-234	EPA 901.1 Modified	2.33E+00	7.84E-01	7.93E-01	1.25E+00	pCi/g
17-10097-07	TRG	29-19-2-31-170714	07/14/17 00:00	10/20/2017	10/23/2017	17-10097	Thallium-208	EPA 901.1 Modified	1.56E+00	1.80E-01	1.97E-01	2.77E-02	pCi/g
17-10097-08	TRG	29-36-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Actinium-228	EPA 901.1 Modified	1.37E+00	1.64E-01	1.78E-01	2.15E-01	pCi/g
17-10097-08	TRG	29-36-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Bismuth-214	EPA 901.1 Modified	1.22E+00	1.46E-01	1.59E-01	1.25E-01	pCi/g
17-10097-08	TRG	29-36-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Potassium-40	EPA 901.1 Modified	1.78E+01	1.89E+00	2.10E+00	6.78E-01	pCi/g
17-10097-08	TRG	29-36-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Protactinium-234m	EPA 901.1 Modified	6.08E+00	4.19E+00	4.20E+00	6.71E+00	pCi/g
17-10097-08	TRG	29-36-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-212	EPA 901.1 Modified	1.25E+00	1.57E-01	1.69E-01	1.11E-01	pCi/g
17-10097-08	TRG	29-36-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-214	EPA 901.1 Modified	1.24E+00	1.65E-01	1.77E-01	1.13E-01	pCi/g
17-10097-08	TRG	29-36-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Radium-226	EPA 901.1 Modified	1.22E+00	1.46E-01	1.59E-01	1.25E-01	pCi/g
17-10097-08	TRG	29-36-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Thorium-234	EPA 901.1 Modified	1.91E+00	9.43E-01	9.48E-01	1.54E+00	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

Eberline Analytical
Final Report of Analysis

Report To:	Work Order Details:	
Jeff Wright	SDG:	17-10097
Weston Solutions, Inc.	Purchase Order:	0095131
13702 Coursey Blvd, Bldg 7 Suite A	Analysis Category:	ENVIRONMENTAL
Baton Rouge, LA 70817-1370	Sample Matrix:	SO

LabID	SampleType	ClientID	SampleDate	ReceiptDate	AnalysisDate	BatchID	Analyte	Method	Result	CU	CSU	MDA	ReportUnits
17-10097-08	TRG	29-36-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Thallium-208	EPA 901.1 Modified	1.36E+00	2.04E-01	2.16E-01	1.69E-01	pCi/g
17-10097-09	TRG	29-39-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Actinium-228	EPA 901.1 Modified	1.78E+00	4.58E-01	4.67E-01	2.89E-01	pCi/g
17-10097-09	TRG	29-39-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Bismuth-214	EPA 901.1 Modified	1.83E+00	2.42E-01	2.59E-01	1.61E-01	pCi/g
17-10097-09	TRG	29-39-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Potassium-40	EPA 901.1 Modified	2.19E+01	2.55E+00	2.79E+00	7.15E-01	pCi/g
17-10097-09	TRG	29-39-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Protactinium-234m	EPA 901.1 Modified	2.83E+00	3.35E+00	3.36E+00	5.13E+00	pCi/g
17-10097-09	TRG	29-39-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-212	EPA 901.1 Modified	1.69E+00	5.15E-01	5.22E-01	1.65E-01	pCi/g
17-10097-09	TRG	29-39-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Lead-214	EPA 901.1 Modified	1.66E+00	5.42E-01	5.49E-01	1.23E-01	pCi/g
17-10097-09	TRG	29-39-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Radium-226	EPA 901.1 Modified	1.83E+00	2.42E-01	2.59E-01	1.61E-01	pCi/g
17-10097-09	TRG	29-39-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Thorium-234	EPA 901.1 Modified	2.15E+00	1.04E+00	1.04E+00	1.70E+00	pCi/g
17-10097-09	TRG	29-39-2-31-170728	07/28/17 00:00	10/20/2017	10/23/2017	17-10097	Thallium-208	EPA 901.1 Modified	1.76E+00	3.36E-01	3.48E-01	4.68E-02	pCi/g

CU=Counting Uncertainty;CSU=Combined Standard Uncertainty (2-sigma);MDA=Minimal Detected Activity;LCS=Laboratory Control Sample; MBL=Blank; DUP=Duplicate; TRG=Normal Sample; DO=Duplicate Original

MEMO

DATE: June 23, 2019

TO: Keith Delhomme, Robert Sherman

FROM: Rick Haaker RF Haaker

SUBJECT: Review of Gamma Spectroscopy Data Package, 17-10097

The file evaluated was SEC17_17-10097.EDD.xlsx.

This package consisted of 6 soil samples (1 of which was a replicate count that was analyzed twice for a total of 7 results), plus method blanks, lab control standards/spikes. All concentration units are in units of pCi/g, unless otherwise noted. The results are considered acceptable for use, except where noted otherwise. The following samples were analyzed by gamma spectroscopy.

SampleID_Table		
ClientID	**LabID**	**Sample Type**
17-09-2-31-170818	17-10097-03	DUP
17-09-2-31-170818	17-10097-04	DO
29-02-2-31-170713	17-10097-05	TRG
29-18-2-31-170714	17-10097-06	TRG
29-19-2-31-170714	17-10097-07	TRG
29-36-2-31-170728	17-10097-08	TRG
29-39-2-31-170728	17-10097-09	TRG

The data was delivered in the usual Microsoft excel data format.

Potassium-40 activity was detected (0.14pCi/g) in the method blank samples at levels that exceeded the minimum detectable activity. This is an insignificant concentration compared to the values always observed in soil samples and is no cause for concern.

The agreement between duplicate sample results was acceptable for all analytes, except for:

- lead-212, a nuisance isotope, was high, so regard those results as **much** more uncertain than usual.
- thorium-234, was high, so regard those results as **much** more uncertain than usual.
- Actinium-228, a nuisance isotope, was more uncertain than usual.

Thorium-234 results were considerably more precise than protactinium-234m results. The protactinium-234m results should not by themselves be considered reliable. Th-234 was reported as present at levels that exceed the minimum detectable activity in samples as follows. Results are in the units of pCi/g.

17-10097

Detected_Pa234m_Th234			
ClientID	**Analyte**	**Results**	**MDAC**
17-09-2-31-170818	Thorium-234	10.33	3.1
29-18-2-31-170714	Thorium-234	2.16	1.36
29-19-2-31-170714	Thorium-234	2.33	1.25
29-36-2-31-170728	Thorium-234	1.91	1.54
29-39-2-31-170728	Thorium-234	2.15	1.7

Ignoring protactinium-234m, all other uranium decay chain analytes were detected in all samples except as follows:

NonDetects6				
ClientID	**Analyte**	**Result**	**MDAC**	**ReportUnits**
29-02-2-31-170713	Thorium-234	2.66	3.3424	pCi/g

This Eberline data package reports radium-226 as equal to bismuth-214, the radium-226 being assigned from the bismuth-214 values.

The degree of agreement between thorium-234 and radium-226 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that the thorium-234 results might be seriously biased by systematic error. The test statistic is the number of standard deviations by which the thorium-234 result exceeds the radium-226 result. If the test statistic is substantially less than zero, it implies that the reported radium-226 concentration is greater than the thorium-234 concentration. Gamma spectroscopy cannot detect thorium-230, so agreement between thorium-234 and radium-226 doesn't provide ***any*** information about equilibrium between thorium-230 and radium-226.

EquilibriumTh234 – Ra-226		
ClientID	**Test Statistic**	**Disequilibrium Evidence**
17-09-2-31-170818	2.03	Moderate
17-09-2-31-170818	-0.83	Weak or none
29-02-2-31-170713	2.27	Moderate
29-18-2-31-170714	2.29	Moderate
29-19-2-31-170714	2.01	Moderate
29-36-2-31-170728	1.44	Weak or none
29-39-2-31-170728	0.59	Weak or none

The degree of agreement between radium-226 and lead-210 is summarized in the following table. The remark about strength of evidence of disequilibrium is subject to the caveat that there is no proficiency testing of radiochemistry laboratories for isotopes having gamma energies similar to those for lead-210. The test statistic is the number of standard deviations by which the radium-226 result exceeds the lead-210 result. If the test statistic is substantially less than zero, it implies that the reported lead-210 concentration is greater than the radium-226 concentration. Agreement between radium-226 and lead-210 doesn't provide ***any*** information about equilibrium between thorium-230 and radium-226.

No Lead-210 results were reported for this data package.

Three days elapsed from the date of receipt by Eberline to the date of analysis in their laboratory. Twenty-one days normally occurs between sealing and counting. The radium-226, lead-214, and bismuth-210 reported results may have a negative bias (i.e. they may have a strong tendency to be reported somewhat below their true value).

My impression is that the laboratory analyses are acceptable for use subject to the caveat that thorium-234 results are more uncertain than usual and the radium-226, lead-214, and bismuth-210 reported results may have a negative bias.

The maximum and estimated 99%UCLs (assuming normal statistics) for nuisance radionuclides in pCi/g, based on all prior datasets are:

Analyte	Maximum	UCL99%
Actinium-228	2.19	1.98
Lead-212	8.45	3.41
Potassium-40	26.79	31.93
Thallium-208	2.12	1.85

For this dataset(data package), the following matrix of linear correlation coefficients was obtained for samples having a radium-226 concentration below 10pCi/g. Correlation coefficients can have a range between 1 and -1, and are a measure of tendency of pairs of ***reported*** isotopic concentrations to go up and down together in a linear fashion. These correlation coefficients are based on observations in the concentration range of interest to project engineers.

	Ac-228	Bi-214	Pb-212	Pb-214	K-40	Pa-234m	Ra-226	Tl-208	Th-234
Ac-228	1.00	-0.91	0.94	-0.93	0.93	-0.73	-0.91	0.95	-0.81
Bi-214	-0.91	1.00	-0.97	0.99	-0.88	0.58	1.00	-0.96	0.96
Pb-212	0.94	-0.97	1.00	-0.96	0.92	-0.69	-0.97	0.98	-0.93
Pb-214	-0.93	0.99	-0.96	1.00	-0.88	0.62	0.99	-0.97	0.93
K-40	0.93	-0.88	0.92	-0.88	1.00	-0.48	-0.88	0.90	-0.85
Pa-234m	-0.73	0.58	-0.69	0.62	-0.48	1.00	0.58	-0.71	0.48
Ra-226	-0.91	1.00	-0.97	0.99	-0.88	0.58	1.00	-0.96	0.96
Tl-208	0.95	-0.96	0.98	-0.97	0.90	-0.71	-0.96	1.00	-0.90
Th-234	-0.81	0.96	-0.93	0.93	-0.85	0.48	0.96	-0.90	1.00

APPENDIX D

BACKGROUND PROUCL STATISTICAL RESULTS

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Section 26
Background Ra-226 BTV_UTL95-95

Background Statistics for Uncensored Full Data Sets

User Selected Options

Date/Time of Computation	ProUCL 5.15/16/2019 9:26:35 AM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	95%
Coverage	95%
New or Future K Observations	1
Number of Bootstrap Operations	2000

C0

General Statistics

Total Number of Observations	20	Number of Distinct Observations	7
Minimum	0.8	First Quartile	1
Second Largest	1.4	Median	1.1
Maximum	1.4	Third Quartile	1.225
Mean	1.115	SD	0.179
Coefficient of Variation	0.16	Skewness	-0.127
Mean of logged Data	0.0962	SD of logged Data	0.165

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.396	d2max (for USL)	2.557

Normal GOF Test

Shapiro Wilk Test Statistic	0.948	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.905	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.14	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.192	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with 95% Coverage	1.543	90% Percentile (z)	1.344
95% UPL (t)	1.431	95% Percentile (z)	1.409
95% USL	1.571	99% Percentile (z)	1.53

Gamma GOF Test

A-D Test Statistic	0.441	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.74	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.149	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.193	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	39.62	k star (bias corrected MLE)	33.71
Theta hat (MLE)	0.0281	Theta star (bias corrected MLE)	0.0331
nu hat (MLE)	1585	nu star (bias corrected)	1348
MLE Mean (bias corrected)	1.115	MLE Sd (bias corrected)	0.192

Section 26
Background Ra-226 BTV_UTL95-95 (continued)

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	1.458	90% Percentile	1.367
95% Hawkins Wixley (HW) Approx. Gamma UPL	1.462	95% Percentile	1.449
95% WH Approx. Gamma UTL with 95% Coverage	1.598	99% Percentile	1.61
95% HW Approx. Gamma UTL with 95% Coverage	1.606		
95% WH USL	1.635	95% HW USL	1.645

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.937	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.905	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.149	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.192	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with 95% Coverage	1.636	90% Percentile (z)	1.361
95% UPL (t)	1.475	95% Percentile (z)	1.445
95% USL	1.68	99% Percentile (z)	1.617

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	20	95% UTL with 95% Coverage	1.4
Approx, f used to compute achieved CC	1.053	Approximate Actual Confidence Coefficient achieved by UTL	0.642
		Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with 95% Coverage	1.4	95% BCA Bootstrap UTL with 95% Coverage	1.4
95% UPL	1.4	90% Percentile	1.31
90% Chebyshev UPL	1.664	95% Percentile	1.4
95% Chebyshev UPL	1.912	99% Percentile	1.4
95% USL	1.4		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers
and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data
represents a background data set and when many onsite observations need to be compared with the BTV.

Section 26
Background Gamma Count BTV_UTL95-95

Background Statistics for Uncensored Full Data Sets

User Selected Options	
Date/Time of Computation	ProUCL 5.15/16/2019 9:24:24 AM
From File	WorkSheet.xls
Full Precision	OFF
Confidence Coefficient	95%
Coverage	95%
New or Future K Observations	1
Number of Bootstrap Operations	2000

C0

General Statistics

Total Number of Observations	20	Number of Distinct Observations	20
Minimum	9024	First Quartile	9268
Second Largest	9673	Median	9454
Maximum	9774	Third Quartile	9579
Mean	9427	SD	199.2
Coefficient of Variation	0.0211	Skewness	-0.296
Mean of logged Data	9.151	SD of logged Data	0.0212

Critical Values for Background Threshold Values (BTVs)

Tolerance Factor K (For UTL)	2.396	d2max (for USL)	2.557

Normal GOF Test

Shapiro Wilk Test Statistic	0.973	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.905	Data appear Normal at 5% Significance Level
Lilliefors Test Statistic	0.103	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.192	Data appear Normal at 5% Significance Level

Data appear Normal at 5% Significance Level

Background Statistics Assuming Normal Distribution

95% UTL with 95% Coverage	9904	90% Percentile (z)	9682
95% UPL (t)	9779	95% Percentile (z)	9754
95% USL	9936	99% Percentile (z)	9890

Gamma GOF Test

A-D Test Statistic	0.276	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.74	Detected data appear Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.0983	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.193	Detected data appear Gamma Distributed at 5% Significance Level

Detected data appear Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	2348	k star (bias corrected MLE)	1996
Theta hat (MLE)	4.015	Theta star (bias corrected MLE)	4.724
nu hat (MLE)	93905	nu star (bias corrected)	79821
MLE Mean (bias corrected)	9427	MLE Sd (bias corrected)	211

Section 26
Background Gamma Count BTV_UTL95-95 (continued)

Background Statistics Assuming Gamma Distribution

95% Wilson Hilferty (WH) Approx. Gamma UPL	9783	90% Percentile	9698
95% Hawkins Wixley (HW) Approx. Gamma UPL	9784	95% Percentile	9776
95% WH Approx. Gamma UTL with 95% Coverage	9912	99% Percentile	9924
95% HW Approx. Gamma UTL with 95% Coverage	9913		
95% WH USL	9945	95% HW USL	9946

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.971	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.905	Data appear Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.107	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.192	Data appear Lognormal at 5% Significance Level

Data appear Lognormal at 5% Significance Level

Background Statistics assuming Lognormal Distribution

95% UTL with 95% Coverage	9916	90% Percentile (z)	9684
95% UPL (t)	9785	95% Percentile (z)	9759
95% USL	9949	99% Percentile (z)	9901

Nonparametric Distribution Free Background Statistics

Data appear Normal at 5% Significance Level

Nonparametric Upper Limits for Background Threshold Values

Order of Statistic, r	20	95% UTL with 95% Coverage	9774
Approx, f used to compute achieved CC	1.053	Approximate Actual Confidence Coefficient achieved by UTL	0.642
		Approximate Sample Size needed to achieve specified CC	59
95% Percentile Bootstrap UTL with 95% Coverage	9774	95% BCA Bootstrap UTL with 95% Coverage	9774
95% UPL	9769	90% Percentile	9627
90% Chebyshev UPL	10039	95% Percentile	9678
95% Chebyshev UPL	10316	99% Percentile	9755
95% USL	9774		

Note: The use of USL tends to yield a conservative estimate of BTV, especially when the sample size starts exceeding 20.
Therefore, one may use USL to estimate a BTV only when the data set represents a background data set free of outliers
and consists of observations collected from clean unimpacted locations.
The use of USL tends to provide a balance between false positives and false negatives provided the data
represents a background data set and when many onsite observations need to be compared with the BTV.

APPENDIX E

HALL ENVIRONMENTAL ANALYSIS LABORATORY ANALYTICAL DATA PACKAGE AND DATA QUALITY ASSURANCE REVIEW

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DATA QUALITY ASSURANCE REVIEW

SITE NAME Tronox Central GSA

WORK ORDER NUMBER 20600.012.001.1035.06 TDD NUMBER 0001/17-035

PROJECT NUMBER ______ SDG NUMBER 1811682

Weston Solutions, Inc. (WESTON®) has completed a QA review for Work Order Number 20600.012.001.1035.06, SDG No. 1811682, Tronox Central GSA. Nine samples were analyzed for Target Analyte List (TAL) metals plus uranium by Hall Environmental Analysis Laboratory, Inc. Sample numbers are listed below.

SAMPLE NUMBERS

17-01-31-181101-M	17-02-31-181101-M	19-01-31-181101-M
19-02-31-181101-M	30-01-31-181101-M	30-02-31-181101-M
33-01-31-181101-M	33-01-32-181101-M	33-02-31-181101-M

This data package was validated to determine if Quality Control (QC) specifications were achieved, following *USEPA National Functional Guidelines for Organic Superfund Methods Data Review* (January, 2017), *USEPA National Functional Guidelines for Inorganic Superfund Data Review* (January, 2017), *USEPA Contract Laboratory Program National Functional Guidelines for High Resolution Superfund Methods Data Review* (April, 2016), *Quality Assurance/Quality Control Guidance for Removal Activities* (September, 2011), and/or the Regional Protocol for Holding Times, Blanks, and VOA Preservation (April 13, 1989). Specific data qualifications are listed in the following discussion.

REVIEWER Gloria J. Switalski DATE June 20, 2019

Data Qualifiers

Data Qualifier Definitions were supplied by the Office of Solid Waste and Emergency Response (September 1989) and are included in the Functional Guidelines. Data qualifiers may be combined (UJ, QJ) with the corresponding combination of meanings. Additional qualifiers may be added to provide additional, more specific information (JL, UB, QJK), modifying the meaning of the primary qualifier. Additional qualifiers utilized by WESTON are H, L, K, B, and Q.

U - The material was analyzed for, but was not detected. The associated numerical value is the sample quantitation or detection limit, which has been adjusted for sample weight/sample volume, extraction volume, percent solids, sample dilution or other analysis specific parameters.

An additional qualifier, "B", may be appended to indicate that while the analyte was detected in the sample, the presence of the analyte may be attributable to blank contamination and the analyte is therefore considered undetected with the sample detection or quantitation limit for the analyte being elevated.

J - The analyte was analyzed for, but the associated numerical value may not be consistent with the amount actually present in the environmental sample or may not be consistent with the sample detection or quantitation limit. The value is an estimated quantity. The data should be seriously considered for decision-making and are usable for many purposes.

An additional qualifier will be appended to the "J" qualifier that indicates the bias in the reported results:

L Low bias

H High bias

K Unknown bias

Q The reported concentration is less than the sample quantitation limit for the specific analyte in the sample.

The L and H qualifier will only be employed when a single qualification is required. When more than one quality control parameter affects the analytical result and a conflict results in assigning a bias, the result will be flagged JK.

R - Quality Control indicates that data are unusable for all purposes. The analyte was analyzed for, but the presence or absence of the analyte has not been verified. Resampling and reanalysis are necessary for verification to confirm or deny the presence of an analyte.

N - The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification."

METALS DATA EVALUATION

1. Analytical Method:

Samples were prepared and analyzed for metals and mercury using the procedures specified in **SW-846 Methods 6010B and 7471.**

2. Holding Times:

All samples met established holding time criteria of 180 days for ICP metals and 28 days for mercury. No qualifications are placed on the data.

3. Initial Calibration:

Level 4 data validation is not being performed on this data set at this time. In the event that level 4 validation is performed, this validation report will be revised to include the level 4 findings. No qualifications are placed on the data.

4. Continuing Calibration:

Level 4 data validation is not being performed on this data set at this time. In the event that level 4 validation is performed, this validation report will be revised to include the level 4 findings. No qualifications are placed on the data.

5. CRDL Standard:

Level 4 data validation is not being performed on this data set at this time. In the event that level 4 validation is performed, this validation report will be revised to include the level 4 findings. No qualifications are placed on the data.

6. Blanks:

A. Laboratory Blanks:

Target analytes were not detected in the method blanks at concentrations that warrant blank action. No qualifications are placed on the data.

B. Field Blanks:

No field blank samples were submitted with this analytical package. No qualifications are placed on the data.

7. ICP Interference Check:

Level 4 data validation is not being performed on this data set at this time. In the event that level 4 validation is performed, this validation report will be revised to include the level 4 findings. No qualifications are placed on the data.

8. Laboratory Control Sample (LCS):

The laboratory analyzed LCS and recoveries for these analyses were within the control limits provided. No qualifications are placed on the data.

9. Duplicate Sample Analysis:

A. Laboratory Duplicate Analysis:

No sample from this analytical package underwent matrix spike/matrix spike duplicate analysis for the soil matrix for ICP metals and mercury. No qualifications are placed on the data.

B. Field Duplicate Analysis:

The following sample pair was submitted as field duplicates for the soil matrix for ICP metals and mercury: 33-01-31-181101-M/33-01-32-181101-M. The relative percent difference (RPD) values for the field duplicate sample analysis were within the QC criteria of less than 30% for aqueous samples and less than 50% for soil samples for concentrations greater than five times the practical quantitation limit (PQL). For sample concentrations less than five times the PQL, the absolute difference between the samples is less than two times the PQL for aqueous samples or less than 3.5 times the PQL for the soil samples. All QC criteria were met. No qualifications are placed on the data.

10. Matrix Spikes/Matrix Spike Duplicates (MS/MSD):

No sample from this analytical package underwent matrix spike/matrix spike duplicate analysis for the soil matrix for ICP metals and mercury. No qualifications are placed on the data.

11. ICP Serial Dilution:

Level 4 data validation is not being performed on this data set at this time. In the event that level 4 validation is performed, this validation report will be revised to include the level 4 findings. No qualifications are placed on the data.

12. Sample Quantitation and Reporting Limits:

Level 4 data validation is not being performed on this data set at this time. In the event that level 4 validation is performed, this validation report will be revised to include the level 4 findings. No qualifications are placed on the data.

All ICP metals analytes in all samples were analyzed at a 2, 5, 10, or 100-fold dilution. PQL for these analytes in these samples were elevated as a result of the dilutions performed.

13. Laboratory Contact

No laboratory contact was required.

14. Overall Assessment:

The analytical data is acceptable for use without qualification.

Hall Environmental Analysis Laboratory, Inc.

Date Reported: **12/17/2018**

CLIENT: Weston Solutions, Inc.
Project: 1 Weston 04217013 181108 001
Lab ID: 1811682-001 **Matrix:** SOIL

Client Sample ID: 17-01-31-181101-M
Collection Date: 11/1/2018
Received Date: 11/9/2018 8:40:00 AM

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed	Batch
EPA METHOD 7471: MERCURY							Analyst: **rde**
Mercury	0.033	0.033		mg/Kg	1	11/20/2018 4:57:56 PM	41644
EPA METHOD 6010B: SOIL METALS							Analyst: **ELS**
Aluminum	14000	300		mg/Kg	100	11/15/2018 1:56:12 PM	41541
Antimony	ND	4.9		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Arsenic	6.1	4.9		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Barium	71	0.20		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Beryllium	0.74	0.30		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Cadmium	ND	0.20		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Calcium	32000	250		mg/Kg	10	11/16/2018 9:03:02 AM	41541
Chromium	9.3	0.59		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Cobalt	6.0	1.5		mg/Kg	5	11/30/2018 2:36:16 PM	41541
Copper	11	0.59		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Iron	18000	250		mg/Kg	100	11/15/2018 1:56:12 PM	41541
Lead	9.9	0.49		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Magnesium	3500	120		mg/Kg	5	11/16/2018 9:01:10 AM	41541
Manganese	220	0.20		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Nickel	17	0.98		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Potassium	2200	250		mg/Kg	5	11/16/2018 9:01:10 AM	41541
Selenium	ND	4.9		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Silver	ND	0.49		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Sodium	250	120		mg/Kg	5	11/16/2018 9:01:10 AM	41541
Thallium	ND	4.9		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Uranium	ND	9.8		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Vanadium	52	4.9		mg/Kg	2	11/16/2018 10:34:56 AM	41541
Zinc	54	12		mg/Kg	5	11/30/2018 2:36:16 PM	41541

SB 6/20/19

Refer to the QC Summary report and sample login checklist for flagged QC data and preservation information.

Qualifiers:

*	Value exceeds Maximum Contaminant Level.	B	Analyte detected in the associated Method Blank
D	Sample Diluted Due to Matrix	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
ND	Not Detected at the Reporting Limit	P	Sample pH Not In Range
PQL	Practical Quanitative Limit	RL	Reporting Detection Limit
S	% Recovery outside of range due to dilution or matrix	W	Sample container temperature is out of limit as specified

Hall Environmental Analysis Laboratory, Inc.

Date Reported: **12/17/2018**

CLIENT: Weston Solutions, Inc.
Client Sample ID: 17-02-31-181101-M
Project: 1 Weston 04217013 181108 001
Collection Date: 11/1/2018
Lab ID: 1811682-002
Matrix: SOIL
Received Date: 11/9/2018 8:40:00 AM

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed	Batch
EPA METHOD 7471: MERCURY						Analyst: **rde**	
Mercury	ND	0.033		mg/Kg	1	11/20/2018 4:59:36 PM	41644
EPA METHOD 6010B: SOIL METALS						Analyst: **ELS**	
Aluminum	15000	300		mg/Kg	100	11/15/2018 1:58:10 PM	41541
Antimony	ND	4.9		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Arsenic	ND	4.9		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Barium	98	0.20		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Beryllium	0.69	0.30		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Cadmium	ND	0.20		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Calcium	15000	120		mg/Kg	5	11/16/2018 9:11:18 AM	41541
Chromium	9.1	0.59		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Cobalt	4.4	0.59		mg/Kg	2	11/30/2018 2:37:51 PM	41541
Copper	7.9	0.59		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Iron	15000	250		mg/Kg	100	11/15/2018 1:58:10 PM	41541
Lead	4.9	0.49		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Magnesium	3000	120		mg/Kg	5	11/16/2018 9:11:18 AM	41541
Manganese	140	0.20		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Nickel	11	0.99		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Potassium	2700	250		mg/Kg	5	11/16/2018 9:11:18 AM	41541
Selenium	ND	4.9		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Silver	ND	0.49		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Sodium	180	120		mg/Kg	5	11/16/2018 9:11:18 AM	41541
Thallium	ND	4.9		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Uranium	ND	9.9		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Vanadium	32	4.9		mg/Kg	2	11/16/2018 10:36:55 AM	41541
Zinc	37	4.9		mg/Kg	2	11/30/2018 2:37:51 PM	41541

6/20/19

Refer to the QC Summary report and sample login checklist for flagged QC data and preservation information.

Qualifiers:

*	Value exceeds Maximum Contaminant Level.	B	Analyte detected in the associated Method Blank
D	Sample Diluted Due to Matrix	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
ND	Not Detected at the Reporting Limit	P	Sample pH Not In Range
PQL	Practical Quanitative Limit	RL	Reporting Detection Limit
S	% Recovery outside of range due to dilution or matrix	W	Sample container temperature is out of limit as specified

Analytical Report
Lab Order **1811682**
Hall Environmental Analysis Laboratory, Inc.
Date Reported: **12/17/2018**

CLIENT: Weston Solutions, Inc. **Client Sample ID:** 19-01-31-181101-M
Project: 1 Weston 04217013 181108 001 **Collection Date:** 11/1/2018
Lab ID: 1811682-003 **Matrix:** SOIL **Received Date:** 11/9/2018 8:40:00 AM

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed	Batch
EPA METHOD 7471: MERCURY							Analyst: **rde**
Mercury	ND	0.032		mg/Kg	1	11/20/2018 5:01:16 PM	41644
EPA METHOD 6010B: SOIL METALS							Analyst: **ELS**
Aluminum	11000	300		mg/Kg	100	11/15/2018 2:00:08 PM	41541
Antimony	ND	4.9		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Arsenic	6.8	4.9		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Barium	81	0.20		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Beryllium	0.73	0.30		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Cadmium	ND	0.20		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Calcium	17000	120		mg/Kg	5	11/16/2018 9:13:10 AM	41541
Chromium	5.4	0.59		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Cobalt	3.5	1.5		mg/Kg	5	11/30/2018 2:42:32 PM	41541
Copper	4.5	0.59		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Iron	13000	250		mg/Kg	100	11/15/2018 2:00:08 PM	41541
Lead	9.0	0.49		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Magnesium	3200	120		mg/Kg	5	11/16/2018 9:13:10 AM	41541
Manganese	190	0.20		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Nickel	5.5	0.98		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Potassium	3100	250		mg/Kg	5	11/16/2018 9:13:10 AM	41541
Selenium	6.8	4.9		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Silver	ND	0.49		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Sodium	210	120		mg/Kg	5	11/16/2018 9:13:10 AM	41541
Thallium	ND	4.9		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Uranium	77	9.8		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Vanadium	98	4.9		mg/Kg	2	11/16/2018 10:38:53 AM	41541
Zinc	32	12		mg/Kg	5	11/30/2018 2:42:32 PM	41541

6/20/19

Refer to the QC Summary report and sample login checklist for flagged QC data and preservation information.

Qualifiers:

*	Value exceeds Maximum Contaminant Level.	B	Analyte detected in the associated Method Blank
D	Sample Diluted Due to Matrix	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
ND	Not Detected at the Reporting Limit	P	Sample pH Not In Range
PQL	Practical Quanitative Limit	RL	Reporting Detection Limit
S	% Recovery outside of range due to dilution or matrix	W	Sample container temperature is out of limit as specified

Hall Environmental Analysis Laboratory, Inc.

Date Reported: **12/17/2018**

CLIENT: Weston Solutions, Inc. **Client Sample ID:** 19-02-31-181101-M
Project: 1 Weston 04217013 181108 001 **Collection Date:** 11/1/2018
Lab ID: 1811682-004 **Matrix:** SOIL **Received Date:** 11/9/2018 8:40:00 AM

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed	Batch
EPA METHOD 7471: MERCURY							Analyst: **rde**
Mercury	ND	0.033		mg/Kg	1	11/20/2018 5:02:57 PM	41644
EPA METHOD 6010B: SOIL METALS							Analyst: **ELS**
Aluminum	15000	290		mg/Kg	100	11/15/2018 2:08:43 PM	41541
Antimony	ND	4.9		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Arsenic	9.8	4.9		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Barium	87	0.20		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Beryllium	0.84	0.29		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Cadmium	ND	0.20		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Calcium	23000	120		mg/Kg	5	11/16/2018 9:15:02 AM	41541
Chromium	8.4	0.59		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Cobalt	5.9	1.5		mg/Kg	5	11/30/2018 2:44:05 PM	41541
Copper	8.4	0.59		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Iron	17000	250		mg/Kg	100	11/15/2018 2:08:43 PM	41541
Lead	8.5	0.49		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Magnesium	4900	120		mg/Kg	5	11/16/2018 9:15:02 AM	41541
Manganese	200	0.20		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Nickel	10	0.98		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Potassium	4800	250		mg/Kg	5	11/16/2018 9:15:02 AM	41541
Selenium	ND	4.9		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Silver	ND	0.49		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Sodium	250	120		mg/Kg	5	11/16/2018 9:15:02 AM	41541
Thallium	ND	4.9		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Uranium	ND	9.8		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Vanadium	65	4.9		mg/Kg	2	11/16/2018 10:40:46 AM	41541
Zinc	48	12		mg/Kg	5	11/30/2018 2:44:05 PM	41541

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Refer to the QC Summary report and sample login checklist for flagged QC data and preservation information.

Qualifiers:

*	Value exceeds Maximum Contaminant Level.	B	Analyte detected in the associated Method Blank
D	Sample Diluted Due to Matrix	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
ND	Not Detected at the Reporting Limit	P	Sample pH Not In Range
PQL	Practical Quanitative Limit	RL	Reporting Detection Limit
S	% Recovery outside of range due to dilution or matrix	W	Sample container temperature is out of limit as specified

Hall Environmental Analysis Laboratory, Inc.

CLIENT: Weston Solutions, Inc.
Project: 1 Weston 04217013 181108 001
Lab ID: 1811682-005 **Matrix:** SOIL

Client Sample ID: 30-01-31-181101-M
Collection Date: 11/1/2018
Received Date: 11/9/2018 8:40:00 AM

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed	Batch
EPA METHOD 7471: MERCURY						Analyst: **rde**	
Mercury	ND	0.032		mg/Kg	1	11/20/2018 5:04:38 PM	41644
EPA METHOD 6010B: SOIL METALS						Analyst: **ELS**	
Aluminum	12000	300		mg/Kg	100	11/15/2018 2:10:42 PM	41541
Antimony	ND	4.9		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Arsenic	5.1	4.9		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Barium	82	0.20		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Beryllium	0.62	0.30		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Cadmium	ND	0.20		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Calcium	24000	120		mg/Kg	5	11/16/2018 9:16:53 AM	41541
Chromium	6.5	0.59		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Cobalt	4.2	0.59		mg/Kg	2	11/30/2018 2:45:37 PM	41541
Copper	4.4	0.59		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Iron	13000	250		mg/Kg	100	11/15/2018 2:10:42 PM	41541
Lead	3.2	0.49		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Magnesium	4700	120		mg/Kg	5	11/16/2018 9:16:53 AM	41541
Manganese	140	0.20		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Nickel	7.0	0.99		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Potassium	3200	250		mg/Kg	5	11/16/2018 9:16:53 AM	41541
Selenium	ND	4.9		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Silver	ND	0.49		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Sodium	190	120		mg/Kg	5	11/16/2018 9:16:53 AM	41541
Thallium	ND	4.9		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Uranium	ND	9.9		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Vanadium	20	4.9		mg/Kg	2	11/16/2018 10:42:44 AM	41541
Zinc	30	4.9		mg/Kg	2	11/30/2018 2:45:37 PM	41541

6/20/19

Refer to the QC Summary report and sample login checklist for flagged QC data and preservation information.

Qualifiers:

*	Value exceeds Maximum Contaminant Level.	B	Analyte detected in the associated Method Blank
D	Sample Diluted Due to Matrix	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
ND	Not Detected at the Reporting Limit	P	Sample pH Not In Range
PQL	Practical Quanitative Limit	RL	Reporting Detection Limit
S	% Recovery outside of range due to dilution or matrix	W	Sample container temperature is out of limit as specified

Hall Environmental Analysis Laboratory, Inc.

CLIENT: Weston Solutions, Inc. **Client Sample ID:** 30-02-31-181101-M
Project: 1 Weston 04217013 181108 001 **Collection Date:** 11/1/2018
Lab ID: 1811682-006 **Matrix:** SOIL **Received Date:** 11/9/2018 8:40:00 AM

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed	Batch
EPA METHOD 7471: MERCURY							Analyst: **rde**
Mercury	ND	0.032		mg/Kg	1	11/20/2018 5:09:54 PM	41644
EPA METHOD 6010B: SOIL METALS							Analyst: **ELS**
Aluminum	11000	300		mg/Kg	100	11/15/2018 2:12:39 PM	41541
Antimony	ND	5.0		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Arsenic	5.2	5.0		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Barium	72	0.20		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Beryllium	0.65	0.30		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Cadmium	ND	0.20		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Calcium	13000	120		mg/Kg	5	11/16/2018 9:20:35 AM	41541
Chromium	6.9	0.59		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Cobalt	4.5	1.5		mg/Kg	5	11/30/2018 2:56:36 PM	41541
Copper	4.5	0.59		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Iron	13000	250		mg/Kg	100	11/15/2018 2:12:39 PM	41541
Lead	3.9	0.50		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Magnesium	4300	120		mg/Kg	5	11/16/2018 9:20:35 AM	41541
Manganese	150	0.20		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Nickel	7.6	0.99		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Potassium	2600	250		mg/Kg	5	11/16/2018 9:20:35 AM	41541
Selenium	ND	5.0		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Silver	ND	0.50		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Sodium	200	120		mg/Kg	5	11/16/2018 9:20:35 AM	41541
Thallium	ND	5.0		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Uranium	ND	9.9		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Vanadium	19	5.0		mg/Kg	2	11/16/2018 10:44:36 AM	41541
Zinc	34	12		mg/Kg	5	11/30/2018 2:56:36 PM	41541

6/20/19

Refer to the QC Summary report and sample login checklist for flagged QC data and preservation information.

Qualifiers:

*	Value exceeds Maximum Contaminant Level.	B	Analyte detected in the associated Method Blank
D	Sample Diluted Due to Matrix	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
ND	Not Detected at the Reporting Limit	P	Sample pH Not In Range
PQL	Practical Quanitative Limit	RL	Reporting Detection Limit
S	% Recovery outside of range due to dilution or matrix	W	Sample container temperature is out of limit as specified

Hall Environmental Analysis Laboratory, Inc.

CLIENT: Weston Solutions, Inc.
Project: 1 Weston 04217013 181108 001
Lab ID: 1811682-007 **Matrix:** SOIL
Client Sample ID: 33-01-31-181101-M
Collection Date: 11/1/2018
Received Date: 11/9/2018 8:40:00 AM

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed	Batch
EPA METHOD 7471: MERCURY						Analyst: **rde**	
Mercury	ND	0.032		mg/Kg	1	11/20/2018 5:11:36 PM	41644
EPA METHOD 6010B: SOIL METALS						Analyst: **ELS**	
Aluminum	10000	300		mg/Kg	100	11/15/2018 2:14:36 PM	41541
Antimony	ND	4.9		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Arsenic	7.5	4.9		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Barium	56	0.20		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Beryllium	0.67	0.30		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Cadmium	ND	0.20		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Calcium	7800	120		mg/Kg	5	11/16/2018 9:22:28 AM	41541
Chromium	6.0	0.59		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Cobalt	3.1	1.5		mg/Kg	5	11/30/2018 2:58:11 PM	41541
Copper	5.3	0.59		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Iron	12000	250		mg/Kg	100	11/15/2018 2:14:36 PM	41541
Lead	9.5	0.49		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Magnesium	2800	120		mg/Kg	5	11/16/2018 9:22:28 AM	41541
Manganese	180	0.20		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Nickel	5.8	0.99		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Potassium	3200	250		mg/Kg	5	11/16/2018 9:22:28 AM	41541
Selenium	7.0	4.9		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Silver	ND	0.49		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Sodium	180	120		mg/Kg	5	11/16/2018 9:22:28 AM	41541
Thallium	ND	4.9		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Uranium	24	9.9		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Vanadium	62	4.9		mg/Kg	2	11/16/2018 10:46:34 AM	41541
Zinc	25	12		mg/Kg	5	11/30/2018 2:58:11 PM	41541

[handwritten initials] 6/20/19

Refer to the QC Summary report and sample login checklist for flagged QC data and preservation information.

Qualifiers:

*	Value exceeds Maximum Contaminant Level.	B	Analyte detected in the associated Method Blank
D	Sample Diluted Due to Matrix	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
ND	Not Detected at the Reporting Limit	P	Sample pH Not In Range
PQL	Practical Quanitative Limit	RL	Reporting Detection Limit
S	% Recovery outside of range due to dilution or matrix	W	Sample container temperature is out of limit as specified

Hall Environmental Analysis Laboratory, Inc.

Date Reported: **12/17/2018**

CLIENT: Weston Solutions, Inc.
Project: 1 Weston 04217013 181108 001
Lab ID: 1811682-008 **Matrix:** SOIL

Client Sample ID: 33-01-32-181101-M
Collection Date: 11/1/2018
Received Date: 11/9/2018 8:40:00 AM

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed	Batch
EPA METHOD 7471: MERCURY						Analyst: **rde**	
Mercury	ND	0.033		mg/Kg	1	11/20/2018 5:13:19 PM	41644
EPA METHOD 6010B: SOIL METALS						Analyst: **ELS**	
Aluminum	8900	300		mg/Kg	100	11/15/2018 2:16:33 PM	41541
Antimony	ND	4.9		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Arsenic	7.9	4.9		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Barium	53	0.20		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Beryllium	0.63	0.30		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Cadmium	ND	0.20		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Calcium	8100	120		mg/Kg	5	11/16/2018 9:24:20 AM	41541
Chromium	4.9	0.59		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Cobalt	3.9	1.5		mg/Kg	5	11/30/2018 3:00:32 PM	41541
Copper	4.9	0.59		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Iron	12000	250		mg/Kg	100	11/15/2018 2:16:33 PM	41541
Lead	13	0.49		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Magnesium	2600	120		mg/Kg	5	11/16/2018 9:24:20 AM	41541
Manganese	170	0.20		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Nickel	6.0	2.5		mg/Kg	5	11/30/2018 3:00:32 PM	41541
Potassium	2900	250		mg/Kg	5	11/16/2018 9:24:20 AM	41541
Selenium	ND	12		mg/Kg	5	11/30/2018 3:00:32 PM	41541
Silver	ND	0.49		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Sodium	160	120		mg/Kg	5	11/16/2018 9:24:20 AM	41541
Thallium	ND	4.9		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Uranium	23	9.9		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Vanadium	63	4.9		mg/Kg	2	11/16/2018 10:56:38 AM	41541
Zinc	32	12		mg/Kg	5	11/30/2018 3:00:32 PM	41541

6/20/19

Refer to the QC Summary report and sample login checklist for flagged QC data and preservation information.

Qualifiers:

*	Value exceeds Maximum Contaminant Level.	B	Analyte detected in the associated Method Blank
D	Sample Diluted Due to Matrix	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
ND	Not Detected at the Reporting Limit	P	Sample pH Not In Range
PQL	Practical Quanitative Limit	RL	Reporting Detection Limit
S	% Recovery outside of range due to dilution or matrix	W	Sample container temperature is out of limit as specified

Hall Environmental Analysis Laboratory, Inc.

CLIENT:	Weston Solutions, Inc.	**Client Sample ID:**	33-02-31-181101-M
Project:	1 Weston 04217013 181108 001	**Collection Date:**	11/1/2018
Lab ID:	1811682-009 **Matrix:** SOIL	**Received Date:**	11/9/2018 8:40:00 AM

Analyses	Result	PQL	Qual	Units	DF	Date Analyzed	Batch
EPA METHOD 7471: MERCURY						Analyst: **rde**	
Mercury	ND	0.031		mg/Kg	1	11/20/2018 5:15:02 PM	41644
EPA METHOD 6010B: SOIL METALS						Analyst: **ELS**	
Aluminum	8200	300		mg/Kg	100	11/15/2018 2:18:30 PM	41541
Antimony	ND	4.9		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Arsenic	ND	4.9		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Barium	65	0.20		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Beryllium	0.56	0.30		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Cadmium	ND	0.20		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Calcium	14000	120		mg/Kg	5	11/16/2018 9:26:12 AM	41541
Chromium	5.0	0.59		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Cobalt	4.4	1.5		mg/Kg	5	11/30/2018 3:02:04 PM	41541
Copper	4.4	0.59		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Iron	12000	250		mg/Kg	100	11/15/2018 2:18:30 PM	41541
Lead	4.4	0.49		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Magnesium	4000	120		mg/Kg	5	11/16/2018 9:26:12 AM	41541
Manganese	140	0.20		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Nickel	7.1	2.5		mg/Kg	5	11/30/2018 3:02:04 PM	41541
Potassium	2200	250		mg/Kg	5	11/16/2018 9:26:12 AM	41541
Selenium	ND	4.9		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Silver	ND	0.49		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Sodium	360	120		mg/Kg	5	11/16/2018 9:26:12 AM	41541
Thallium	ND	4.9		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Uranium	ND	9.9		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Vanadium	18	4.9		mg/Kg	2	11/16/2018 10:58:31 AM	41541
Zinc	30	12		mg/Kg	5	11/30/2018 3:02:04 PM	41541

6/20/19

Refer to the QC Summary report and sample login checklist for flagged QC data and preservation information.

Qualifiers:

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D	Sample Diluted Due to Matrix	E	Value above quantitation range
H	Holding times for preparation or analysis exceeded	J	Analyte detected below quantitation limits
ND	Not Detected at the Reporting Limit	P	Sample pH Not In Range
PQL	Practical Quanitative Limit	RL	Reporting Detection Limit
S	% Recovery outside of range due to dilution or matrix	W	Sample container temperature is out of limit as specified

APPENDIX F

DRAFT REVEGETATION PLAN

Draft Revegetation Plan

Central Geographic Sub Area Mines
McKinley County, New Mexico

Prepared For:
US Environmental Protection Agency Region 6
Weston Solutions

OCTOBER 2018

NV5

7511 Fourth St. NW
Albuquerque, NM 87107
Phone: 505.898.8848

444618-1440000.03

CONTENTS

1 – INTRODUCTION

The US Environmental Protection Agency (USEPA) proposes to initiate a mine waste removal on approximately 1,322 acres consisting of a former uranium mine site and associated lands to reestablish pre-mine arid grassland and scrub habitats. The removal areas are located within the Ambrosia Lake Sub-District (ALSD) area of the Grants Mining District of the Central Geographic Sub Area within McKinley County, New Mexico (Figure 1a, Appendix D). The reclamation study area consists of a former underground uranium mine and associated lands. For the purposes of this draft plan, the study and removal areas total approximately 1,322 acres. However, the final removal area will be determined once ongoing analyses are evaluated.

The area is eligible for abatement activities subject to the Tronox Navajo Area Uranium Mine (NAUM) settlement, and has been identified as the Central Geographic Sub Area.

The USEPA proposes to excavate at least 12 inches of top soils throughout the removal area and dispose of them at a nearby previously disturbed location, then revegetate and re-contour the site to restore, to the extent feasible, pre-mining conditions.

Revegetation Objectives

The USEPA identified the following revegetation objectives:

- Restore Grazing/Forage to Pre-mine Condition
- Restore Suitability for Wildlife Use
- Sustainability

Revegetation Standards

This draft plan has been developed to comply with the following standards:

- New Mexico Environment Department and New Mexico Energy, Minerals, and Natural Resources Department Mining and Minerals Division Joint Guidance for the cleanup and reclamation of existing uranium mines in New Mexico, March 2016 (Attachments 1 and 2).

- New Mexico State Land Office Reclamation Plan for State Mineral Lease Rule 5 Template (7-14-15).

Geographical Description of Removal Area

The removal area is located within the ALSD in McKinley County, New Mexico. The ALSD is located within an area of uranium mineralization that extends approximately 100 miles long and 25 miles wide encompassing portions of McKinley, Cibola, Sandoval, and Bernalillo counties in New Mexico. The study area occurs from approximately 6,900 to 7,160 feet in elevation above mean sea level. It is located northeast of Mesa Montosa and west of San Mateo Mesa (Figure 1a).

Removal Area Location

The CGSA removal area consists of approximately 1,322-acres of a former underground uranium mine and associated lands selected for remediation within a larger study area. The site is located in the ALSD, McKinley County, New Mexico approximately 15 miles north of Grants, New Mexico and 3 miles north of the intersection of New Mexico State Highways 509 and 605 (Figure 1b).

In relation to regional population centers, the site is located approximately 70 air miles and 100 road miles west/northwest of Albuquerque, New Mexico; 340 air miles and 540 road miles from Denver, Colorado; and approximately 280 air miles and 360 road miles northeast of Phoenix, Arizona.

The removal are is located in Township 14 North, Range 09 West Sections 17, 18, 19, 20, 29, 30, 31, 32, and 33. It appears on the *Ambrosia Lake, New Mexico* US Geological Survey 7.5-minute quadrangle map (Figure 1a). The geographic center of the site is located at approximately Universal Trans Mercator (UTM) Z13S, North American Datum (NAD) 243694 3922588; Latitude 35.413750 degrees north/Longitude 107.822685 degrees west.

<u>Site Access/Constraints</u>
The total distance from Interstate 40 (I-40) to the site is approximately 17 miles. The site is accessed directly from the New Mexico 509 roadway (NM 509). This is a secondary 2-lane (11-foot wide lanes) with unpaved shoulders and 3-foot wide paved taper. NM 509 is accessed via the New Mexico 605 roadway (NM 605) approximately 4 miles south of the entrance to the site.

NM 605 has a similar typical section. NM 605 extends approximately 13.5 miles southward to its junction with historic U.S. 66 in Milan, New Mexico. It is a four-lane divided roadway with a median, 12-foot wide lanes, and 8-foot wide exterior paved shoulders. It is located 0.2 mile from Interstate 40 (I-40). No constraining bridges or underpasses occur between I-40 and the entrance to the site.

Access to the site from the north is available via NM 509, approximately 30 miles to its junction with the Navajo 9 roadway, another secondary roadway with 11-foot wide lanes, but with 6-foot paved shoulders. The Navajo 9 junction with NM 371 (also a 2-lane roadway with 6-shoulder facility) occurs approximately 20 miles to the west. East of the junction with NM 509, Navajo 9 becomes NM 197. It terminates at US Highway 550 near Cuba, New Mexico, approximately 64.5 miles from the junction of NM 509.

<u>Land Ownership</u>
Land ownership is private and Bureau of Land Management (BLM). Land ownership is depicted on Figure 1a (Appendix A).

Summary of Site Conditions

The removal area occurs within the Semiarid Tablelands ecoregion (Griffith et al. 2006). This ecoregion is characterized by dry plains, mesas, valleys, and canyons formed from sedimentary rocks. It supports grasslands, savannas, and desert scrub communities (Dick-Peddie 1993).

<u>Vegetation</u>
The removal supports three primary vegetation communities: Juniper Savannah/Plains Mesa Grassland and two shrub communities. There is little distinction between grassland and shrub/scrub land (shrublands) across much of the project area. Many grasses occur as associates within the shrublands and most of the shrubs as associates in the grasslands. In order to define a boundary for seeding purposes, areas with an estimated shrub cover in excess of 20 percent were considered shrublands. Those with less were treated as grasslands. Grassland communities cover approximately 40 percent and shrublands cover about 60 percent of the removal area.

From the standpoint of reseeding, the shrub community was divided into areas dominated principally by rabbitbrush with a high percentage of grasses and areas dominated principally by alkali tolerant species such as alkali sacaton. Within the largest scrub/shrub community, the most common species present (based on limited field observation and the Natural Resources Evaluation prepared by others) were rubber rabbitbrush (*Ericameria nauseousa*) and four-wing saltbush (*Atriplex canescens*). They are intergraded with other shrubby associates such as broom snakeweed (*Gutierrezia sarothrae*), and Bigelow's sagebrush (*Artemisia bigelovii*).

The less common scrub/shrub community occurs in a number of low lying areas, swales, and small playa features where saltbush is replaced by alkali sacaton (*Sporobolus airoides*) but rubber rabbitbrush remains dominant. These areas also support enclaves of other alkali tolerant species such as shadscale (*Atriplex confertifolia*), New Mexico saltbush (*Atriplex obovata*), and greasewood (*Sarcobatus vermiculatus*).

The grassland community is defined by the presence and relative abundance of blue grama (*Bouteloua gracilis*). A second indicator grass species is galleta (*Pleuraphis jamesii*). In most areas winterfat (*Krascheninnikovia lanata*) is also scattered throughout this community. Other associates present are broom snakeweed, purple threeawn (*Aristida purpurea*), and in sandier areas, Indian ricegrass (*Oryzopsis*). A small Juniper Savanna community is present, but it only differs from grassland in that one-seed juniper (*Juniperus monosperma*) trees are present, so it is treated as grassland for seeding. The vertical vegetative structure of the trees provides important habitat for wildlife and the trees are to be excluded.

Existing Soils

Soils at the study area consist of the following US Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS 2018) map units listed by highest percent occurrence in the study area: Penistaja-Tintero complex, 1 to 10 percent slopes; Berryhill-Casamero clays, 2 to 10 percent slopes; Hagerwest-Bond fine sandy loams, 1 to 8 percent slopes; Sparank-San Mateo-Zia complex, 0 to 3 percent slopes; and Uranium-mined lands.

Area soils range from very low to very high surface runoff, but are generally well drained; not hydric or slightly hydric; moderately susceptible to wind and water erosion; and occur more than 200 centimeters from ground water depth. Soil chemistry and fertility analyses generally indicate soils are high in Calcium, Magnesium, and potash; low in Sodium, Phosphate, Boron, Sulfur, and Nitrates; and moderate in Iron, Manganese, and Copper. Overall, area soils have a low Carbon/Nitrogen ratio ranging from 4:1 to 8:1. The pH ranges from 6.67 to 8.99, which is within a typical range for the area.

Special Features

One special feature is present at the site:

- Existing Pond (augmented with planting) (Figure 2)

Restricted Areas

The following areas must be avoided (Figure 2):

- Cliff Habitat
- Juniper trees scattered throughout

<u>Ecological Function</u>
Grassland and grassland/shrub communities provide habitat for keystone species such as prairie dogs and associated animals, like the burrowing owl. They also provide browse and forage for elk and deer; graze for cattle; cover for a variety of small mammals and reptiles; and nest sites for small songbirds. The savanna area provides some small mammal habitat and potential nest sites for birds, including raptors. Trees provide perch sites for raptors and vertical structure for songbirds.

A pond feature retains stormwater flow near the northeastern corner of the removal area (on BLM land). It supports no tree cover or wetland vegetation, but provides water for wildlife.

All vegetation provides erosion control. Grasses provide a food source for mammals and insects. Insects provide a food source for reptiles, mammals, and birds.

2 - RECLAMATION GOALS /PERFORMANCE

Reclamation Units

The removal area has been divided into five reclamation units for planting purposes. Each unit is associated with specific soil preparation and seeding methodology. Unit boundaries were defined based on existing vegetation and soil characteristics observed in the field; vegetation, soils, and wildlife described by others (Natural Resources Evaluation); available 2018 soil sampling data; and historic aerial photography. Some portions of the study area are not included in the removal area. All units, with the exception of Unit 4, are associated with one soil treatment and planting schedule.

<u>Reclamation Unit Boundaries</u>
Reclamation units are identified in Figure 2. The reclamation units are:

- Unit 1A – Plains Mesa Grassland
- Unit 1B – Plains Mesa Grassland/Juniper Savanna
- Unit 2 – Great Basin Scrub A
- Unit 3 – Great Basin Scrub B
- Unit 4 – Arroyo/Pond Wetland

Defining points along the boundaries of reclamation units (or center point for disconnected units/unit portions) are provided in Figure 2 and associated with UTM coordinates provided in Table A1 (Appendix A).

Unit Performance Goals and Standards

The general objective for reclamation units is to meet or exceed the existing percent cover. Percentages are derived from the natural resources evaluation prepared by others and augmented by previous work in the area. The minimum percent cover is based on existing conditions, which were evaluated by community type. Some areas will be avoided for removal and some communities are combined for revegetation.

Unit 1 - Plains Mesa Grassland

This is a large grassland community with low shrub cover. The objective for this unit is to meet a minimum total of 22 percent cover comprised of mostly of grasses, equal or greater than the current percent cover, and reflect the general species composition of the area (Table 2.1).

Table 2.1 – Target Range for Percent Cover by Species: Unit 1A

Species	Range Percent Cover
Blue grama (*Bouteloua gracilis*)	
Galleta (*Pleuraphis jamesii*)	
Spike muhly (*Muhlenbergia wrightii*)	
Purple threeawn (*Aristida purpurea*)	
Spike dropseed (*Sporobolus contractus*)	
Subtotal	**22-37%**
Broom snakeweed (*Gutterezia sarothrae*)	
Winterfat (*Krascheninnkovia lanata*)	
Subtotal	**1-5%**
Total	**23-42%**

Unit 1B - Plains Mesa Grassland/Juniper Savanna

Juniper Savanna occurs in grasslands located in the northern portions of the project area. The seeding will not differ from the grassland areas, but avoidance of trees will be required. The objective for this unit is to meet a minimum total of 13 percent cover comprised of mostly of grasses, equal or greater than the current percent cover, and reflect the general species composition of the area.

Table 2.2 – Target Range for Percent Cover by Species: Unit 1B

Species	Percent Cover Range
Blue grama (*Bouteloua gracilis*)	
Galleta (*Pleuraphis jamesii*)	
Spike muhly (*Muhlenbergia wrightii*)	
Alkali sacaton (*Sporobolus airoides*)	
Subtotal - Grasses	**12-32%**
One-seed juniper (*Juniperus monosperma*)	
Winterfat (*Krascheninnkovia lanata*)	
Broom snakeweed (*Gutterezia sarothrae*)	
Subtotal - Shrubs	**1-5%**
Total	**13-37%**

Unit 2 - Great Basin Scrub A – Rabbitbrush/Saltbush

This is principally a shrub community that provides about 15 percent ground cover of grasses. The objective for this unit is to meet a minimum total of 50 percent overall cover, nearly half of shrubs with a ground cover of grasses equal to or greater than the current percent cover, and reflect the general species composition of the area (Table 2.3).

Table 2.3 – Target Range for Percent Cover by Species: Unit 2

Species	Percent Cover Range
Blue grama (*Bouteloua gracilis*)	
Galleta (*Pleuraphis jamesii*)	
Spike muhly (*Muhlenbergia wrightii*)	
Subtotal - Grasses	**10-15%**
Four-wing saltbush (*Atriplex canescens*)	
Rubber rabbitbrush (*Ericameria nauseosa*)	
Bigelow's sage (*Artemisia bigelovii*)	
Subtotal - Shrubs	**15-35%**
Total	**25-50%**

Unit 3 - Great Basin Scrub B - Rabbitbrush and Alkali Sacaton

This is a shrub community dominated by rubber rabbitbrush and alkaline tolerant grasses. The objective for this unit is to meet a minimum total of 30 percent cover comprised of grasses and shrubs, equal to or greater than the current percent cover, and reflect the general species composition of the area (Table 2.4).

Table 2.4 – Target Range for Percent Cover by Species: Unit 3

Species	Range Percent Cover
Alkali sacaton (*Sporobolus airoides*)	
Vine mesquite (Panicum obtusum)	
Spike dropseed (*Sporobolus contractus*)	
Hoary tansyaster (*Macheranthera canescens*)	
Subtotal - Grasses and Forbes	**15-20%**
Rubber rabbitbrush (Ericameria nauseosa)	
Subtotal - Shrubs	**15-20%**
Total	**30-40%**

Unit 4 - Pond

This unit consists of an existing stock tank and immediately surrounding area located along the eastern edge of the project area. Stormwater runoff from surrounding slopes and arroyos collects in the pond with sufficient frequency to sustain facultative wetland vegetation. The objective for this unit is to increase tree and ground cover. No existing wetland vegetation would be removed. Trees would be planted and the Unit 4 seed mix, composed of annual species, would be raked into surrounding soils (Table 2.5) .

Table 2.5 – Target Range for Percent Cover by Species: Unit 4

Species	Range Percent Cover
Rio Grande cottonwood (*Populus deltoides*)	
Subtotal - Trees	**10-20%**
Total	**10-20%**

<u>Ecological Function</u>

Unit 1 - Grassland communities are to provide burrow systems and nesting habitat for keystone species such as Gunnison's prairie dogs and nesting habitat for burrowing owls, as well as some browse/forage for elk and deer; graze for cattle; cover for a variety of small mammals and reptiles; and nest sites for small songbirds. Grasses provide a food source for mammals and insects. Insects provide a food source for reptiles, mammals, and birds.

Unit 2- Grassy shrublands dominated by rabbitbrush are to provide structure for nesting birds and small wildlife. The grassy ground cover provides habitat for small colonial mammals and forage for elk as well as graze for cattle. The larger open areas along the edges of this unit may also provide habitat for prairie dogs.

Unit 3 – The rabbitbrush and alkaline grasses provide cover and habitat for small mammals and nesting habitat for small songbirds and predatory birds, particularly species such as sparrows; as well as provide forage for elk and livestock and cover to small mammals.

Unit 4- The pond is to be planted with cottonwoods and sunflowers to add vertical structure; increase shade and cover; and provide a wider range of water and food resources to birds, reptiles, insects, mammals, and amphibians. It would also provide sediment catchment and surface water quality improvement.

3 – RECLAMATION/REVEGETATION WORK PLAN

Due to the size of the reclamation area, it may be necessary to complete revegetation by reclamation unit over a period of several years. Reclamation tasks shall be completed for each reclamation unit in the order provided in Table 3.1. Seasonal limitations associated with each task, if any, are identified by color coding (green-suitable, red-unsuitable) in the schedule below.

Work Schedule: Task Order by Monthly Task Suitability

Task Order	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
Install BMPs	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Clear/Grub*	Suitable	Suitable	Suitable	Suitable	Suitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable
Remove Soil	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Grade	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Constructed Features	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Soil Preparation	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Stabilizing Cover Crop	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Seeding/Planting	Suitable	Suitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Suitable
Irrigation	Suitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Suitable	Suitable	Suitable	Suitable	Suitable	Suitable
Vegetation Monitoring	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Suitable	Suitable	Suitable	Suitable

Unsuitable - **Suitable**

*Avoid nesting season or provide preconstruction surveys

<u>Staging Areas/Limitations</u>

Materials used in Reclamation Unit 4 will include live plants. The staging area for this unit is to be located close enough to a water source to allow for watering the material awaiting planting.

- No staging area will be placed within a restricted location.
- The contractor will site staging areas more than 200 feet from the arroyo/pond banks.
- All staging areas will be graded/vegetated according to their assigned reclamation unit specifications prior to completion of work.

Availability of Water and Limitations of Use

Water piped through the site may be available for use in watering the site to establish vegetation. Water needed for dust control during excavation and grading, as well as irrigation, is also expected to be available from this source.

Revegetation Schedule

The revegetation schedule is dependent upon the seeding and planting schedule, which will occur in the fall. Soil preparation and soil amendment predate the planting and must be completed sequentially prior to fall seeding and planting.

Clearing and Grubbing

Once restricted areas have been identified, the removal of shrubs and other vegetation may proceed. Because of sensitivity of nesting birds, this operation should be completed outside the nesting season (March to September). If it cannot be completed outside the nesting season, a detailed survey of every clearing zone for active bird nests must be completed prior to the onset of clearing and grubbing.

Constructed Features

Constructed features will include installation of protective fencing and planting protections at the Unit 4 pond wetland.

Soil Preparation—Fertilizers, Micronutrients, and Soil Amendments

Soil preparation would occur upon completion of clearing, grubbing, and soil removal within the reclamation area. Since it appears that the soil removal will consist of a protracted series of events, the soil preparation may occur sequentially as tracts of land are cleared and excavated. The pace of soil preparation will be dependent upon the rate of soil removal. However, within each calendar year, applications of fertilizers, micronutrients, and amendments must be completed by the middle of September.

Seeding, Planting, Cover Crop, and Mulching

Seeding and planting is recommended for the fall when seeds/plants are dormant. The cover crop would be planted at the same time, as it is included in the seed mix. Mulching would occur immediately after seeding. However, clearing and excavation processes will be ongoing year-round, leaving open areas that could be vulnerable to erosion. A sterile interim-cover crop is recommended to stabilize these areas until the site is ready for fall planting. Water would be broadcast to establish cover crops. The cover crop would be mowed in the fall and disked into the soil prior to seeding.

Watering

If an interim cover crop is used, then watering would likely be required to establish and maintain it. Since the primary reclamation plants will be seeded in the fall, they should germinate from winter and early spring moisture. Precipitation events should be monitored during the growing season and, if a drought develops, watering should be implemented as described in the revegetation section.

Grading Plan and Constructed Features

There are no specific grading requirements or constructed features within Units 1A/1B, 2, or 3.

Re-contouring of the Unit 4 arroyo channel and pond after excavating to reflect pre-removal ratios is recommended. The purpose is to maintain the flow along the channel once removal is complete.

Soil Preparation

Upon completion of excavation, soil should be graded and smoothed to remove high or low spots created by excavation that might impede soil preparation or the seeding process. Access to the soil preparation areas will be available via temporary roads created during the excavation. Staging areas will be those used during the excavation process.

Once the surface soil is removed, the entire site should be evaluated to determine whether special equipment may be necessary to prepare the soil for planting.

Soil analysis from the study area indicated that carbon to nitrogen (C/N) ratios generally ranged from 4:1 to 8:1. A ratio of 30:1 promotes rapid composting. Researchers report optimum values ranging from 20 to 31:1 (Whatcom 2016). Because nitrogen levels are low throughout most of the removal area, these levels must first be adjusted, then soil amendments must be added to balance the C/N ratio to a desirable level of 30:1.

Soil Amendment Sources

Traditional organic soil amendments include sawdust, bark, and manure. Other potential sources of amendments are compost and humate, both of which are available locally. The following is a discussion of each of these products and their potential application rates (Potential sources are provided in Appendix B).

Humate

Humate is a naturally occurring material composed of highly weathered organic compounds including salts of humic, ulmic, and fulvic acids. It is used principally as a soil amendment in agriculture. Humate, when used as a soil amendment or conditioner, has many useful properties which include the following: an increase in root density, an increase in soil depth, retention of soil moisture, increase in soil aeration, and a decrease in soil density.

By whole rock analysis, humate contains 80 percent organic material (most of which is carbon) and 20 percent inorganic material. Humate contains 2 to 5 percent nitrogen. New Mexico humate also contains gypsum, pyrite, and siderite, and sources of calcium, sulfur, and iron (Sandia National Laboratories 2012, 2013). The application of humate can raise the C/N ratio, increase the available nitrogen, and increase available micronutrients. One of these micronutrients is Boron, which was low within most samples in the removal area. Recent studies (Lodhi et. al. 2013) indicate that the C/N ratio within humates generally ranges from 30.92 to 44.16. New Mexico material near Cuba was found to have a C/N ratio of 30 to 40:1. Nitrogen content within state humates ranges from 1 to 5 percent (Peace 2016).

Based on a desired C/N ratio of 30:1, and that the soil amendment is to be applied to the top 6 inches of soil, the recommended application of humate was calculated. To calculate the proper amount of humate to add to the soil to reach a C/N ratio of 30:1, the existing level of nitrogen was used as the starting point. The existing levels of nitrogen vary widely across the site. Four of the 22 samples had medium levels of nitrogen present. The higher the levels of existing nitrogen, the more humate will need to be added to reach the C/N ratio of 30:1.

When humate is used, specific standards should be applied to the material. Accepted industry standards set a minimum of 70 percent humic substances (i.e. humic, fulvic, and ulmic acids). Humate comes out of the ground at approximately 22 percent moisture content. Exposed to the dry southwest atmosphere, it loses moisture rapidly. When used as a soil amendment no specific moisture content is needed, but from the economic standpoint, as far as weight, it should not be more than 22 percent moisture.

Run of mine material excavated from the mine varies in particle size from ablation (almost powder) to 90 millimeters (mm) in size. As the material dries it breaks down into smaller particle sizes. Smaller particles are released into the soil quicker than larger particles. Particles 1-2 millimeters in size fast-release in a few weeks to a month or two. Particles can be screened to calibrate the size. However, using runoff mine material provides a wider range of particle sizes, from the powder that would release into the soil very quickly to pieces over in inch in size that would be a much slower release. The run of mine material may be most suitable for the reclamation process as it provides a slow release of material over time.

Table 3.1 presents the existing nitrogen in ppm for 15 samples collected, as well as the volume of humate in pounds that would need to be added to elevate the C/N ratio to 30:1. The soil samples are taken at point locations and as they represent a localized area, they can, as a single point, be high or low, but taken as a whole they do provide a general idea of the C/N ratio across the project area. Within the project area most of the habitat has C/N ratios of 4:1-8:1. The C/N values at each of the 15 collection points varied. These sample locations were spread across the project area. For example, Unit 1A had five soil samples and Unit 2 had seven sample locations present within its boundaries. To adjust for the individual variation found within each of the soil samples in the units, the C/N data was averaged resulting in a single pounds per acre recommendation for each unit.

Table 3.1 - Application Rates of Humate in Pounds per Acre to Adjust C/N at Sample Sites

Soil Sample	Revegetation Unit	Nitrate Nitrogen PPM	Pounds/Acre Humate to achieve 30:1 C/N
S01-171208	1B	15.0	1258
S02-171208	2	8.4	705
S03-171208	2	8.3	697
S04-171208	1A	6.7	562
S05-171208	2	15	1258
S06-171208	2	10	840
S07-171208	2	6.2	520
S08-171208	1A	6.0	504
S09-171208	3	5.7	478
S010-171208	1A	15	1258
S011-171208	2	10	840
S012-171208	1A	7.2	604
S013-171208	2	6.0	504
S014-171208	3	8.1	680

Soil Sample	Revegetation Unit	Nitrate Nitrogen PPM	Pounds/Acre Humate to achieve 30:1 C/N
S015-171208	1A	8.8	739

Sawdust

Sawdust is a common amendment used to improve C/N ratio, which varies depending upon weathering. Nearly all the sawdust available in New Mexico is from pine trees. Fresh pine sawdust (2 months) can have a C/N ratio of 625:1 (Whatcom 2016). Applications of amendments with such a high C/N ratio would probably require the application of additional nitrogen at a rate of 5 to 10 pounds per ton of fresh sawdust. However the C/N ratio in sawdust weather for 3 years declines to about 142:1. Uncomposted sawdust is slow to break down and can tie up nitrogen (CSU Extension 2016). If uncomposted sawdust is used, the C/N ratio must be determined prior to application to determine whether additional nitrogen is needed.

US Forest Service studies (Koll et. al 2010) found application rates of 7.6 tons of pine sawdust per acre provided amendment properties similar to peat and hardwood sawdust. On average, dry sawdust weighs approximately 353 pounds per cubic yard. Recommended application rates of dry weathered sawdust are 7 to 10 tons or 40 to 55 cubic yards per acre. Although there are numerous lumberyards in New Mexico, state directories currently only list four active sawmill operations (Appendix B).

Manure

Manure is a byproduct of dairy operations and feed yards. Composted dairy manure C/N ratios vary. If manure is a selected soil amendment, the use of dry composted dairy manure and testing of sources is recommended to allow accurate calculation of application rates. Application rates vary from 30 to 100 cubic yards per acre, with 50 cubic yards per acre being typical. Dry manure contains about 2.5 cubic yards per ton. Studies in Vermont (Magdoff and Van Es 2009) found that within heavy clay soils, organic matter levels were only maintained at rates equal to 20 tons or more of manure per acre, which would be approximately 50 cubic yards per acre. There are many dairy manure sources in New Mexico (Appendix B).

Compost

Composted material is available at a variety of locations in New Mexico. Most offer municipal yard waste, which includes leaves, brush, and grass clippings. Fresh yard trimmings can contain 1.2 to 2.3 percent nitrogen, 0.2 to 0.3 percent phosphorus, 0.5 to 1.0 percent potassium, 50 to 60 percent organic matter. Because of the uncertainty of the origin of the source material for the compost, rates of application can vary from 40 to 270 cubic yards per acre with a typical rate of application of 50 cubic yards per acre.

Many municipal compost sources are vegetative-product based, but incorporate bio-solids, feed, and stable beddings, which can increase levels of nitrogen and may lower the C/N ratio. If compost is derived principally from wood and brush cuttings, it may have a higher C/N ratio and may require applying nitrogen.

Typically, composted material is applied at a rate of 40 to 50 cubic yards per acre, but this may vary depending upon the material. Particle size of the compost material can also vary. Active compost facilities nearest to the site are listed in Appendix B.

Recommended Amendment Procedure

The recommended source of carbon for amending removal area soils is humate sourced from New Mexico. Based on soil sample analysis, nitrogen is low or very low at about 80% of sampling locations.

These areas of low nitrogen appear to be distributed more or less evenly across all of the revegetation units.

Boron and Zinc were low to very low at every sampling location. Phosphate was low or very low at about 86% of the sample locations spread across all of the revegetation units.

Sulphur was low or very low at about 80% of the locations but extremely high at two location, at one of these more than 100 time higher than the surrounding areas, and about 50 times higher than would be considered normal for the area. These readings may be the result of a past dumping or spillage activity that concentrated sulfur, but overall, sulfur was low across all units.

Manganese was low only in four of the 15 sample sites which were scattered across three of the revegetation units. Copper was also low in only three samples that coincided with three of the four manganese samples, whereas magnesium was high or very high across all of the samples. Potash was medium, high, or very high across all of the samples except sample 13 in Unit 2 which had low levels of potash. No supplements are recommended for these micronutrients.

The pH is high in most of the reclamation units, but overall, the rates were not extreme with a range of 6.67-8.99, and the average pH from the samples was 8.15. One of the samples was actually slightly acidic (pH of 6.67) and more than half of the samples ranged from 8.5-9.0. Sulfur will be added to the soil to adjust the pH.

The soil analysis that the application of gypsum would balance the salts and increase the amount of oxygen in the soil to reduce seed and root rot. The sulfur in the gypsum would also increase the overall sulfur content in the soil, which is needed for enzyme formation in nitrogen utilization.

The rate of application of amendments will vary slightly between the reclamation units. Application rates of nitrogen and micronutrients were adjusted to account for the use of humate as the primary carbon source (if humate is not the selected, the rates must be adjusted). Table 3.2 provides the application rates per unit. Unit 4 is excluded as it will be planted but not cleared or graded. Humate contains nitrogen and many micronutrients needed in the removal area soils. However, the addition of sulfur, zinc, boron, nitrogen, and phosphorus is recommended. Unit 4 is only 0.15 acres in area and it is recommended that no amendments be added to this unit. The soils should be amended according to the following order to ensure efficacy:

1. **Add humate**, run of mine (minimum of 70 percent humic substances/22 percent moisture) plus **Sulfur** in the form of S-granules at 90 percent purity and approximately 0.3 centimeters (cm) particle size.

2. **Zinc** and **Boron** can be mixed in water then sprayed onto prepared soils and allowed to dry prior to application of next in sequence.

3. **Nitrogen** in ammonium and nitrate form (UN 32 16 percent Urea, 8 percent nitrate) plus **Phosphorus** in the form of rock phosphate applied together and tilled to six inches.

4. **Gypsum** should be spread on the surface and tilled into top six inches of the soil.

Humate should be acquired from New Mexico sources for which the micronutrient composition is known. If other sources are used, then a chemical analysis should be completed on micronutrient content and adjustments to the application rate of fertilizers and micronutrients may be required (minimum of 70 percent humic substances [humic, fulvic, and ulmic acids], with no more than 22 percent moisture content). Screened or run of mine material would be acceptable, but run of mine material provides a slow release of material over time and is most suitable for reclamation.

Humate is to be broadcast and tilled/disked into soil to a depth of 6 inches. If humate is unavailable, use of dry composted dairy manure is recommended. Final application rates are to be determined after testing. It will be spread with a manure spreader and disk/till into the soil to a depth of 6 inches.

Table 3.2 - Pounds per Acre Application of Soil Amendments within Reclamation Units

Reclamation Unit	Nitrogen	Phosphorus	Zinc	Boron	Sulfur	Gypsum	Humate
1A	85	95	8	1	400	2000	700-800
1B	45	0	8	1	100	2000	700-800
2	75	80	8	1	350	2000	700-800
3	85	85	8	1	250	2000	600-700
4	NA	NA	NA	NA	NA	NA	NA

Nitrogen and Micronutrients

Sulfur in the form of S-granules at 90 percent purity and approximately 0.3 centimeters (cm) particle size should be used. Disper/sul or SSP are sulfur products that should dissolve readily and can be used if the soil cannot be tilled.

Zinc sulfate should be mixed into water and the subsequent zinc solution should be sprayed onto the soil and tilled in.

Boron fertilizer should be dissolved in water and sprayed onto the soil. If boron fertilizer cannot be found, 20 Mule Team Borax can be utilized by mixing 1 tbsp into 5 gallons of water and applying the spray to 85 gallons per acre.

Nitrogen will all be added in solid form and be broadcast and subsequently tilled into the soil to a depth of 6 inches. After the application, the site should be watered to prevent the formation of hot spots in the soil.

Rock Phosphorus and elemental sulfur should be broadcast and tilled into the soil.

<u>Seeding and Planting</u>

It is recommended that seeding and planting not occur less than 4 weeks after the application of humate/sulfur to ensure a stable soil pH. Sixteen vascular plant species were selected for revegetation, including warm and cold season grasses, riparian and upland shrubs, and a riparian tree. Table 3.3 provides a list of plant species recommended for the revegetation of the removal area and a summary of specific soil needs and seasonal attributes for each species.

Table 3.3 – Revegetation Species

Species	Season	Soil Type	Sodium/pH Tolerance	Precip. (inches)	Flowering	Rhizomes
GRASSES						
Galleta (*Pleuraphis jamesii*)	Warm	All	Tolerant	5-16	Summer	Yes
Blue Grama (*Bouteloua gracilis*)	Warm	Clay	pH 6.5 to 8.3	12-14	Summer	Short
Spike dropseed (*Sporobolus contractus*)	Warm	Sandy	Fairly Tolerant	8-10	Summer	No
Alkali sacaton (*Sporobolus airoides*)	Warm	Clay	Saline pH 6.5 to 8.6	6-10	Summer	No
Western Wheatgrass (*Pascopyrum smithii*)	Cool	Fine/heavy well drained	Tolerant	Best @12-20 seeded	Seeds in June	Yes
Bottlebrush squirreltail (*Elymus elymoides*)	Cool	Fine texture to coarse/ gravelly	Tolerant Moderately saline	8-10	Spring-Summer	No
Vine mesquite (*Panicum obtusum*)	Warm	Clay	pH 4.8-7.0	8	Summer	Stolon-iferous
Spike muhly (*Muhlenbergia wrightii*)	Warm	Fine - coarse	Moderate	>12-16	Summer	No
SHRUBS						
Winterfat (*Krascheninnikovia lanata*)	NA	All soils	Fairly Tolerant	5 -20	Spring - Fall	No
Four-wing saltbush (*Atriplex canescens)*	NA	Calcareous soils	Very Tolerant	8 -15	Summer	No
Rubber rabbitbrush (*Ericameria nauseosa*)	NA	Medium to coarse	Moderate pH 5.4 to 8.2	6 -18	Fall-winter	No
Torrey wolfberry (*Lycium torreyi*)	NA	Alkali soils	Tolerant Alkaline	8-15	April-October	No
TREES						
Cottonwood (*Populus deltoides ssp. wislizeni*)	NA	Most	Tolerant	6-15	Spring	No
FORBS						
Hoary tansyaster (*Macheranthera* canescens)	NA	Wide range	pH6.0-8.4 Alkaline/saline	8-15	Summer	No
Common sunflower (*Helianthus annuus*)	NA	Wide range	5.5-8.0	8-15	Summer	No
COVER CROP						
Quickguard (Sterile Triticate)	Cool	Wide range	Tolerant	1 -10	Sterile	No

<u>Seed Application Methods and Times</u>

Due to the types and sizes of seeds being used, seeding will require both drilling and broadcast methods. There are no restrictions as to the sourcing of the seeds, but all seeds should be certified weed-free and should be from regional southwestern or Great Basin area suppliers. Specific varieties have been recommended for several grass species. The seeding specifications apply to all reclamation units. Unless otherwise noted in the contract, the prescribed mix and rate will be uniformly applied over each reclamation unit. Prior to shipping, the seed mix should be divided by the seed supplier into those that are to be drilled and those to be broadcast.

The seedbed will be prepared to a depth of 6 inches by tilling with a disc, harrow, or chiseling tool. All competitive vegetation will be uprooted during seedbed preparation, and the soil will be uniformly worked to a surface free of clods, large stones, or other foreign material that would interfere with seeding equipment. The extent of seedbed preparation will not exceed the area detailed in the plans. On slopes of 3:1 or less, a combination of drill seeding and broadcast seeding will be used.

Drill seeders must be capable of handling a variety of different seed textures. Drill rows will be no greater than 12 inches on center. All drilling will be completed parallel to the contour of the land where it is practical. Seed will be drilled to a depth of 0.25 to 0.50 inches.

Steeper slopes (greater than 3:1) will be broadcast seeded. Broadcast seeding will also be used for certain tiny seeds that need to be planted at shallow depths or those with fluffy seed coats. Broadcast seeding can be accomplished with handheld spreader, all-terrain-vehicle mounted, tractor-mounted, or other methods acceptable to the USEPA and capable of spreading seeds uniformly may be used. The volume of seeds should be doubled for those species that are specified for drilling but need to be broadcast on steep slopes.

Vehicles and other equipment unrelated to the seeding process will not travel over seeded areas. If rain or some other event prevents seeding to the proper depth, the contractor will again prepare the seedbed. The contractor will protect and care for seeded areas until final acceptance of the work and will repair all damage to seeded areas caused by pedestrian or vehicular traffic.

Each bag of seed will be sealed and labeled by the seed provider in accordance with federal and New Mexico Department of Agriculture labeling laws. The seed analysis will be no older than live (5 months) for seed shipped interstate and no older than 9 months for seed shipped intrastate. Additionally, the contractor will furnish documentation as to origin and pure live-seed content as determined by a certified testing laboratory. Pure live seed shall be defined as percent purity times percent germination, including dormant seed, divided by 100.

Areas will be seeded at the onset of the dormant period in the fall, from the middle of September, until the beginning of summer. The recommended cover crop (Quickguard Sterile Triticate) will be incorporated into the seed mix. Fall planting is recommended in order to minimize the failure of seeding due to sporadic or insufficient precipitation. Planting into the dormant season allows the seeds to take advantage of the winter moisture. However, if sufficient irrigation water is available to establish and maintain seeded material, seeding may be completed throughout the growing season into the fall.

Mulching

Barley straw mulch will be applied at a rate of 2,000 to 3,000 pounds of air-dry straw per acre and crimped. Rotted or moldy straw will not be used. Mulching will not be permitted when wind velocity exceeds 15 miles per hour. The mulch shall be spread uniformly over the area either by hand or with a mechanical mulch spreader. When spread by hand, the bales of mulch shall be torn apart and fluffed before spreading.

Planted Material

All planted material must be acquired from local or regional sources so material is naturalized to the area's climate. It is recommended that acquired plant material be in 1 gallon stem pots 4x4x14 inches deep, or some similar container. Care must be taken when transporting material to ensure that the root balls are not desiccated in the process. Once the material arrives at the site, it should be inspected to ensure it is healthy and meets the pot specification requirements. If the material must be stored prior to planting, it should be placed in a shaded area and should be inspected on a daily basis and watered as needed.

Fall planting is recommended and the material should be going into fall dormancy at the time of planting. The leaves on the planted material should be falling or already have fallen at the time of planting.

Potted material should be planted to the top of the surface layer in the pot and immediately watered after installation. A log will be kept identifying the height of shrubs, and both height and stem diameter at the base of the planted trees will be recorded when they are planted. This information will serve as a baseline for future monitoring.

During the first month after installation in the planted areas, it should be inspected on a weekly basis by the revegetation manager to make sure there is no damage from wildlife.

Some potted material (cottonwood) will be eaten by elk and mule deer if not protected. Protection cages will be installed around each planted cottonwood tree (Figure 3b). Cages will be constructed by placing three T-posts (each 8 feet long) in a triangular position around each tree, approximately 18 inches from the trunk. Chicken wire will be wrapped around the T-posts from the ground to the top of the 8-foot T-posts. This wire will be left in place until the trees are 4 to 8 inches in diameter at which time the bark should be thick enough that wildlife or livestock would not affect their growth.

Watering

If seeding occurs in the fall (including the cover crop), the seeded material is not to be watered. The seeds will be planted while dormant and, under normal winter conditions, will receive sufficient moisture to germinate the following spring. Water may be necessary during the following growing season if drought conditions develop. The seeded areas should be inspected at least twice weekly in the spring and early summer.

If drought occurs when seedlings are establishing, intense watering may be necessary until the root systems develop. This may require watering lightly several times a week (soaking down to at least 1 inch). If drought persists through the summer, water should be applied to the maturing vegetation weekly at the rate of the expected monthly annual precipitation for the area (based on climate history data).

The establishment of a cover crop as an erosion control measure during the spring or summer will require intensive watering. If the area is not mulched, water would need to be applied every day for the first 15 days such that the soil at a depth of 1 inch will hold water consistently. If the site is mulched and crimped, then water can be applied every 2 to 3 days for 15 days when the seeds should have germinated and the seedlings develop root systems.

Since piped water is expected to be available, it is recommended that the contractor develop a rotation watering system using trucks or install a temporary sprinkler system at seeded areas to increase the likelihood of successful vegetation establishment.

Rooted material should be watered when planted, and weekly for several weeks after planting. However, since this material will be planted during the dormant season, it should require only periodic watering in the winter during dry periods (once bi-weekly) to prevent the root balls from drying out. Water should be applied on a weekly basis during the following spring until the plants are established. If drought conditions occur during the growing season, then watering may be needed every few days.

Seed Mix Specifications

Unit 1A and Unit 1B

Unit 1A covers approximately 482.94 acres and Unit 1B approximately 17.24 acres. The seed mix for both units is designed to produce a grassland community with scattered low growing shrubs such as winterfat. This community would intergrade into surrounding larger shrub communities dominated by rabbitbrush and four-wing saltbush. The two communities share virtually all of the same herbaceous vegetation but differ in the presence of scattered junipers. The junipers require that a slightly varied excavation method be employed for Unit 1B. However, the seed mixtures and application methods will be the same. The seed mixture was adjusted to account for the fine sandy loams that dominated the areas where these units occur. The soil profiles indicate that these sandy loam soils can extend to depths of 48 inches from the surface. Species such as blue grama favor these well drained soils. However, galleta can thrive in both loamy and clay soils. Because of its wider range of soil texture tolerance a higher percentage of galleta was included in the seed mix than would normally be applied to reestablish the blue grama/galleta community. Although western wheatgrass was sporadic in the overall project area it was added to the mixture because it adds a cool season grass component.

Units 1A and 1B components will require 9.41 pounds of native seed and 10 pounds of cover crop seed per acre (Table 3.4). Approximately 0.51 pounds of this seed mix consists of either tiny seeds or fluffy seeds for which general broadcast seeding is recommended either by equipment or by hand. The remaining 8.9 pounds of native seed and the 10 pounds of cover crop seed will be installed via drilling. The Unit 1 is generally flat to slightly rolling, and does not have grades likely to exceed 3:1 slopes.

Table 3.4- Unit 1A and Unit 1B Seed Mix

Species	Lbs/acre (pls)	Seeds/lb	Pls/sq foot	Depth (inches)	Variety
DRILLED SEED					
Blue grama (*Bouteloua gracilis*)	2.0	711,000	32.6	¼ to ½	-
Galleta (*Pleuraphis jamesii*)	4.0	160,000	14.6	¼ to ½	Viva
Spike muhly (*Muhlenbergia wrightii)*	0.4	1,635,000	15.0	1/4 to 1/2	El Vado
Western wheat grass (*Pascopyrum smithii*)	2.5	110,000	6.3	1/4 to 1/2	Arriba
Total Natives	**8.9**		**68.5**		
Cover Crop	10.0	13,000	3.0	¼ to ½	Quickquard
Total Drilled	**18.9**		**71.5**		
BROADCAST SEED					
Spike dropseed (*Sporobolus contractus*)	0.01	2,885,000	0.6	Surface to ¼	-
Winterfat (*Krascheninnkovia lanata*)	0.50	111,000	1.2	Surface to ¼	-
Total Broadcast	**0.51**		**1.8**		

Unit 2

Units 2 covers approximately 563.34 acres. It is designed to be principally a shrub community but with pockets of grassland within the shrubs. The existing vegetation within this community is a complex mixture of species that occur within sheet flood areas associated with ephemeral drainages surrounded by pockets of upland areas unaffected by surface flows. The seed mix for this unit is designed to produce a shrub community dominated by rabbitbrush intermixed with four-wing saltbush and patches of grama and galleta grass. It will also include herbaceous species associated with arroyo or sheet flood conditions. Western wheatgrass is likely to be uncommon. It is anticipated that it will develop in shaded areas around the north sides of rabbitbrush and four-wing saltbush. The Unit 2 planting areas will require 9.7 pounds of native seed and 10.0 pounds of cover crop seed per acre (Table 3.5). Approximately 1.1 pounds of this seed mix consists of either tiny seeds or fluffy seeds for which general broadcast seeding is recommended either by equipment or by hand. The remaining 8.6 pounds of native seed and the 10 pounds of cover crop seed will be installed via drilling. Most the Unit 2 areas are flat and slopes greater than 3:1 are not expected.

Table 3.5 - Unit 2 Seed Mix

Species	Lbs/Acre (PLS)	Seeds/ Lb	PLS/ Sq Foot	Depth (inches)	Variety
DRILLED SEED					
Four-wing saltbush (*Atriplex canescens*)	0.25	70,000	0.4	½ to ¾	De-winged
Galleta (*Pleuraphis jamesii*)	2	160,000	7.3	¼ to ½	Viva
Western wheat grass (*Pascopyrum smithii*)	4	110,000	10.1	¼ to ½	Arriba
Blue grama (*Bouteloua gracilis*)	2.0	711,000	32.6	¼ to ½	-
Spike muhly (*Muhlenbergia wrightii)*	0.25	1,635,000	9.3	¼ to ½	El Vado
Common sunflower (*Helianthus annuus*)	0.1	60,000	0.1	¼ to ½	Wild Seed
Total Natives	**8.6**		**59.8**		
Cover Crop	10	13,000	3.0	¼ to ½	Quickquard
Total Drilled	**18.6**		**62.8**		
BROADCAST SEED					
Rubber rabbitbrush (*Ericameria nauseosa*)	0.75	330000	4.2	Surface to ¼	-
Alkali sacaton (*Sporobolus airoides*)	0.25	1,750,000	10.0	Surface to ¼	-
Hoary tansyaster (*Macheranthera canescens*)	0.1	1,066,900	2.4	Surface to ¼	-
Total Broadcast	**1.1**		**16.6**		

Unit 3

Unit 3 covers approximately 258.39 acres. Its seed mix is designed to replicate existing shrub communities in the project area that are dominated by rubber rabbitbrush associated with high coverage of alkali sacaton. Soil samples taken on site found a dominance sandy loam soils to a depth of 48 inches throughout the unit. Large portions of this unit occur on old floodplains of waterways. Based on the existing vegetation, soil texture, and chemistry, the proposed seed mix should produce a shrub community dominated by rubber rabbitbrush with occasional four-wing saltbush and a groundcover dominated by alkali sacaton with scattered spike dropseed, vine mesquite, and hoary tansyaster. It is expected that in the areas where shrubs do not thrive the grasses will fill in the gaps.

Unit 3 will require 8.86 pounds of native seed and 10 pounds of cover crop seed per acre (Table 3.6). Approximately 1.1 pounds of the native seed mix consists of either tiny seeds or fluffy seeds for which general broadcast seeding is recommended either by equipment or by hand. The remaining 7.75 pounds of native seed and the 10 pounds of cover crop seed will be installed via drilling. Unit 3 is flat and there are no slopes steeper than 3:1.

Table 3.6 -Unit 3 Seed Mix

Species	Lbs/Acre (PLS)	Seeds/Lb	PLS/Sq Foot	Depth (inches)	Variety
DRILLED SEED					
Galleta (*Pleuraphis jamesii*)	4	160,000	14.6	¼ to ½	Viva
Vine mesquite (*Panicum obtusum*)	0.25	145,000	0.8	¼ to ½	-
Four-wing saltbush (*Atriplex canescens*)	1.5	70,000	2.4	½ to ¾	De-winged
Blue grama (*Bouteloua gracilis*)	2.0	711,000	32.6	¼ to ½	-
Total Natives	**7.75**		**50.4**		
Cover Crop	10	13,000	3.0	¼ to ½	Quickquard
Total Drilled	**17.75**		**53.4**		
BROADCAST SEED					
Rubber rabbitbrush (*Ericameria nauseosa*)	0.75	330000	4.2	Surface to ¼	-
Alkali sacaton (*Sporobolus airoides*)	0.25	1,750,000	10.0	Surface to ¼	-
Spike dropseed (*Sporobolus contractus*)	0.01	2,885,000	0.6	Surface to ¼	-
Hoary tansyaster (*Macheranthera canescens*)	0.1	1,066,900	2.0	Surface to ¼	-
Total Broadcast	**1.11**		**16.8**		

<u>Unit 4</u>

Unit 4 is an existing pond approximately 0.45 acres in size. About 0.15 acres occurs within the project area. Only this 0.15-acre area would be revegetated. No contours are recommended since they would likely adversely impact the remaining 0.3-acre area outside of the project area. This is the only pond in the study area that by analysis of historic photography has consistently had water present over the last 20 years. Water is conveyed into the pond via ephemeral waterways.

The pond is heavily used by livestock and, consequently, no perennial vegetation is present. There appears to be sufficient and persistent water to support woody riparian vegetation such as cottonwood trees (*Populus deltoides ssp. wislizenii*). The presence of large trees would provide habitat for birds of prey and migratory bird species. The planting of cottonwood trees around the bank is recommended. Area waterholes often support annual species such as sunflowers, and the recommended seed would consist only of the common sunflower. Seeds would be raked into bare ground around the pond to a depth of 0.25-0.5 inches.

Cottonwood trees would be placed in designated locations (Figures 3a and 3b) with the root crown set at the edge of the maximum pool size. Trees will be vulnerable to damage from livestock, so Unit 4 will be fenced for 5 years to allow for establishment. The fence should consist of three-strand class 1, 12 ½ gauge, 2-point barbed wire strung on 5-foot tall studded T-posts. Since most of the pond occurs outside of the project area the fencing will extend through the water in the center of the pond. The unfenced eastern part of the pond will allow wildlife and cattle access to the water.

Table 3.7 -Unit 4 Seed

Species	Lbs /Acre (PLS)	Seeds/Lb	PLS/Sq Foot	Depth (inches)	Variety
Raked Seed					
Common sunflower (*Helianthus annuus*)	0.5	60,000	0.3	¼ to ½	Wild Seed

Table 3.7 -Unit 4 Planted Material

Species	Quantity	Type	Specification
Plantings			
Cottonwood (*Populus deltoides ssp. wislizeni*)	26	Tree	1-gallon stem pots 4x4x14 inches deep

Retain Existing Vegetation

Areas meeting the following criteria are to retain existing vegetation. No earthwork is to be completed in these areas.

- Juniper trees within Unit 1A
- Slopes steeper than 2:1 (cliff area at the south end of Unit 1A)

4- PERFORMANCE MONITORING

Monitoring Plan

Monitoring Period

The USEPA proposes to provide annual monitoring during the growing season beginning at 2 years post seeding/planting for a period of 12 years from seeding – per reclamation unit. Performance standards are based on achieving or surpassing existing conditions with regard to percent cover and species composition. Conditions have naturalized since the mine ceased operations. No formal reference plots were available outside the site, but nearby areas were observed to estimate cover and species composition for informal comparison.

Assessment Methods

The following assessment methods are proposed in order to evaluate revegetation success prior to final abandonment/closeout:

- Percent foliar cover (line transect)

Twenty permanent 100 meter transects would be established on the reclamation site to be distributed over the reclamation units relative to unit size and complexity. For each of the reclamation units, the proposed number of transects and performance goals are provided below (Tables 4.1-4.4):

Unit 1A: 4 Transects

The objective for this unit is to meet a minimum total 23 percent cover comprised of grasses and reflect the general species composition of the area.

Table 4.1

Vegetative Type	Percent Cover
Subtotal - Grasses	22-37%
Subtotal - Shrubs	1-5%
Total	**23 -42%**

Unit 1B: 2 Transects
The objective for this unit is to meet a minimum total 13 percent, retain juniper trees, and reflect the general species composition of the area.

Table 4.2

Vegetative type	Percent Cover
Subtotal - Grasses	12-32%
Subtotal - Shrubs	1-5%
Total	**13 -37%**

Unit 2: 8 Transects
The objective for this unit is to meet a minimum total 25 percent cover and reflect the general species composition of the area.

Table 4.3

Vegetative type	Percent Cover
Subtotal - Grasses	10-15%
Subtotal - Shrubs	15-35%
Total	**25-50%**

Unit 3: 6 Transects
The objective for this unit is to meet a minimum total 30 percent and reflect the general species composition of the area.

Table 4.4

Vegetative Type	Percent Cover
Subtotal - Grasses	15-20%
Subtotal - Shrubs	15 -20%
Total	**30 -40%**

Unit 4: 1 Transect
The objective for this unit is to provide vertical tree structure, shade, and annual edible plants.

- <u>Photo point monitoring</u>

At least 20 permanent photo points, each located at an endpoint of a line transect (at least one per reclamation unit/subunit) will be established to provide qualitative documentation of revegetation success.

- Species List

A complete species list for plants observed within the line transects and within a 25-foot area on either side (50-foot swath) will be provided for each transect. New species or species absent relative to previous monitoring years will be identified and total number of plant species observed provided.

Timeline

The target timeline for meeting performance standards is at or before the end of the of the 12 year monitoring period.

Ecological Function Indicators

During the monitoring period, field visits to the site will include documentation of the presence or absence of qualitative indicators that the site is providing the desired ecological function.

Unit 1

- Presence of prairie dog colonies
- Evidence of small mammal use (burrows, trails, and scat)
- Presence of insects

Units 2 and 3

- Growth of shrubs (stem diameter and height)
- Browse/forage activity by elk and deer
- Bird nests
- Presence of insects

Unit 4

- Survival of at least 50 percent of trees
- Growth of trees (stem diameter and height)
- Evidence of wildlife use (tracks, observations, and photo-documentation)

Sustainability

The following indicators of site sustainability will be provided in the monitoring report.

- Presence of mammals, birds, and reptiles for 5 or more repeated years
- Growth of shrubs/trees (stem diameter and height)
- Size/vigor/condition of planted material

5 - ADAPTIVE MANAGEMENT PLAN

Parties Responsible for Adaptive Management

The USEPA is the responsible party for implementing revegetation and subsequent monitoring. Long-term maintenance requirements will be identified by the USEPA in coordination with landowners and management agencies.

Potential Challenges

At least five types of events that could reduce either the short-term or long-term success of revegetation have been identified. These are: (1) site flooding leading to sedimentation; (2) site scouring leading to loss of vegetation and soil; (3) protracted drought resulting in a loss of surface hydrology and loss of vegetation; (4) infestation of invasive species supplanting desired species; and (5) over use by wildlife or livestock. These events are described in more detail in the paragraphs that follow.

<u>Flooding or Siltation of Planted Area</u>
Flooding of the unit could lead to the deposition of fine silts and clays that bury emergent vegetation or the deposition of sediment over seeded areas such that germinating seeds are not able to reach the surface. The impacts of siltation are most damaging during the first season when seeds are germinating or seedlings are growing (sediment deposits of 1-inch deep or more could affect seed germination or bury seedlings).

- Few drainages are present in the removal area and potential for flooding is low, but flooding is still possible.

Action for Flooding, Siltation, and Sedimentation
Following large storm events, these actions are advised:

1. The reclamation unit (in particular Unit 4) should be inspected immediately and an evaluation of the level of siltation should be completed. In Unit 4, an examination of the constructed features and planted material should be completed.

2. If siltation of at least 1 inch on seeded areas, or other damage, is detected, the USEPA should be contacted.

3. If substantial amounts of sediment have been deposited on un-germinated seeds, or if seedlings are buried, an evaluation of the extent of the damage should be completed. Small areas of damage can be reseeded by hand. Large areas may require the use of equipment. Watering may be necessary to re-establish the vegetation.

4. If substantial sediment buildup occurs within the wetland pond Unit 4, removal of material may be necessary. Any planted material buried by silt may need to be replanted.

<u>Flood Scouring of Seeded Areas, Planted Areas, and Constructed Features</u>
In the event of a large flow event, scour could remove displace seeds, plants, or soil amendments, fertilizers and micronutrients, and damage constructed features.

- Unit 4 is vulnerable to scour during large flow events.

Action for Scouring from Flooding

1. The reclamation units should be inspected immediately and an evaluation extent of scouring and cutting should be completed. These three observations should be documented:
    a) Determine whether the scouring was deeper than 1 inch of the surface, which would have removed seeds or established vegetation.
    b) Determine whether the scouring was deeper than 6 inches, which would remove the soil treated with amendments, fertilizers, or micronutrients.
    c) Determine whether the scouring was deeper than 6 inches below the surface, which would alter the contours of the landscape. Within Unit 4a, a determination should be made as to whether the constructed features are damaged.
2. If substantial scour has occurred to planted areas or if constructed features have been damaged, then the USEPA should be contacted.
3. Shallow scours less than 1 inch that remove vegetation but do no impact the subsoil can be mitigated by spreading a thin layer of soil over the area (approximately 1 inch), reseeding, and mulching.

   Scours to a depth of 6 inches will likely need localized recontouring followed by reapplication of amendments, fertilizers, micronutrients, seeding, and mulching. Cuts deeper than 6 inches may require regrading of a broader area to return the contours to the pre-flood conditions with the ultimate response developed in coordination with the designing engineer and the USEPA.
4. Damage to the constructed features may require repair or design modifications. A certified engineer in cooperation with the USEPA should complete any modification of the designs.

<u>Drought</u>
The proposed revegetation plan is designed to accommodate local average rainfall patterns, particularly the summer monsoon season. The current drought status of the removal area is currently classified as *not in drought* (National Drought Mitigation Center). An evaluation of area temperature averages and drought status should be conducted prior to seeding or planting. Regular monitoring should occur during the revegetation process along with inspection of seeded sites to determine whether supplemental watering is required. The fall planting schedule was identified in anticipation of dry conditions. However, changing short or long term climate patterns should be considered.

In all units, drought could result in the failure of seeded material to germinate, the death of seedlings, or the death/weakening of planted or established vegetation.

Action for Drought

1. Supplemental water is expected to be available. However, if not available, and weather monitoring indicates that precipitation levels are below 50 percent of normal and are likely to continue, then consideration should be given to postponing planting.
2. If drought conditions develop after planting, weekly monitoring of the seeded and planted areas should be implemented to look for signs of stress (withered leaves, brown leaves, or yellowing).

3. If supplemental water is available, it should be provided to the planted and seeded material. Watering should reflect natural events of a good monsoon season (minimum of 0.5 inches per week from July 1 through September 30). The reclamation area is so large that regular watering of the entire area may be impractical. If full watering of the site is not possible, then a triage approach is recommended.
    a) The planted wetland vegetation in Unit 4 is most vulnerable and should be watered first.
    b) Areas where seeded vegetation has rooted and is growing should be watered next. (Replacing established vegetation is more difficult than reseeding.)
    c) Seeded areas that have germinated would be third on the list.
    d) Seeded areas that have not germinated should be watered last.

<u>Invasive Species</u>

Three New Mexico noxious weed species are currently present (Halogeton, salt cedar, and Russian olive).

Action for Invasive Species

1. If the salt cedars sprout once soils are scraped, they will be spot treated with spray-on herbicide (Arsenal), or if there is concern about killing desirable seeded vegetation, the top of each individual stem can be cut off during the early spring and concentrated herbicide can be applied directly to the fresh cut with a small paintbrush.

2. Mechanical clearing of the Russian olives present will occur during the grubbing process. No other treatment is expected to be necessary.

3. If patches of other species of weeds invade the site after the clearing, then grubbing and excavation is recommended followed immediately by herbicide.

<u>Overuse by Wildlife and Livestock</u>

Livestock will be excluded from the site during the revegetation process and should not damage vegetation. However, deer and elk occur in the area. Elk will graze on grasses once they sprout and it would be difficult to exclude them from the seeded areas. Elk and deer will eat cottonwood saplings.

Action for Overuse by Wildlife and Livestock

1. Livestock should be excluded from the area until the native vegetation has become fully established (5 years recommended).
2. If deer or elk are damaging seeded areas, the New Mexico Department of Game and Fish (NMDGF) should be contacted. NMDGF maintains a Wildlife Depredation and Nuisance Abatement Program designed to reduce wildlife damage to property.
3. Damage from browsing may occur to the planted vegetation in Unit 4. Wire cages have been recommended to avoid or reduce browsing. However, these cages can be damaged. Therefore, they must be periodically inspected and repaired or replaced as needed.

Procedures for Modifying Performance Standards and Timeframe

As reclamation proceeds, altering the work plan and performance standards may be required. Deviations from expected performance will become evident during the annual monitoring of the site. The reclamation management contractor and the USEPA will be notified of a need to modify any of the following due to availability of materials, natural events that alter the landscape/potential for success, or other events:

- Soil amendments
- Seed mix
- Planting material
- Constructed features
- Performance goals
- Performance standards

In coordination with state agency stakeholders, the USEPA will determine whether modifications are acceptable and develop new standards if needed, which will be provided to the contractor as soon as feasible for implementation.

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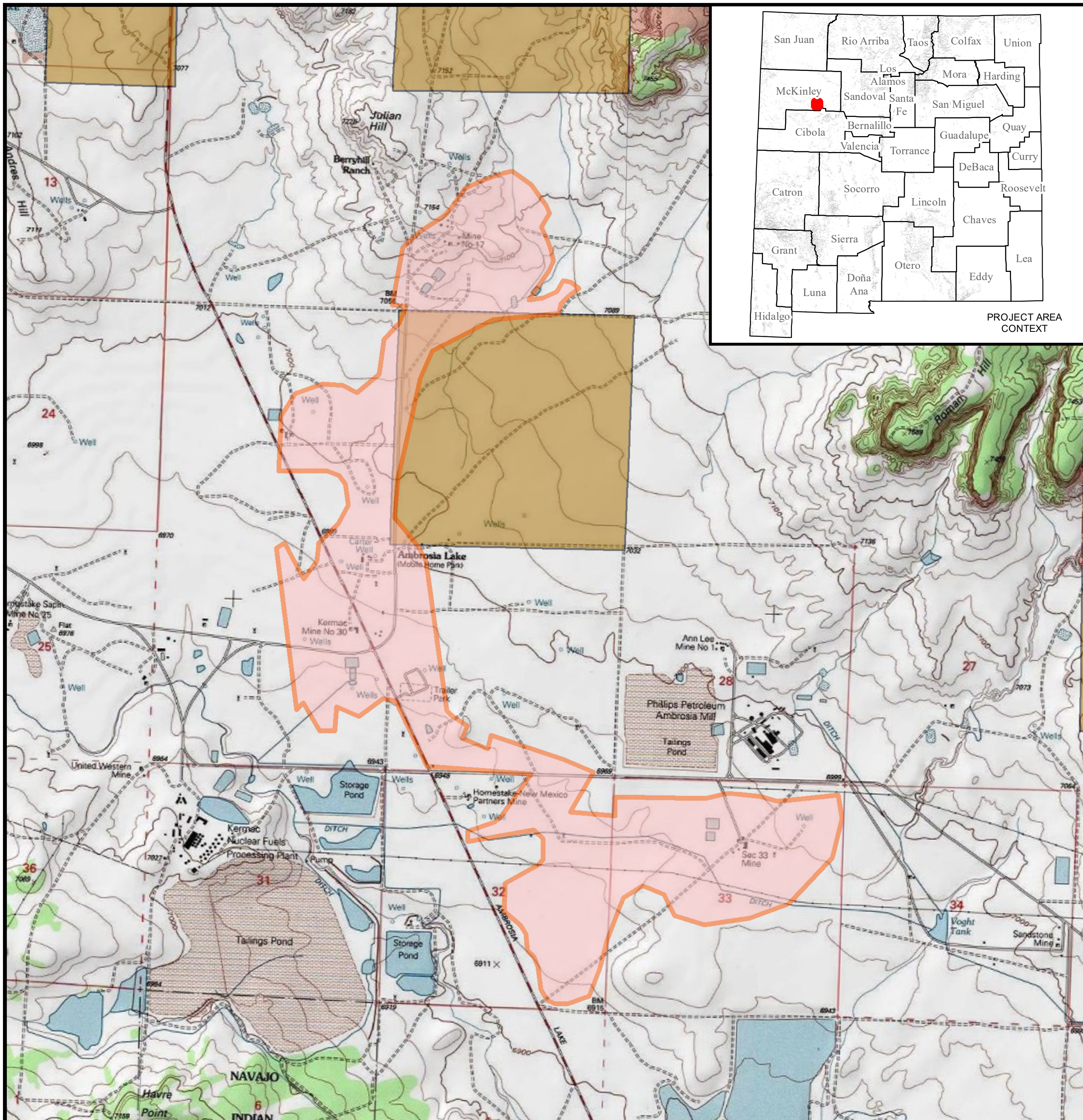
APPENDIX A

Figures

Exhibits



Legend

Removal Area

Land Ownership

BLM

Private

NOTES:
T14N, R09W; Secs.17, 18, 19, 20, 29, 30, 31, 32 &33 Ambrosia Lake, NM USGS 7.5' Quadrangle McKinley County, New Mexico

0 0.25 0.5 1 Miles

0 0.25 0.5 1 Kilometers

N

1:40,000

Project Location Map

FIGURE 1a

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PROJECT NO.:	444618-1440000.03
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DRAWN BY:	cj.vialpando
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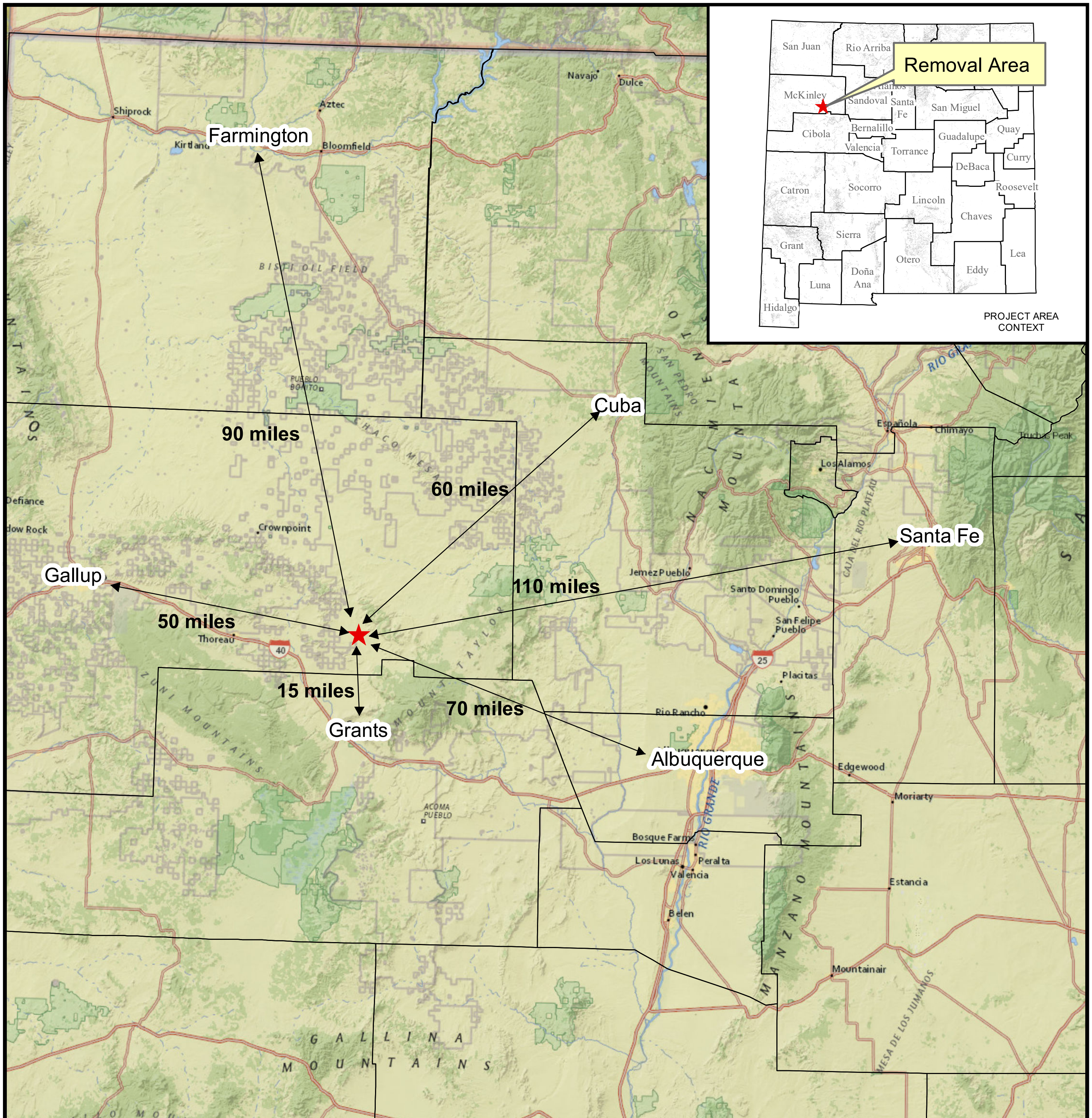
FILE NAME:
18_144_03_Fig_1a_topo.MXD

USEPA Tronox Central GSA Revegetation, McKinley County, New Mexico



Legend

★ Removal Area

NOTES:
T14N, R09W; Secs.17, 18, 19, 20, 29, 30, 31, 32 &33
Ambrosia Lake, NM USGS 7.5' Quadrangle McKinley County, New Mexico

0 15 30 60 Miles

0 25 50 100 Kilometers

1:1,700,000

Reference Distance Map

FIGURE 1b

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Sources: National Geographic, Esri,

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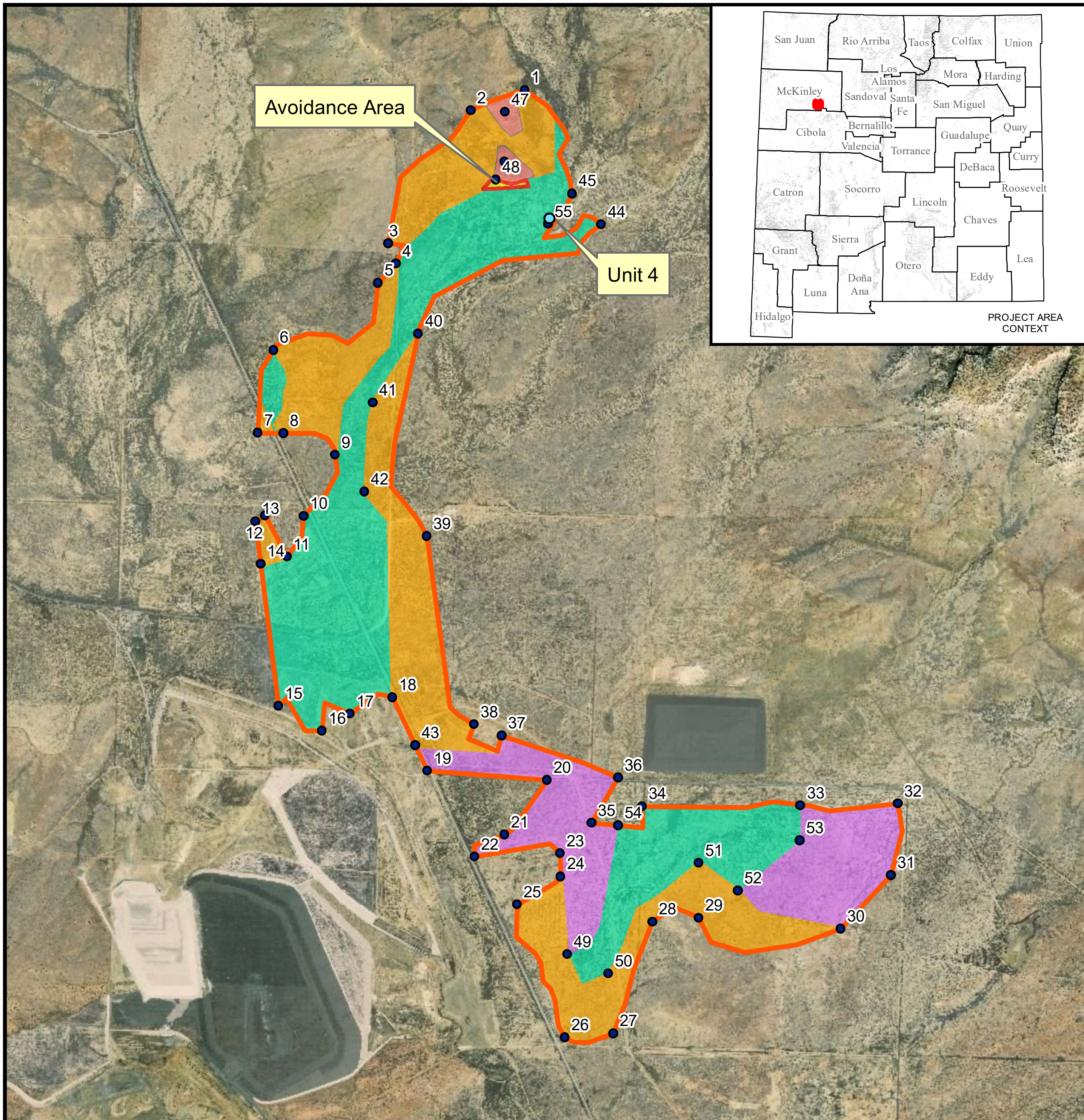
USEPA Tronox Central GSA Revegetation, McKinley County, New Mexico



Legend

- Unit Points
- Removal Area
- Avoidance Area
- Unit 1A
- Unit 1B
- Unit 2
- Unit 3
- Unit 4

NOTES:
T14N, R09W; Secs.17, 18, 19, 20, 29, 30, 31, 32 &33 Ambrosia Lake, NM USGS 7.5' Quadrangle McKinley County, New Mexico

0 0.25 0.5 1 Miles

0 0.25 0.5 1 Kilometers

N

1:35,000

Reclamation Units MAP

FIGURE 2

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FILE NAME:
18_144_03_Fig_2.MXD

USEPA Tronox Central GSA Revegetation, McKinley County, New Mexico

Reclalamation Unit ID Sites			
Point ID		UTM	
Id	Unit	Xcoord	Ycoord
1	1A	244631.2	3925943
2	1A	244299	3925817
3	1A	243789.9	3925003
4	2	243839.2	3924877
5	1A	243730.3	3924761
6	1A	243087.8	3924349
7	2	242992.3	3923840
8	1A	243149.4	3923837
9	2	243465.9	3923705
10	2	243273.6	3923329
11	2	243170.7	3923079
12	1A	243035.6	3923332
13	1A	242976.3	3923297
14	1A	243009.2	3923035
15	2	243119.1	3922163
16	2	243385.1	3922013
17	2	243555.7	3922116
18	2	243817.2	3922216
19	3	244032.5	3921767
20	3	244765.8	3921710
21	3	244505.8	3921375
22	3	244321.7	3921239
23	3	244845.6	3921260
24	3	244849.4	3921119
25	1A	244583.6	3920945
26	1A	244875.9	3920130
27	1A	245171	3920155
28	1A	245410.7	3920840
29	1A	245697.6	3920864
30	1A	246566.6	3920798
31	3	246875.3	3921125
32	3	246917.2	3921564
33	3	246320.4	3921553
34	2	245349.6	3921548
35	3	245040	3921445
36	3	245202.7	3921725
37	3	244487	3921982
38	1A	244317.7	3922051
39	1A	244028	3923206
40	1A	243976.4	3924448
41	2	243695.7	3924024
42	2	243647.1	3923478
43	1A	243957.2	3921924
44	2	245099.6	3925118

45	2	244921	3925308
46	1B	244505.2	3925503
47	1B	244507.8	3925808
48	1B	244451.9	3925394
49	2	244891.9	3920640
50	2	245142.2	3920521
51	2	245695.7	3921199
52	2	245937.7	3921032
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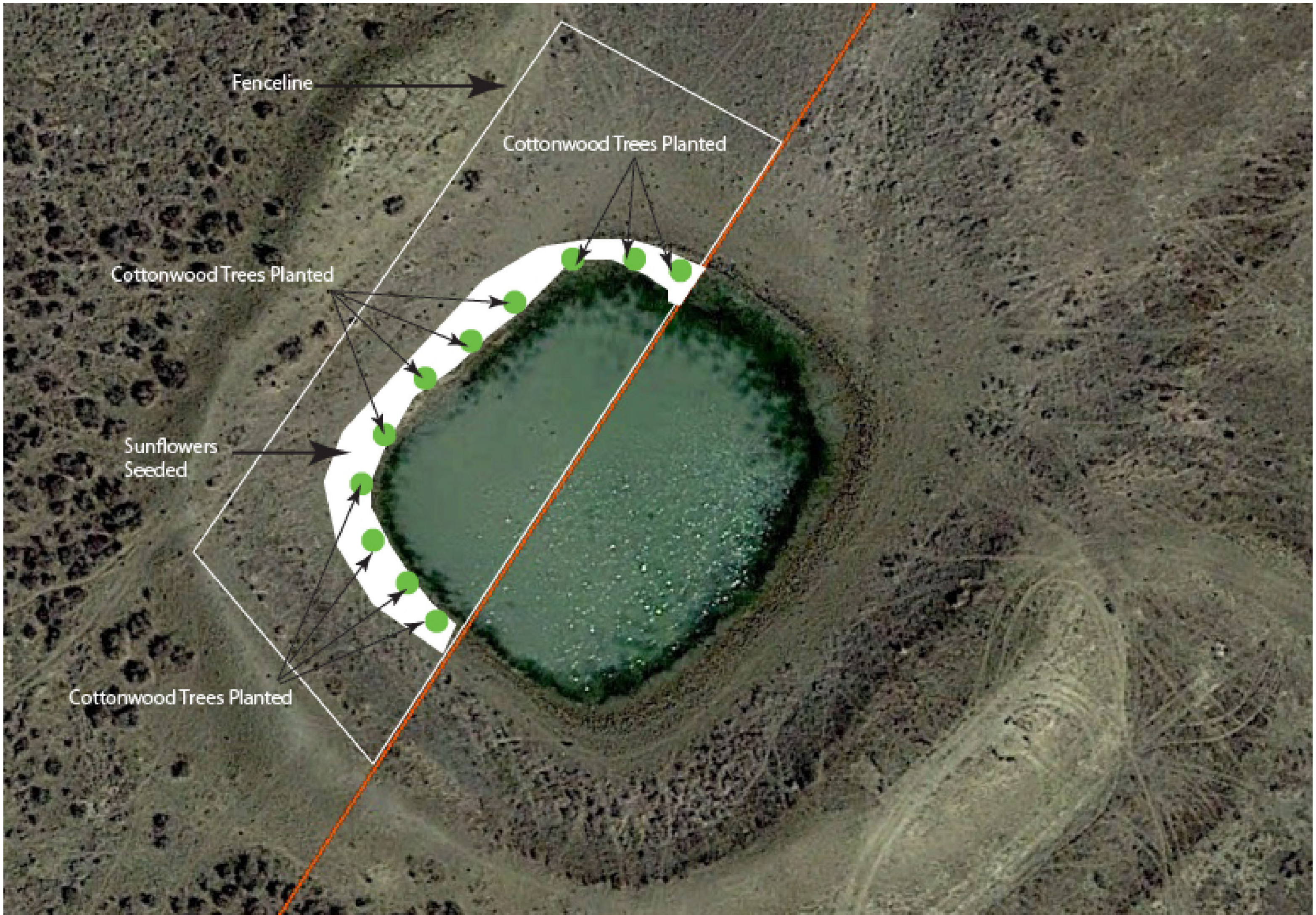

Unit 4

Not to scale

Conceptual Planting Overview

FIGURE 3a

NOTES:
T14N, R09W; Secs.17, 18, 19, 20, 29, 30, 31, 32 &33
Ambrosia Lake, NM
USGS 7.5' Quadrangle
McKinley County,
New Mexico

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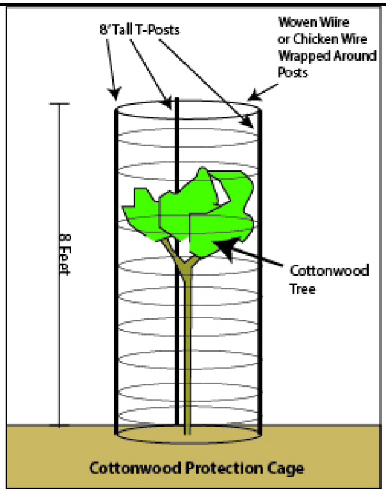
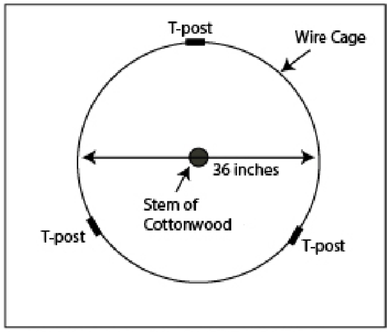
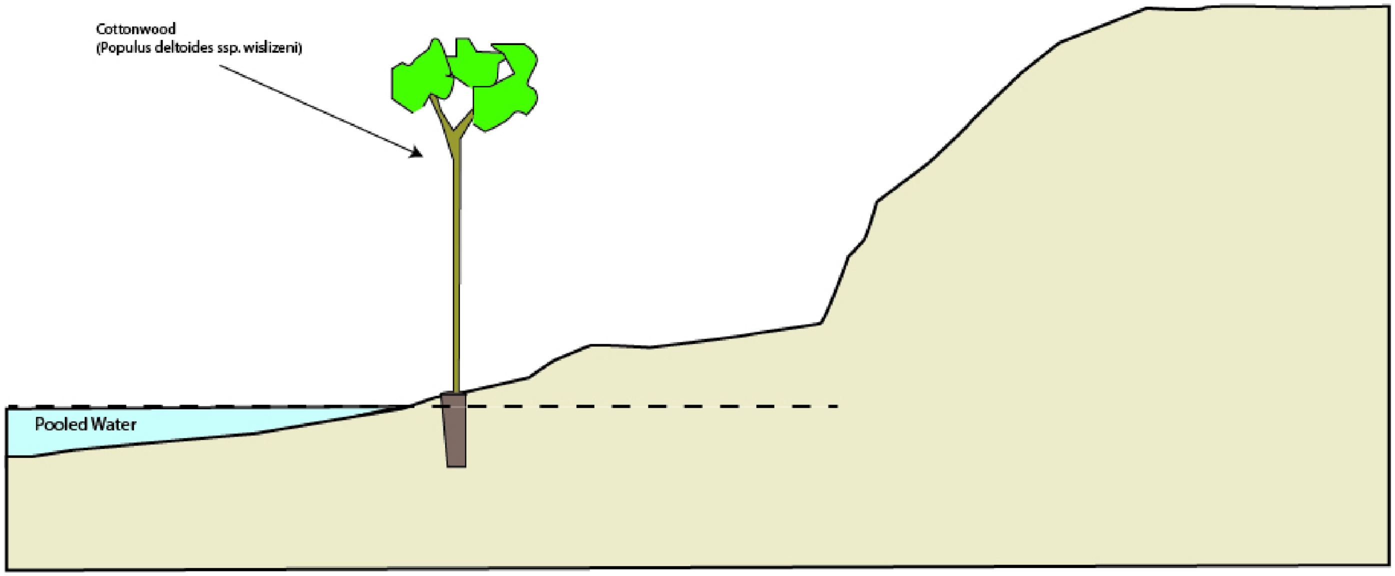
16053_Fig_3a_overview.MXD

USEPA Tronox Central
GSA Revegetation,
McKinley County, New Mexico





Plan View of Cottonwood Protection Cage



Unit 4

Conceptual Planting Plan View

Figure 3b

NOTES:
T14N, R09W; Secs.17, 18, 19, 20, 29, 30, 31, 32 &33
Ambrosia Lake, NM
USGS 7.5' Quadrangle
McKinley County,
New Mexico

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FILE NAME:
16053_Fig_3b_overview.MXD

USEPA Tronox Central
GSA Revegetation,
McKinley County, New Mexico

APPENDIX B

Soil Amendment Sources

Humate Sources

Menefee Mining Corporation
36 Duke City Rd,
Cuba, NM 87103
575-289-0259

Mesa Verde Resources
P.O. box 1368
Placitas, NM 87043
Contact: Bruce Reid
505-362-3777

Horizon Ag Products
23 Cubita Road, Cuba,
NM 87013. Sandoval County
Contact: Steve Brady
575-289-2565

Sawdust Sources

Olguin Sawmill
Taos , New Meixco-
Sawdust available 575-758-1506

El Molino Sawmill
Alto, NM
575-336-1237-
Boards, firewood, uncertain about sawdust

Spotted Owl Timber,
Santa Fe, NM 505-474-5326
Sawdust, mulch and landscaping material

Mt. Taylor Manufacturing LLC.
Milan, NM.
505-877-0890 Albuquerque,
Milan 505 287-9469
Possibly sawdust and compost from wood products

Dairy Manure Sources

De Smet Dairy and Creamery
2405 McNew Rd
Bosque Farms, NM 87068
(505) 916-0475

Old Windmill Dairy
52 Paso Ranch Rd
Estancia, NM 87016
(505) 384-0033

asband Dairy
7116 Isleta Blvd SW
Albuquerque, NM 87105
(505) 873-2171

Mickey's Cash & Carry Dairy
5102 Coors Blvd SW
Albuquerque, NM 87105
(505) 873-0542

Edeal Dairy
147 Edeal Rd
Los Lunas, NM 87031
(505) 865-9517

Creamland Dairies
1201 W Apache St
Farmington, NM, 87401
(505) 325-0281

Willard Dairy
190 Dairy Rd
Willard, NM 87063
(505) 384-0573

Pareo Farm Inc
PO Box 489,
Veguita, NM 87062
(505) 864-8103

Caballo Dairy
1 Caballo Alto Rd
Arrey, NM 87930
(575) 267-3061

Gonzalez Dairy Inc
14310 Stern Dr
Mesquite, NM 88048
(575) 233-4801

F&A Dairy Products, Inc.
355 Crawford Blvd
Las Cruces, NM 88007
(575) 647-1696

Las Uvas Valley Dairy
Las Uvas Diary Rd
Hatch, NM 87937
(575) 267-3037

Compost Sources

Albuquerque/Bernalillo County Water Utility Authority, Soils Amendment Facility 7401 Access Road NW
Albuquerque, NM 87102
4201 2nd St. SW (waste water treatment plant)
Albuquerque, NM 87105
Contact: Joe Bailey, Supervisor
E-mail: jbailey@abcwua.org
Phone: 505-205-5721 or 505-873-6989
Feedstocks: 20% solids (municipal biosolids), waste horse stable bedding, pulverized green waste, bark fines and chips
Quantity produced: 45,000 cu. yds. per year capacity.

Barela Landscaping
7713 Bates Rd. SE
Albuquerque, NM 87105
Contact: Eddie Barela, owner
E-mail: cb0513@myway.com
Phone: 505-877-8522
Feedstocks: yard trimmings, steer manure, dairy manure, chili peelings Quantity produced: 40,000 cu. yds. per year

Barela Timber management Co
Contact: Ralph Barela
viga@newmexico.com
699 Harlan Dr.
Las Vegas, NM 87701
Phone: 505-617-1966, 505-425-9479, 505-454-4311 60,000 cu. yds. Capacity
Compost, Colored Mulches, Aged Mulch, Vigas

Midwest Bio-Systems
3333 Majestic Ridge -207B
Las Cruces, NM 88011
Contact: Greg Berry
Phone: 575-521-3692 Fax 521-3699
E-mail: gberry@totacc.com
Applications: Composting systems, microbe applications and Aeromaster turning equipment, Compost and balanced soil fertility consulting.

Mountain Rich Soils
HCR 74, Box 22612
El Prado, NM 87529
Contact: Dave West
Phone: 505-758-4150
Email: growfoodnow@tierralucero.org
Feedstocks: alfalfa, forest waste, manure, straw, humates, Production: approx. 10,000 cu. yds. per year

Sandoval County Landfill
Contact: Buster Roseberry
Phone: 505-269-6120

E-mail: rmsanchez@sandovalcounty.com
Feedstocks: Green waste, cow manure, horse manure
Future feedstocks to include biosolids and municipal solid waste
Quantity Produced: to be determined
Application: county projects, general public

Santa Fe, City of
73 Paseo Real
Santa Fe, NM 87507
General Information 505-955-4650
Contact: Sherman Bilbo, Compost
Phone: 505-955-4681
E-mail: swbilbo@santafenm.gov
Website: www.santafenm.gov/compost
Feedstocks: wood chips, biosolids, horse stable bedding
Quantity produced: 30,000-35,000 Cubic Yards per year will eventually be produced .
The composting operation processes all biosolids with appropriate high-carbon feedstocks to produce a marketable soil conditioner product. (Screened Compost $11.50/cubic yard; Unscreened Compost $9.00/cubic yard; Compost Overs $6.00/cubic yard)

Santa Fe Solid Waste Management Agency Caja del Rio Landfill
149 Wildlife Way
Santa Fe, NM 87507 Contact: Randall Kippenbrock, Executive Director
E-mail: rkippenbrock@sfswma.org
Phone: 505-424-1850 ext. 100 or 505-820-0208 (Transfer Station)
Feedstocks: ground green waste and horse manure / stable bedding
Qty Produced: Actual 2004 = 10,000 Tons
Application: DOT Erosion Control Compost, currently some sales sold as mulch. If loaded, charge for compost is $6 / cu. yd.; screened compost is $10 / cu. yd. Mulch $2 / cu. yd.

Soilutions, Inc.
P.O. Box 1479
Tijeras, NM 87059
9008 Bates Road, SE (no zip - Delivery address)
Albuquerque, NM
Contact: Jim Brooks, Misch Lehrer, Walter Dods
Phone: 505-877-0220 or 505-281-8425
E-mail: walter@soilutions.net
Feedstocks: Yard trimmings, selected animal manures, stall bedding, agricultural and food processing residuals
Quantity Produced: 5,000-10,000 cu. yds. annually
Products Available: Premium Compost, soil blends, mulches, NMDOT erosion control products, composting worms, green waste, food waste and C&D recycling services
Comments: Company is actively pursuing nitrogen sources as well as distributorships in New Mexico.
Quantity Produced: 300,000+ cu. Yds. Per year
Types of equipment: extensive
Application: Wholesale, retail, golf courses and other turf grass applications, etc.

APPENDIX G

DRAFT COMINGLED CONTAMINATION INVESTIGATION WORK PLAN

*“**Appendix G is withheld until consensus is reached with other federal and state stakeholders**.”*

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APPENDIX H

HUMAN HEALTH AND ECOLOGICAL STREAMLINED RISK EVALUATION

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HUMAN HEALTH AND ECOLOGICAL RISK EVALUATION

Uranium mine wastes are known to contain elevated levels of radium-226 (Ra-226) and associated progeny. Radium-226, a daughter product in the uranium-238 (U-238) decay chain, has been found to be the predominant contributor of radiological risk to human health and is the radionuclide for which historical cleanup limits have been specified at uranium mines. Radium-226 has been identified as a human health contaminant of potential concern (COPC) at the Central Geographic Sub-Area (GSA) Mines Site to be addressed as part of cleanup actions. Radium is formed when uranium and thorium undergo natural decay in the environment. During the decay processes, alpha, beta, and gamma radiation are released. Results of Site investigations have indicated the need for a response action to control releases and prevent human exposure to radiation at the Site. Table H-1 summarizes the radionuclide analytical results and the human health risks associated with Ra-226 and other isotopes of the Uranium-235 (U-235) and U-238 decay chains at the Central GSA Mines Site, assuming no action is taken. EPA considered contributions to human health and ecological risks from all of the isotopes in the U-238 and U-235 decay chains. Note that the risk estimates presented in Table H-1 also include contribution of the background level of Ra-226 (1.5 picocuries per gram [pCi/g]). The estimated cancer risk associated with some of the waste soil currently present at the Central GSA Mines Site exceeds the EPA 10^{-4} overall cancer risk threshold, and therefore it is anticipated that action will be taken to reduce the human health risk.

Several other non-radionuclide metals were also identified as exceeding human health screening levels or background (Table H-2). Table H-3 summarizes the human health risks associated with non-radionuclide metals. Tables H-4 through H-8 present the results of an ecological risk evaluation for the Central GSA Mines Site. Table H-9 presents an evaluation of the grazing of forage by domesticated animals and wildlife.

The following sections describe the Removal Site Evaluation (RSE) process. Based on this evaluation, it is concluded that Site actions are required to address radiological human health risks at the Central GSA Mines Site, and that actions taken to address radionuclides will be protective for non-radionuclide chemical exposure, and for exposure of ecological receptors.

1. Analytical Data Used in Streamlined Risk Evaluation Calculations

Analytical results of soil samples collected during the Removal Site Evaluation at the Central GSA Mines Site (WESTON, 2019) served as input data for the human health and ecological streamlined risk evaluation (SRE). These samples were analyzed for radioisotopes (i.e., Ra-226) via gamma spectroscopy by an off-site laboratory (surface samples) or in the field using an on-site Multi-Channel Analyzer (MCA), with approximately 12% of the samples sent to an off-site laboratory for verification of MCA results (subsurface samples). Seventeen surface and 234 subsurface samples, plus 25 field duplicates, were collected for gamma spectroscopy analysis (see Table 1-2 [surface] and Table 1-3 [subsurface]). If both an off-site laboratory result and on-site MCA result were available, the off-site laboratory result was used in the SRE.

Surface soil (0-to-6-inches below ground surface [bgs]) samples were collected to verify that radioactive contamination existed in areas of elevated gamma and were from areas above and below the action level. Surface composite soil samples were collected from five locations in Section 17 (one location was a grab sample), two locations in Section 19, one location in Sections 20 and 29, three locations in Section 32, and five locations in Section 33. The composite samples were also used to develop a correlation with Site gamma measurements in counts per minute (cpm) (Weston, 2019).

To determine the vertical extent of contamination, subsurface soil samples (12-to-24-inches bgs) were collected from "mine impact" (direct impact from surface-related mining operations) and "sheet flow" (mining operation surface water discharge) areas throughout the surface-contaminated areas. The samples were collected in "mine areas" at a density of one sample for each 2 acres. Subsurface soil samples were collected from 42 locations in Section 17, from 16 locations in Section 20, from 37 locations in Section 29, 50 locations in Section 30, from 27 locations in Section 32, and from 62 locations in Section 33.

The EPA collected eight surface soil samples, plus one duplicate, for analysis of Target Analyte List (TAL) metals plus uranium. Two surface soil samples were collected from Sections 17, 19, and 30, and two surface soil samples plus one duplicate were collected from Section 33. The metals analysis was performed to evaluate if common mining-related heavy metals present a potential risk to human health or to the environment. A minimal number of samples were analyzed for TAL metals and uranium metals due to consistent geochemistry and limited historical processing for metals other than uranium as product. There is no history of non-uranium metals mining in the Ambrosia Lake Sub-District (ALSD) of the Grants Mining District. The soil sample analytical results used in the evaluations are summarized in Table 1-2, Table 1-3, and Table 1-4.

Additionally, EPA collected fifteen vegetative metals uptake samples to determine the current vegetative nutrient values and uptake of potentially hazardous constituents available to grazing animals (domesticated animals and wildlife). The analytical results are presented in Appendix A and summarized in Table H-9. Native plant tissue samples were analyzed for nutrients (iron, zinc, copper, and manganese) and for toxicity metals (molybdenum, uranium, vanadium, and selenium).

2. Screening to Identify Contaminants of Potential Concern

The non-radionuclide sampling results were screened against the May 2020 EPA [2020a] residential Regional Screening Levels (RSLs) (https://www.epa.gov/risk/regional-screening-levels-rsls), the New Mexico Environment Department (NMED, 2019) generic soil screening levels (SSLs) for residential land use, and the local background concentrations to identify human health non-radionuclide COPCs. Table H-2 summarizes this screening process, showing contaminants that were considered, the minimum and maximum concentrations, associated RSLs and SSLs, and background concentrations, and either identifies each contaminant as a COPC or explains why it was screened from consideration. RSLs were adjusted to a target cancer risk of 10^{-6} and SSLs to 10^{-5}, and a target hazard quotient of 0.1, to account for additive risk. Aluminum, arsenic, cobalt, iron, manganese, uranium, and vanadium concentrations exceeded the most stringent of their respective RSLs.

Site-specific background levels were not available. Background levels for the metals were obtained from literature values for New Mexico (EPA, 2007) and the Western United States (Shacklette and Boernren, 1984). These background levels are also considered in the risk evaluation. Background information is important to risk managers because the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) program generally does not clean up to concentrations below natural or anthropogenic background levels (EPA, 2002). Aluminum, cobalt, iron, and manganese concentrations do not exceed background levels. The maximum arsenic concentration (10 mg/kg) exceeds the mean concentration (5.9 mg/kg) but is less than 2 times the mean background (11.8 mg/kg). Similarly, the maximum vanadium concentration (98 mg/kg) exceeds the mean concentration (71.4 mg/kg) but is less than 2 times the mean background (142.8 mg/kg). However, the maximum uranium concentration (77 mg/kg) exceeds the mean concentration (2.5 mg/kg) and also exceeds at 2 times the mean background (5.0 mg/kg).

As shown in Table H-2, uranium was identified as a non-radionuclide human health COPC in soil. Therefore, uranium is carried through the risk evaluation as a COPC and is discussed in the following section.

A separate screening procedure was performed in the ecological streamlined risk evaluation. The results of the screening level ecological risk characterization are included in Table H-4 for radionuclides and Table H-5 for metals. Literature-based ecological screening benchmark values for direct contact and food-chain evaluations are used to characterize potential ecological effects. The ecological streamlined risk evaluation is detailed in Section 4.

3. Human Health Streamlined Risk Evaluation

The results of the human health SRE are summarized in Table H-1 for radionuclides. Cancer is the major effect of concern from radionuclides. Radium is known to cause bone, head, and nasal passage tumors in humans; and radon, via inhalation exposure, causes lung cancer in humans. The potential excess lifetime cancer risk on human receptors from exposure to Ra-226 and other isotopes of the U-235 and U-238 decay chains in soil was assessed for the Central GSA Mines Site. The potential for non-carcinogenic adverse health effects on human receptors was also assessed for the non-radionuclide chemicals identified as COPCs in soil at the Central GSA Mines Site (i.e., uranium). Radionuclides in the soil may be absorbed by plants and consumed by livestock and humans. Persons working at the Site may be exposed to contaminated dust by inhalation of particulate matter. Whole body (external) radiation may be experienced by people on or near the Site itself. Key assumptions used in the human health streamlined risk evaluation are described below.

Many sections of the Ambrosia Lake Valley are used for grazing cattle, although some sections are not currently grazed due to the radioactive contamination in the surface soil. There are currently no residences in the former mining area of the Central GSA Mines Site and it is unlikely that the property would be used for residential development due to the remoteness of the area. Cattle ranching is considered to remain as the future use of the Site. A rancher may be exposed to radiological contaminants through incidental ingestion of soil, external radiation from contaminants, inhalation of fugitive dusts, and meat consumption, taking into account the potential future land use of grazing and associated ranching activities.

The indoor and outdoor radon inhalation pathway was not included in this assessment. The indoor inhalation pathway was not considered because there are no occupied buildings on the Site and no future plans for Site development. An EPA review of outdoor radon data collected at uranium mine and mill sites (WESTON, 2012; Rio Algom Mining, 2016) in the vicinity of the Central GSA Mines Site verified that clean-air dilution of radon emissions from those sites rapidly reduces the airborne concentrations to inconsequential levels (i.e., less than the EPA recommended limit for *indoor* concentrations of 4 pCi/L).

The risk to a rancher from potential exposure to isotopes of the U-235 and U-238 decay chains was evaluated at the Central GSA Mines Site area. The EPA Preliminary Remediation Goal (PRG) calculator (https://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search) was used to calculate site-specific risk estimates for exposure from incidental ingestion of soil, external exposure, inhalation of particulates (details are included in Attachment 1), and consumption of meat (i.e., beef). The risk estimates considered the isotopes of the U-235 decay chain (i.e., Th-231, Pa-231, Ac-227, Th-227, Fr-223, Ra-223, At-219, Rn-219, Bi-215, Po-215, Pb-211, Bi-211, Po-211, and Tl-207) and the U-238 decay chain (i.e., Th-234, Pa-234m, U-234, Pa-234, Th-230, Ra-226, Rn-222, Po-218, Pb-214, At-218, Bi-214, Rn-218, Po-214, Tl-210, Pb-210, Pb-210, Bi-210, Hg-206, Po-210, and Tl-206) as being in secular equilibrium. The assumption of secular equilibrium is that the parent is continually being renewed. The single isotopes of U-235 and U-238 were selected, and the calculator identified all the daughters in the chain. The risk estimates for each daughter are combined with the parent on a fractional basis. The fractional basis is determined by branching fractions where a progeny may decay into more than one isotope. The resulting risk estimate is now based on secular equilibrium of the full chain (EPA [2020b] PRG Calculator User's Guide (https://epa-prgs.ornl.gov/radionuclides/prg_guide.html).

A combination of three land-use scenario templates in the PRG Calculator were used to develop the risk estimates: the "Composite Worker" to model outdoor ranching activities; the "Indoor Worker" to model ranching activities inside a truck; and the "Farmer" to model the consumption of site-raised beef. A number of conservative default assumptions presented in the PRG Calculator and literature sources were reviewed to develop conservative assumptions for calculating risk estimates for the rancher. EPA derived PRG Calculator default values to represent reasonable maximum exposure to broad-based populations, typically 90-to-95 percentile values, which are well above the mean. These assumptions are described below.

- Ranching was assumed to occur on the site 5 days per week for 50 weeks per year for 25 years, which is the default exposure frequency and duration of an indoor worker and composite worker (EPA, 2020b).

- Two cattle ranchers who operate on lands near the Site were interviewed to determine a reasonable amount of time a cattle rancher might spend ranching. Consequently, EPA used a value of 400 hours per year (1.6 hours/day [interviews] for 250 days/year [PRG Calculator default value for Composite and Indoor Worker]) for annual exposure frequency. Half of this time was determined to be spent outdoors (0.8 hours; see discussion below).

- Traveling in a vehicle will limit external exposure to radionuclides; a rancher was assumed half of their exposure time (0.8 hours per day) in a truck (EPA, 2011, Table 16-24: Time Spent in Truck, Doers. Western Census Region, 95 percentile; 235 minutes/day = 3.9 hours = approximately 50% of an 8-hour workday). A vehicle was estimated to provide a gamma shielding factor of 0.7 by a Certified Health Physicist conducting a reproducible field experiment (Attachment 2). No cover layer was assumed for exposure outside a vehicle.

- A default composite worker soil intake rate of 100 milligrams per day (mg/day) (EPA, 2020b) was applied for a rancher.

- Inhalation rate of a rancher was assumed to be 60 cubic meters/day based on the PRG Calculator default value for an outdoor worker (EPA, 2020b).

- Average body weights of 80 kilograms for an adult was assumed over the exposure period (EPA, 2020b).

- Inhalation of chemicals adsorbed to respirable particles (particles less than or equal to 10 micrometers in diameter) was assessed using a default particulate emission factor (PEF) equal to 2.57E+09 cubic meters per kilogram. The default PEF was derived using default values adjusted to apply to the climate zone for Albuquerque, New Mexico, and a 250-acre source size (approximately equivalent to 1 million square meters, the largest Area Correction Factor choice in the PRG Calculator [the site equals approximately

5 million square meters]). The PEF equation relates the contaminant concentration in soil with the concentration of respirable particles in the air due to fugitive dust emissions from contaminated soils. The relationship is derived by Cowherd, et al. (Cowherd, 1985; as cited by EPA, 2020b) for a rapid assessment procedure applicable to a typical hazardous waste site, where the surface contamination provides a relatively continuous and constant potential for emission over an extended period of time (i.e., years). This represents an annual average emission rate based on wind erosion that should be compared with chronic health criteria; it is not appropriate for evaluating the potential for more acute exposures (EPA, 2020b).

- It is assumed that 48% of meat consumed by a rancher was home-produced (i.e., from on-site animals), which is based on the percent consuming home-produced meats value for "Western households who farm" presented in Table 13-19 of EPA's 2011 Exposure Factors Handbook. Default home-produced meat consumption rate of 165.3 grams/day for 350 days/year was assumed based on the default PRG Calculator value for beef (EPA, 2020b). These values are an annual consumption rate so an exposure frequency (EF) of 350 days/year was applied.

- Cattle were considered to graze on the Site 37.5% of the time annually, based on research citing that rangeland experts suggest only 25 to 50% of arid rangeland in fair to good condition should be consumed or utilized by livestock to leave sufficient vegetation for re-generation (Hurd et al, 2007).

- Concentrations in beef were estimated from soil concentrations using radionuclide-specific transfer factors incorporated into the PRG Calculator. The PRG Calculator default mass loading factor of 0.25 was applied for all forage (EPA, 2020b). A forage intake rate of 11.77 kg/day and a soil intake rate of 0.5 kg/day were applied (EPA, 2020b; PRG Calculator default for beef) for cattle.

EPA manages risk to achieve 10^{-6} to 10^{-4} (1E-06 to 1E-04) overall excess cancer risks. EPA risk assessment guidance suggests that the average of the concentration is regarded as a reasonable estimate of the concentration likely to be contacted over time (EPA, 1989). Because of the uncertainty associated with any estimate of the representative average, the 95th percentile upper confidence limit (95UCL) on the arithmetic mean is generally used as the reasonable maximum exposure concentration (EPA, 1989) (Attachment 3). Risk estimates were calculated using the reasonable maximum exposure point concentration (EPC). The EPC is based on the lower of the maximum detected and the 95% UCL on the mean. The sum of ratios approach was used to estimate human health risk from outdoor ranching activities and from ranching activities inside a truck, and for the consumption of site-raised beef. The section-specific EPC is divided by its exposure-route specific PRG, and this ratio is multiplied by 10^{-4} (1E-04) to calculate a cancer risk estimate. Individual cancer risk estimates are summed to represent a total cancer risk for each section. As shown in Table H-1, total cancer risks for the isotopes of the U-235 and U-238 decay chains (expressed as Ra-226 concentrations) for the Central GSA Mines Site equaled or exceeded the 10^{-4} overall cancer risk threshold in all sections except subsurface soils in Sections 20, 29, and 32 (no subsurface soils were collected in Section 19). The lowest risk was at 4E-05 for Section 29 subsurface soil and the highest risk was at 3E-03 for Section 17 surface soil from one single grab sample. The lowest Ra-226 concentrations were measured in Section 29. These results indicate the need for a response action to control releases and prevent radionuclide exposure. Note that these risk estimates also include contribution of the background level of Ra-226 (1.5 pCi/g).

For the non-radionuclide COPC (i.e., uranium), the USEPA RSL Calculator (https://epa-prgs.ornl.gov/cgi-bin/chemicals/csl_search) was used to develop site-specific risk-based screening levels and to calculate cancer risk estimates, and non-cancer hazard quotients (HQs) for exposure from incidental ingestion of soil, and dermal absorption and inhalation of particulates. Systemic, non-cancer effects are of concern for all the non-radionuclide COPCs (uranium). Dermal contact with uranium is not quantified because this metal is not considered to be dermally absorbed through the skin and does not have an EPA-recommended dermal absorption factor. The "Composite Worker" land-use scenario template in the RSL Calculator was used to develop the risk estimates for the outdoor ranching activities (details are included in Attachment 1). External exposure is not an exposure route for non-radionuclides, so ranching activities inside a truck are not evaluated for the non-radionuclides. In addition, risk-based screening levels were developed for the home-grown meat exposure pathway for metals following methods used for radionuclides in the PRG Calculator (details are included in Attachment 1). The sum of ratios approach was used to estimate human health risk from beef consumption. The site-specific concentration is divided by its non-cancer-based screening level for residential soil to meat consumption to calculate a HQ. The individual HQs for each scenario (ranching outdoors and beef consumption), and for each COPC, are summed to represent a total non-cancer hazard index (HI). A HI of one or less is generally considered "safe." A ratio greater than one suggests that, at a minimum, further evaluation (EPA, 2020a) is necessary.

As shown in Table H-3, using maximum non-radionuclide chemical concentrations in soil, the total non-radionuclide HI was 0.3, based solely on uranium. For non-cancer hazard estimates, dose additivity is most properly applied to compounds that induce the same non-cancer effect.

Segregation of HI by the major target tissue/organ effects should be performed if the total HI for multiple contaminants exceeds one. The target system for uranium is the urinary system. As the non-cancer hazard index for non-radionuclide COPC exposure is less than the threshold of one, adverse non-cancer health effects from exposure to uranium in soil at the Central GSA Mines Site is not likely.

It is anticipated that Site actions to address radionuclide exposure by human receptors will be protective for exposure of human receptors to both radionuclides and non-radionuclide chemicals.

4. Ecological Streamlined Risk Evaluation

The Central GSA Mines Site are located in a remote area with the revegetated, previously disturbed mine area potentially providing habitat for ecological receptors. Wildlife inhabiting the Site may directly ingest radionuclides and chemicals, which may then be transported to organs or other sites within the wildlife receptors. Radionuclides and chemicals in the soil may be absorbed by plants consumed by wildlife. Radionuclides such as radium, radon, and daughter progeny may be inhaled, creating alpha-particle-emitting sources in the lungs of wildlife receptors. A screening level ecological risk assessment, or SLERA (i.e., Steps 1 and 2 of EPA's 8-step ecological risk assessment process [EPA, 1997]), was performed as the ecological SRE to assess potential risk to ecological receptors from both radionuclide and non-radionuclide chemical contaminants. The results of the screening level ecological risk characterization are included in Table H-4 for radionuclides and Table H-5 for metals. A refinement of conservative screening level assumptions (i.e., Step 3a of EPA's 8-step ecological risk assessment process [EPA, 2001]) was also performed to consider how the risk estimates would change if more realistic assumptions were used. The results of the refined ecological risk characterization are included in Table H-6 through Table H-8.

4.1 Ecological Risk-Based Screening Values

Literature-based ecological screening benchmark values for direct contact and food-chain evaluations are used to characterize potential ecological effects. The following sources were used to identify proposed ecological screening benchmark values for radionuclides and chemicals:

- EPA Ecological Soil Screening Levels (Eco-SSLs) (https://www.epa.gov/risk/ecological-soil-screening-level-eco-ssl-guidance-and-documents)

- Los Alamos National Laboratory (LANL) ECORISK database, Release 4.1 (LANL, 2017).
- New Mexico Environment Department (NMED, 2017). Risk Assessment Guidance for Site Investigations and Remediation. Volume II-Soil Screening Guidance for Ecological Risk Assessments. March 2017. Tier 1 ecological screening level (ESL).
- USEPA Region 4 Ecological Risk Assessment Supplemental Guidance (2018) – Soil Screening Values for Hazardous Waste Sites (https://www.epa.gov/risk/regional-ecological-risk-assessment-era-supplemental-guidance), Table 3 Screening Level.
- Sheppard, Steve C., Marsha I. Sheppard, Marie-Odile Galler and Barb Sanipelli. 2005. Derivation of ecotoxicity thresholds for uranium, *Journal of Environmental Radioactivity*, Volume 79 (1), pages 55-83).

The Eco-SSLs include values for plant, soil invertebrate, bird, and mammal exposure to metals through direct contact and the food chain. Eco-SSLs are also available for protection of birds and mammals from the three primary feeding groups (herbivores, insectivores, and carnivores). The Eco-SSLs are based on no-effect toxicity values: 1) to ensure risks are not underestimated, and 2) to provide a defensible conclusion that negligible ecological risk exists or that certain contaminants and exposure pathways can be eliminated from consideration (EPA, 1997). The Eco-SSLs are intended to be conservative screening values that can be used to eliminate contaminants clearly not associated with unacceptable risks (EPA, 2005a–2005h, 2006, and 2007a–2007e, 2008b).

The LANL EcoRisk database includes ecological screening levels (ESLs) for avian, mammalian, earthworm, and plant exposure models for radionuclides and chemicals in soil. The ESLs for soil-dwelling invertebrates and terrestrial plants are based on direct contact with soil by plants and soil-dwelling organisms living in impacted soil. The ESLs for upper level wildlife are based on incidental ingestion of soil while feeding, preening, or nesting on the ground, and based on ingestion of food sources that have bio-accumulated contaminants. The wildlife functional feeding guilds for birds and mammals used to develop ESLs include herbivores, insectivores, and carnivores. The LANL EcoRisk database provides both no-effect and low-effect ESLs. The no-effect ESL is based on a no-observed-adverse-effect-level (NOAEL)-based toxicity reference value (TRV) that is protective of wildlife populations and sensitive individuals because it represents an exposure that is not associated with adverse impacts of low-level long-term chemical effects (i.e., adverse effects on ability of individuals to develop into viable organisms, search for mates, breed successfully, and produce live and equally viable offspring). The NOAEL values are often extremely conservative and protective, and are designed to be an indication of no impacts if not exceeded (LANL, 2017). The low-effect ESL applies a lowest-observed-adverse-effect-level-based TRV that is the lowest chronic effect level and is generally considered to be protective of wildlife populations.

The NMED has developed Tier 1 ESLs protective of plant community, deer mouse, horned lark, kit fox (evaluated at sites greater than 267 acres), Pronghorn (evaluated at sites greater than 342 acres), and Red-tailed hawk (evaluated at sites greater than 177 acres). The key receptors selected as the representative species represent the primary producers as well as the three levels of consumer (primary, secondary, and tertiary) for the most common receptors found at hazardous waste sites in New Mexico. For plants, the Tier 1 screening level is based on an effect concentration for plant communities. For wildlife receptors, the Tier 1 screening level is based on NOAEL-based toxicity reference values (NMED, 2017).

As referenced previously, EPA Region 4 has compiled soil ecological screening values for soil, surface water, and sediment. Soil screening values that are intended to protect plants, soils, invertebrates, avian wildlife, or mammalian wildlife are reported from various sources. The Region 4 soil screening values typically address toxicity through direct exposure (e.g., toxicity to soil invertebrates such as earthworms and plants). For those chemicals that biomagnify, screening values may be back-calculated to derive screening values for avian or mammalian wildlife by considering trophic transfers from the abiotic medium to prey items.

The Sheppard et al (2005) study summarizes the literature available to set PNECs (predicted no-effect concentrations) for chemical toxicity of uranium to non-human biota. Values for terrestrial plants and other soil biota are used in this evaluation.

4.2 Ecological Risk Estimates

Screening level risk characterization was performed using the hazard quotient (HQ) method to compare maximum surface (0-to-6 inches bgs) soil concentrations to ecological screening benchmark values. A HQ of less than 1 indicates that the concentration is unlikely to cause adverse ecological effects. A HQ greater than 1 indicates that the potential for ecological risk is present and therefore the risk assessment process should continue. A HQ of 1 is a condition where the exposure and the dose associated with no adverse chronic effects are equal, indicating adverse effects at or below this soil concentration are unlikely (EPA, 2005a). The screening process considered the isotopes of the U-235 and U-238 decay chains, though screening levels were not available for all isotopes. The ecological SRE indicates potential for risk to ecological receptors from exposure to Ra-226, Th-230, aluminum, lead, mercury, selenium, and vanadium (Table H-4 for radionuclides; Table H-5 for metals). Concentrations of aluminum, lead, and mercury were below background levels (Table H-6) and, as a result, are not considered to be chemicals of potential ecological concern (COPECs).

A SLERA uses conservative screening-level assumptions such as 100% site use, 100% bioavailability, 100% diet consisting of the most contaminated diet, and no-effect toxicity data to evaluate risk to populations of upper level organisms. Under more realistic site use conditions, the potential risk to individual organisms would be reduced. The average soil concentration and low effect ecological screening values were used to refine these risk estimates. In the refined ecological risk characterization (Table H-6), risks were calculated using the maximum soil concentration. The maximum surface and subsurface soil concentrations of Ra-226 exceed the low effect ESLs for soil invertebrates and avian insectivores (i.e., HQ>1), indicating potential risk to these receptor groups. As a result, Ra-226 was further refined using the average concentration by section as shown on Table H-7. Results on Table H-7 indicate soil invertebrate receptor group exceedances for surface soil in Sections 17 and 33 and for subsurface soil in Sections 17, 30, and 33. Additionally, Ra-226 exceeded a HQ of 1 for the avian ground insectivore receptor group for surface soil in Section 17.

Maximum concentrations of aluminum, lead, and mercury do not exceed low-effect ESLs (i.e., HQ ≤1) for any receptor group, indicating these metals are not considered to pose risk to populations of higher level organisms (Table H-6). The maximum concentrations of selenium and vanadium exceeds low-effect ESLs for avian herbivores and avian ground insectivores, and additionally for selenium for plants and mammalian herbivores and insectivores (i.e., HQ>1). Further refinement of selenium and vanadium using average concentrations by section are provided on Table H-8.

The average concentration of selenium exceeds low-effect ESLs for the following receptor groups by Section (i.e., HQ>1):

- Section 17 – selenium was non-detect
- Section 19 - plants, avian herbivores and insectivores, and mammalian herbivores and insectivores.
- Section 30 – no selenium exceedances.
- Section 33 - plants, avian herbivores and insectivores, and mammalian herbivores and insectivores.

The average concentration of vanadium exceeds low-effect ESLs for the following receptor groups by section (i.e., HQ>1):

- Sections 17, 19, 30, and 33 – avian herbivores and insectivores.

Note that vanadium was at concentrations below its hazard threshold in native plant tissue samples collected from the Central GSA Mines Site (Table H-9), suggesting limited bioavailability of vanadium. The refined ecological risk evaluation indicates potential for risk to ecological receptors from exposure to Ra-226 (soil invertebrates only in most sections and avian insectivores in Section 17), selenium, and vanadium (Tables H-7 and H-8, respectively). Locations where elevated levels of selenium and vanadium were measured are co-located with locations of elevated Ra-226. With the exception of Section 19, vanadium concentrations measured in soil were less than regional background.

Ecological screening benchmarks for radionuclides are higher (less stringent) than the proposed action level for protection of human health. Thus, it is anticipated that Site actions to address radionuclide exposure by human receptors will be protective for exposure of ecological receptors to radionuclides. Selenium and vanadium are common metals in association with uranium in the Grants Mineral Belt deposits (Brookins, 1982). As an impurity, they may have been a waste metal in the uranium mine waste. Actions to address uranium are also expected to be protective of ecological receptors.

5. Evaluation of Grazing of Forage by Domesticated Animals and Wildlife

The results of the evaluation of the vegetative metals uptake samples are included in Table H-9. Fifteen surface vegetation samples were collected to determine the current vegetative nutrient values and uptake of potential hazardous constituents available to grazing animals (domesticated animals and wildlife) within the entire Central GSA (WESTON, 2019). Tissue concentrations were compared to maximum tolerable limits (MTLs) developed by the National Research Council's Committee on Minerals and Toxic Substances in Diets and Water for Animals (NRC, 2005), which are defined as dietary level, that, when fed for a defined period of time, will not impair animal health or performance. Tissue concentrations are also compared to concentrations of trace elements in mature leaf tissue that are considered sufficient or normal and excessive or toxic (Kabata-Pendias and Pendias, 1992). With the exception of iron, average nutrient (iron, zinc, copper, and manganese) concentrations are less than MTLs for animals and within, or less than, the sufficient/normal concentrations for plants (Table H-9). The iron concentrations ranged from 129-to-1,193 parts per minute (ppm). Iron is an essential nutrient; iron toxicity is dependent on absorption (NRC, 2005). The average and the maximum within the area of potential effect (APE) for molybdenum exceeded their respective MTLs for poultry and swine feed. Molybdenum toxicity is often associated with inadequate availability of copper; cattle show overt toxicosis when dietary molybdenum level is at 100 mg/kg or higher regardless of dietary copper or sulfur levels (NRC, 2005). No molybdenum concentrations in tissue exceed 100 mg/kg. The average and the maximum sample concentrations within the APE for selenium and iron exceeded their respective MTLs for animal feed (i.e., rodents, poultry, swine, horse, cattle, and sheep). The maximum sample concentration within the APE for zinc exceeded its MTL for sheep feed.

The average molybdenum and selenium concentrations and the maximum zinc concentration in tissue samples fall within the excessive/toxic levels for plants. While selenium is a common micronutrient supplement for cattle and sheep, it can be toxic at elevated concentrations. Native selenium has been found in the sandstone formations of the Grants Mineral Belt area (Brookins, 1982), and as an impurity, it may have been a waste metal in the uranium mine tailings. Tissue samples for uranium (toxic metals) do not exceed thresholds. Molybdenum is commonly associated with uranium in the Grants Mineral Belt deposits (Brookins, 1982); molybdenum concentrations were not measured in soil and thus could not be compared to the regional background.

6. Appendix H References

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7. List of Tables

Appendix H, Table H-1
Summary of Radionuclide Risk Estimates
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Rancher Soil PRG (pCi/g)	Surface Soil (0-6 inches bgs)			Subsurface Soil (12-18 inches bgs)		
	Secular Equilibrium for U-235[#]	Secular Equilibrium for U-238*	Uranium TOTAL	Secular Equilibrium for U-235[#]	Secular Equilibrium for U-238*	Uranium TOTAL
Outdoors						
Ingestion PRG	291	63.5	NA	291	63.5	NA
Inhalation PRG	65,500	142,000	NA	65,500	142,000	NA
External Exposure PRG	75.1	20.6	NA	75.1	20.6	NA
Total Outdoor PRG	59.7	15.6	NA	59.7	15.6	NA
Inside Truck						
External Exposure PRG	107	29.5	NA	107	29.5	NA
Beef Consumption						
Beef Consumption PRG	163	8.43	NA	163	8.43	NA
	95UCL Radium-226 EPC/Max *(n = 5)*			**95UCL Radium-226 EPC**		
Section 17 (pCi/g)	7.0	156	163	1.6	35	36
Cancer Risk [a]						
Rancher - Soil Outdoors						
Ingestion	2.4E-06	2.5E-04	2.5E-04	5.4E-07	5.5E-05	5.5E-05
Inhalation	1.1E-08	1.1E-07	1.2E-07	5.4E-07	5.5E-05	5.5E-05
External Exposure	9.3E-06	7.6E-04	7.7E-04	5.4E-07	5.5E-05	5.5E-05
Total Outdoor	1.2E-05	1.0E-03	1.0E-03	5.4E-07	5.5E-05	5.5E-05
Rancher - Soil Inside Truck						
External Exposure	6.6E-06	5.3E-04	5.4E-04	5.4E-07	5.5E-05	5.5E-05
Rancher - Beef Consumption						
Beef Consumption	4.3E-06	1.9E-03	1.9E-03	5.4E-07	5.5E-05	5.5E-05
TOTAL	2E-05	**3E-03**	**3E-03**	2E-06	**2E-04**	**2E-04**
	95UCL Radium-226 EPC/Max *(n = 2)*			**95UCL Radium-226 EPC**		
Section 19 (pCi/g)	0.3	6.4	7	--	NS	--
Cancer Risk [a]						
Rancher - Soil Outdoors						
Ingestion	9.9E-08	1.0E-05	1.0E-05			
Inhalation	4.4E-10	4.5E-09	5.0E-09			
External Exposure	3.8E-07	3.1E-05	3.2E-05			
Total Outdoor	1.2E-05	4.1E-05	5.3E-05			
Rancher - Soil Inside Truck						
External Exposure	2.7E-07	2.2E-05	2.2E-05			
Rancher - Beef Consumption						
Beef Consumption	1.8E-07	7.6E-05	7.6E-05			
TOTAL	1E-05	**1E-04**	**2E-04**			
	95UCL Radium-226 EPC/Max *(n = 1)*			**95UCL Radium-226 EPC**		
Section 20 (pCi/g)	0.4	9.3	10	0.17	3.80	3.97
Cancer Risk [a]						
Rancher - Soil Outdoors						
Ingestion	1.4E-07	1.5E-05	1.5E-05	5.9E-08	6.0E-06	6.0E-06
Inhalation	6.4E-10	6.5E-09	7.2E-09	2.6E-10	2.7E-09	2.9E-09
External Exposure	5.6E-07	4.5E-05	4.6E-05	2.3E-07	1.8E-05	1.9E-05
Total Outdoor	7.0E-07	5.9E-05	6.0E-05	2.9E-07	2.4E-05	2.5E-05
Rancher - Soil Inside Truck						
External Exposure	3.9E-07	3.1E-05	3.2E-05	1.6E-07	1.3E-05	1.3E-05
Rancher - Beef Consumption						
Beef Consumption	2.6E-07	1.1E-04	1.1E-04	1.0E-07	4.5E-05	4.5E-05
TOTAL	1E-06	**2E-04**	**2E-04**	6E-07	8E-05	8E-05

Appendix H, Table H-1 (continued)
Summary of Radionuclide Risk Estimates
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Rancher Soil PRG (pCi/g)	Surface Soil (0-6 inches bgs)			Subsurface Soil (12-18 inches bgs)		
	Secular Equilibrium for U-235[#]	Secular Equilibrium for U-238*	Uranium TOTAL	Secular Equilibrium for U-235[#]	Secular Equilibrium for U-238*	Uranium TOTAL
	95UCL Radium-226 EPC/Max *(n = 1)*			95UCL Radium-226 EPC		
Section 29 (pCi/g)	0.4	7.9	8	0.09	2.0	2.12
Cancer Risk [a]						
Rancher - Soil Outdoors						
Ingestion	1.2E-07	1.2E-05	1.3E-05	3.1E-08	3.2E-06	3.2E-06
Inhalation	5.4E-10	5.6E-09	6.1E-09	1.4E-10	1.4E-09	1.6E-09
External Exposure	4.7E-07	3.8E-05	3.9E-05	1.2E-07	9.8E-06	1.0E-05
Total Outdoor	6.0E-07	5.1E-05	5.1E-05	1.5E-07	1.3E-05	1.3E-05
Rancher - Soil Inside Truck						
External Exposure	3.3E-07	2.7E-05	2.7E-05	8.5E-08	6.9E-06	7.0E-06
Rancher - Beef Consumption						
Beef Consumption	2.2E-07	9.4E-05	9.4E-05	5.6E-08	2.4E-05	2.4E-05
TOTAL	1E-06	**2E-04**	**2E-04**	3E-07	4E-05	4E-05
	95UCL Radium-226 EPC			95UCL Radium-226 EPC		
Section 30 (pCi/g)	--	NS	--	2.86	63.5	66.33
Cancer Risk [a]						
Rancher - Soil Outdoors						
Ingestion				9.8E-07	1.0E-04	1.0E-04
Inhalation				4.4E-09	4.5E-08	4.9E-08
External Exposure				3.8E-06	3.1E-04	3.1E-04
Total Outdoor				4.8E-06	4.1E-04	4.1E-04
Rancher - Soil Inside Truck						
External Exposure				2.7E-06	2.2E-04	2.2E-04
Rancher - Beef Consumption						
Beef Consumption				1.8E-06	7.5E-04	7.5E-04
TOTAL				9E-06	**1E-03**	**1E-03**
	95UCL Radium-226 EPC/Max *(n = 3)*			95UCL Radium-226 EPC		
Section 32 (pCi/g)	0.6	13.8	14	0.13	2.95	3.08
Cancer Risk [a]						
Rancher - Soil Outdoors						
Ingestion	2.1E-07	2.2E-05	2.2E-05	4.6E-08	4.6E-06	4.7E-06
Inhalation	9.5E-10	9.7E-09	1.1E-08	2.0E-10	2.1E-09	2.3E-09
External Exposure	8.3E-07	6.7E-05	6.8E-05	1.8E-07	1.4E-05	1.4E-05
Total Outdoor	1.0E-06	8.8E-05	8.9E-05	2.2E-07	1.9E-05	1.9E-05
Rancher - Soil Inside Truck						
External Exposure	5.8E-07	4.7E-05	4.7E-05	1.2E-07	1.0E-05	1.0E-05
Rancher - Beef Consumption						
Beef Consumption	3.8E-07	1.6E-04	1.6E-04	8.1E-08	3.5E-05	3.5E-05
TOTAL	2E-06	**3E-04**	**3E-04**	4E-07	6E-05	6E-05

Rancher Soil PRG (pCi/g)	Surface Soil (0-6 inches bgs)			Subsurface Soil (12-18 inches bgs)		
	Secular Equilibrium for U-235[#]	Secular Equilibrium for U-238*	Uranium TOTAL	Secular Equilibrium for U-235[#]	Secular Equilibrium for U-238*	Uranium TOTAL
	95UCL Radium-226 EPC/Max *(n = 5)*			95UCL Radium-226 EPC		
Section 33 (pCi/g)	1.2	27.2	28	1.04	23.0	24.07
	Cancer Risk [a]					
Rancher - Soil Outdoors						
Ingestion	4.2E-07	4.3E-05	4.3E-05	3.6E-07	3.6E-05	3.7E-05
Inhalation	1.9E-09	1.9E-08	2.1E-08	1.6E-09	1.6E-08	1.8E-08
External Exposure	1.6E-06	1.3E-04	1.3E-04	1.4E-06	1.1E-04	1.1E-04
Total Outdoor	2.1E-06	1.7E-04	1.8E-04	1.7E-06	1.5E-04	1.5E-04
Rancher - Soil Inside Truck						
External Exposure	1.1E-06	9.2E-05	9.3E-05	9.7E-07	7.8E-05	7.9E-05
Rancher - Beef Consumption						
Beef Consumption	7.5E-07	3.2E-04	3.2E-04	6.4E-07	2.7E-04	2.7E-04
TOTAL	4E-06	**6E-04**	**6E-04**	3E-06	**5E-04**	**5E-04**

Notes:

[a] Cancer risk calculated using the U.S. EPA's on-line PRG Calculator (https://epa-prgs.ornl.gov/cgi-bin/radionuclides/rprg_search) to develop exposure-route PRG, which are based on a target cancer risk of 10^{-4}. Output provided in Attachment 1. Concentrations also include background contribution (1.5 pCi/g Ra-226). Risk = (concentration / PRG) x 10^{-4}.

* Assumes in secular equilibrium with radium-226 (no decay).

# Istope in U-235 decay chain; assume all isotopes in secular equilibrium (no decay); concentration based 0.045 times radium-226 concentration, where U-235 activity is approximately 2.2% of natural uranium (U-238, U-234, U-235) and assuming secular equilibrium and solving for U-235 (i.e., 0.022 x [U-238 + U-234 + U-235]= U-235). U total is simply referring to the concentrations of just U-235 in secular equilibrium plus U-238 in secular equilibrium (which includes U-234 in decay chain, whose concentration is typically included under the 'ordinary' definition of U total).
bgs = below ground surface.

EPC = Exposure Point Concentration. The EPC is the 95% upper confidence limit (95% UCL) on the mean of soil samples unless otherwise noted. All surface soil locations had 5 or less samples; therefore, the maximum concentration was used for surface soil locations.

NS = Not Sampled.

NA = Not Applicable.

pCi/g = picocuries per gram.

PRG = Preliminary Remediation Goal.

UCL = Upper Confidence Limit.

Appendix H, Table H-2
Summary of Non-Radionuclide Analytical Results
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Chemical Name	Number Detected^	Number Analyzed^	Minimum Concentration	Maximum Concentration	Sample ID for Maximum	EPA Residential May 2020 Residential Regional Screening Level[a]	NMED June 2019 Residential Soil Screening Level[b]	Mean Background[c]	COPC?
Non-Radionuclides									
Aluminum	8	8	8,200	15,000	17-02-31-181101-M & 19-02-31-181101-M	7,700	7,800	54,423	No; ASL; BBC
Antimony	0	8	ND	ND	--	3.1	3.1	1.0	ND
Arsenic	8	8	4	10	19-02-31-181101-M	0.68	0.71	5.9	No; ASL; BBC#
Barium	8	8	53	98	17-02-31-181101-M	1,500	1,556	727	No; BSL
Beryllium	8	8	1	1	19-02-31-181101-M	16	16	1.0	No; BSL
Cadmium	0	8	ND	ND	--	7.1	7.1	NA	ND
Calcium	8	8	7,800	32,000	17-01-31-181101-M	--	1.30E+07 (NUT)	35,809	No; BSL
Chromium	8	8	5	9	17-01-31-181101-M	12,000	9.7	55.5	No; BSL
Cobalt	8	8	3	6	17-01-31-181101-M	2.3	2.3	8.8	No; ASL; BBC
Copper	8	8	4	11	17-01-31-181101-M	310	313	21	No; BSL
Iron	8	8	12,000	18,000	17-01-31-181101-M	5,500	5,475	20,898	No; ASL; BBC
Lead	8	8	3	13	33-01-32-181101-M	400	400	18.1	No; BSL
Magnesium	8	8	2,600	4,900	19-02-31-181101-M	--	3.39E+05 (NUT)	7400 [d]	No; BSL
Manganese	8	8	140	220	17-01-31-181101-M	180	1055	366.8	No; ASL; BBC
Mercury	8	8	0	0	17-01-31-181101-M	1.1	2.3	0.046 [d]	No; BSL
Nickel	8	8	6	17	17-01-31-181101-M	150	156	27.9	No; BSL
Potassium	8	8	2,200	4,800	19-02-31-181101-M	--	1.56E+07 (NUT)	18000 [d]	No; BSL
Silver	0	8	ND	ND	--	39	39	NA	ND
Sodium	8	8	160	360	33-02-31-181101-M	--	7.82E+06 (NUT)	9700 [d]	No; BSL
Thallium	0	8	ND	ND	--	0.078	0.078	9.1 [d]	ND
Selenium	2	8	7	7	33-01-31-181101-M	39	39	0.29	No; BSL
Uranium	2	8	23	77	19-01-31-181101-M	1.6	23	2.5 [d]	Yes; ASL; ABC
Vanadium	8	8	18	98	19-01-31-181101-M	39	39	71.4	No; ASL; BBC#
Zinc	8	8	25	54	17-01-31-181101-M	2,300	2346	44.3	No; BSL

All concentrations in mg/kg (ppm).

ASL - Above Screening Level.

ABC - Above Background Concentration.

BSL - Below Screening Level.

BBC - Below Background Concentration.

COPC - Chemical of Potential Concern.

NUT - essential nutrient.

[a] EPA Residential Regional Screening Level based on target risk of 10^{-6} and target hazard quotient of 0.1.

[b] NMED Residential generic soil screening level based on target risk of 10^{-5} and target hazard quotient of 1, adjusted by a factor of 10 to account for additive risk.

[c] Average concentration, New Mexico, Background Soil Concentration Database, EcoSSL Attachment 1-4, Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs), Review of Background Concentrations for Metals, OSWER Directive 92857-55, Revised July 2007. https://www.epa.gov/sites/production/files/2015-09/documents/ecossl_attachment_1-4.pdf. Average for cadmium is value for "not specified".

[d] Mean for Western US (Shacklette, H.T. and J.G. Boernren. 1984. Element Concentrations in Soil and Other Surface Materials of the Counterminous United States. USGS Professional Paper 1270)

Maximum concentration is less than 2 times the mean background.

^ Includes field duplicate samples; maximum value taken from normal and duplicate sample results.

Appendix H, Table H-3
Summary of Non-Radionuclide Noncancer Hazards
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Non-radionuclide COPC	EPC' (mg/kg)	Ranching - Outside HQ	Site-Raised Beef HQ	Hazard Index
	Uranium Rancher PRG:	***234***	***4629***	
Uranium	77	0.3	0.017	0.3

Per Appendix H, Table H-2, Uranium is the only COPC.

Uranium Results by Section
Section 17 = ND.
Section 19 = 77 mg/kg and ND.
Section 30 = ND.
Section 33 = 24 mg/kg and duplicate (23 mg/kg) and ND.

COPC chemical of potential concern

*EPC = Exposure point concentration defaulted to maximum for worst-case Hazard Index.

HQ = hazard quotient.

Appendix H, Table H-4
Screening Level Ecological Risk Characterization - Radionuclides
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

COPEC	Frequency of Detection	Range of Detected Concentrations* Minimum (mg/kg)	Range of Detected Concentrations* Maximum (mg/kg)	Location of Maximum Concentration	Background[a]	Plant EcoSSL[b]	Plant HQ (max)	Soil invertebrates EcoSSL[b]	Soil invertebrates HQ (max)	Avian herbivore EcoSSL[b]	Avian herbivore HQ (max)	Avian ground insectivore EcoSSL[b]	Avian ground insectivore HQ (max)	Avian carnivore EcoSSL[b]	Avian carnivore HQ (max)	Mammalian herbivore EcoSSL[b]	Mammalian herbivore HQ (max)	Mammalian ground insectivore EcoSSL[b]	Mammalian ground insectivore HQ (max)	Mammalian carnivore EcoSSL[b]	Mammalian carnivore HQ (max)
Surface Soil (0-6 in bgs)																					
Uranium 238 Decay Chain Isotopes																					
U-238**	--	--	156	--	--	400	0.4	1100	0.1	3300	0.0	4000	0.039	4200	0.0	2000	0.1	2100	0.1	2100	0.1
Th-234**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pa-234m**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pa-234**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
U-234**	--	--	156	--	--	440	0.4	2200	0.1	14000	0.01	69000	0.002	260000	0.001	36000	0.004	140000	0.001	110000	0.001
Th-230**	--	--	156	--	--	200	**1**	52	**3**	1200	0.1	2200	0.1	17000	0.01	9900	0.02	81000	0.002	68000	0.002
Radium 226 (pCi/g)*	17/17	156	156	17-01-31-170415	1.5	54	**3**	1.5	**100**	34	**5**	8.2	**20**	61	**3**	340	0.5	510	0.3	370	0.4
Rn-222**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Po-218**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pb-214**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
At-218**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Bi-214**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Rn-218**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Po-214**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Tl-210**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pb-210**	--	--	156	--	--	3400	0.05	1200	0.1	6000	0.03	6200	0.03	8500	0.02	4400	0.0	4500	0.0	4400	0.0
Bi-210**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Po-210**	--	--	156	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Uranium 235 Decay Chain Isotopes																					
Uranium-235[&]	--	--	7.0	--	0.068	440	0.02	1600	0.00	6300	0.001	9500	0.001	10000	0.001	4700	0.001	5200	0.001	5200	0.001
Th-231	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pa-231	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Ac-227	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Th-227	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Fr-223	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Ra-223	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
At-219	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Rn-219	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Bi-215	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Po-215	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pb-211	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Bi-211	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Tl-207	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Po-211	--	--	7.0	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Subsurface Soil (12-18 in bgs)																					
Uranium 238 Decay Chain Isotopes																					
U-238**	--	--	319	--	--	400	0.8	1100	0.3	3300	0.1	4000	0.1	4200	0.1	2000	0.2	2100	0.2	2100	0.2
Th-234**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pa-234m**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pa-234**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
U-234**	--	--	319	--	--	440	0.7	2200	0.1	14000	0.02	69000	0.005	260000	0.001	36000	0.01	140000	0.002	110000	0.003
Th-230**	--	--	319	--	--	200	**2**	52	**6**	1200	0.3	2200	0.1	17000	0.02	9900	0.03	81000	0.004	68000	0.00
Radium 226 (pCi/g)*	234/234	1.01	319	30-13-2-31-170322	1.5	54	**6**	1.5	**200**	34	**9**	8.2	**40**	61	**5**	340	**1**	510	0.6	370	**1**
Rn-222**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Po-218**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pb-214**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
At-218**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Bi-214**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Rn-218**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Po-214**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Tl-210**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pb-210**	--	--	319	--	--	3400	0.1	1200	0.3	6000	0.1	6200	0.1	8500	0.04	4400	0.1	4500	0.1	4400	0.1
Bi-210**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Po-210**	--	--	319	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Uranium 235 Decay Chain Isotopes																					
Uranium-235[&]	--	--	14.36	--	0.068	440	0.03	1600	0.01	6300	0.002	9500	0.002	10000	0.001	4700	0.003	5200	0.003	5200	0.003
Th-231	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pa-231	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Ac-227	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Th-227	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Fr-223	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Ra-223	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
At-219	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Rn-219	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Bi-215	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Po-215	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Pb-211	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Bi-211	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Tl-207	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Po-211	--	--	14.36	--	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--

Bold values indicate concentrations that exceed ecological screening level or background; bold and shading indicates HQ exceeds unity (based on one significant figure).

* Dataset includes minimum/maximimum of MCA and offsite laboratory results; if both MCA and lab results available, the lab result was selected.

** Isotope in U-238 decay chain; assumes in secular equilibrium with radium-226.

& Isotope in U-235 decay chain; assume all isotopes in secular equilibrium; concentration based 0.045 times radium-226 concentration, where U-235 activity is approximately 2.2% of natural uranium (U-238, U-234, U-235) and assuming secular equilibrium and solving for U-235 (i.e., 0.022 x [U-238 + U-234 + U-235]= U-235). U total is simply referring to the concentrations of just U-235 in secular equilibrium plus U-238 in secular equilibrium (which includes U-234 in decay chain, whose concentration is typically included under the 'ordinary' definition of U total).

[a] Background threshold value for radium-226 as reported in the Central GSA Removal Site Evaluation Report (Weston, July 2019).

[b] LANL ESL Version 4.1; values for avian herbivore (American robin), avian insectivore (American robin), and avian intermediate carnivore (Amercian kestrel); mammalian herbivore (desert cottontail); mammalian insectivore (montane shrew) and mammalian top carnivore (red fox).

COPEC = chemical of potential environmental concern.

HQ = hazard quotient = maximum concentration / screening level.

max = maximum concentration.

NSL = no screening level.

SSL = soil screening level.

Appendix H, Table H-5
Screening Level Ecological Risk Characterization - Metals
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

COPEC	Frequency of Detection[#]	Range of Detected Concentrations* Minimum (mg/kg)	Range of Detected Concentrations* Maximum (mg/kg)	Location of Maximum Concentration	Background[a]	Plant EcoSSL[c]	Plant HQ (max)	Plant NMED Tier 1 ESL[d]	Plant HQ (max)	Soil invertebrates EcoSSL[c]	Soil invertebrates HQ (max)	Avian herbivore EcoSSL[c]	Avian herbivore HQ (max)	Avian ground insectivore EcoSSL[c]	Avian ground insectivore HQ (max)
Non-Radionuclides															
Aluminum*	8/8	8,200	15,000	17-02-31-181101-M & 19-02-31-181101-M	54,423	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Antimony[$]	0/8	ND	ND	--	1.0	11	--	11.4	--	78	--	NSL	--	NSL	--
Arsenic[$]	8/8	4.3	10	19-02-31-181101-M	5.9	18	0.5	18	0.5	6.8	**1**	67	0.1	43	0.2
Barium[$]	8/8	53	98	17-02-31-181101-M	727	110	0.9	118	**1**	330	0.3	720	0.1	820	0.1
Beryllium[$]	8/8	0.56	0.84	19-02-31-181101-M	1.0	2.5	0.3	2.5	0.3	40	0.02	NSL	--	NSL	--
Cadmium	0/8	ND	ND	--	NA	32	--	32	--	140	--	28	--	0.77	--
Calcium	8/8	7,800	32,000	17-01-31-181101-M	35,809	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--
Chromium[$]	8/8	4.9	9.3	17-01-31-181101-M	55.5	NSL	--	NSL	--	NSL	--	78	0.1	23	0.4
Cobalt	8/8	3.1	6.0	17-01-31-181101-M	8.8	13	0.5	13	0.5	NSL	--	270	0.02	120	0.05
Copper	8/8	4.4	11	17-01-31-181101-M	21	70	0.2	70	0.2	80	0.1	76	0.1	28	0.4
Iron	8/8	12,000	18,000	17-01-31-181101-M	20,898	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Lead	8/8	3.2	13	33-01-32-181101-M	18.1	120	0.1	120	0.1	1700	0.01	46	0.3	11	**1**
Magnesium	8/8	2,600	4,900	19-02-31-181101-M	7,400 [b]	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--
Manganese	8/8	140	220	17-01-31-181101-M	367	220	**1**	220	**1**	450	0.5	4300	0.1	4300	0.1
Mercury[$,^]	8/8	0.012	0.033	17-01-31-181101-M	0.046 [b]	0.3	0.11	34.9	0.0009	0.05	0.7	0.067	0.5	0.013	**3**
Nickel	8/8	5.5	17	17-01-31-181101-M	27.9	38	0.4	38	0.4	280	0.06	210	0.08	NSL	--
Potassium	8/8	2,200	4,800	19-02-31-181101-M	18,000 [b]	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--
Selenium	2/8	6.8	7.0	33-01-31-181101-M	0.29	0.52	**13**	0.52	**13**	4.1	**2**	2.2	**3**	1.2	**6**
Silver	0/8	ND	ND	--	NA	560	--	560	--	NSL	--	69	--	4.2	--
Sodium	8/8	160	360	33-02-31-181101-M	9,700 [b]	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--
Thallium[$]	0/8	ND	ND	--	9.1 [b]	0.05	--	0.05	--	NSL	--	6.9	--	4.5	--
Uranium [@]	2/8	23	77	19-01-31-181101-M	2.5 [b]	250	0.3	NSL	--	NSL	--	1500	0.1	1100	0.1
Vanadium[$]	8/8	18	98	19-01-31-181101-M	71.4	60	**2**	60	**2**	NSL	--	13	**8**	7.8	**13**
Zinc	8/8	25	54	17-01-31-181101-M	44.3	160	0.3	160	0.3	120	0.5	950	0.06	46	**1**

COPEC	Omnivore (Horned Lark) NMED Tier 1 ESL[d]	Omnivore (Horned Lark) HQ (max)	Avian carnivore EcoSSL[c]	Avian carnivore HQ (max)	Top Carnivore (Red-tailed hawk; 177 acres) NMED Tier 1 ESL[d]	Top Carnivore (Red-tailed hawk; 177 acres) HQ (max)	Mammalian herbivore EcoSSL[c]	Mammalian herbivore HQ (max)	Mammalian ground insectivore EcoSSL[c]	Mammalian ground insectivore HQ (max)	Omniovore (Deer mouse) NMED Tier 1 ESL[d]	Omniovore (Deer mouse) HQ (max)	Mammalian carnivore EcoSSL[c]	Mammalian carnivore HQ (max)	Carnivore (Kit fox; 267 acres) NMED Tier 1 ESL[d]	Carnivore (Kit fox; 267 acres) HQ (max)	Herbivore (Longhorn antelope; 342 acres) NMED Tier 1 ESL[d]	Herbivore (Longhorn antelope; 342 acres) HQ (max)
Non-Radionuclides																		
Aluminum*	520	**29**	NSL	--	4000	**4**	NSL	--	NSL	--	564	**27**	NSL	--	2500	**6**	NSL	--
Antimony[$]	NSL	--	NSL	--	NSL	--	10	--	0.27	--	0.536	--	4.9	--	2.380	--	NSL	--
Arsenic[$]	10.6	0.9	1100	0.01	81.5	0.12	170	0.06	46	0.2	9.5	**1**	170	0.06	42.0	0.2	36.1	0.3
Barium[$]	348	0.3	7500	0.01	2680	0.04	3200	0.03	2000	0.05	471	0.2	9100	0.01	2090	0.05	NSL	--
Beryllium[$]	NSL	--	NSL	--	NSL	--	21	0.04	34	0.02	4.8	0.2	90	0.01	21.5	0.04	NSL	--
Cadmium	7.0	--	630	--	53.5	--	73	--	0.36	--	7.0	--	84	--	31.1	--	NSL	--
Calcium	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--
Chromium[$]	12.6	**1**	780	0.01	96.8	0.1	380	0.02	34	0.3	21.8	0.4	180	0.05	97.0	0.1	NSL	--
Cobalt	36.0	0.2	1300	0.005	277	0.02	2100	0.003	230	0.03	66.6	0.09	470	0.01	296	0.02	58	0.1
Copper	19.2	0.6	1600	0.01	147	0.1	1100	0.01	49	0.2	50.9	0.2	560	0.02	226	0.05	NSL	--
Iron	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Lead	7.7	**2**	510	0.03	59.3	0.2	1200	0.01	56	0.2	42.7	0.3	460	0.03	190	0.07	173	0.08
Magnesium	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--
Manganese	847	0.3	65000	0.003	6520	0.03	5300	0.04	4000	0.06	468	0.5	6200	0.04	2080	0.1	5770	0.04
Mercury[$,^]	0.1	0.4	0.058	0.6	0.692	0.05	23	0.001	1.7	0.02	12.8	0.003	76	0.0004	57.0	0.0006	NSL	--
Nickel	31.7	0.5	2800	0.006	244	0.07	340	0.05	NSL	--	15.5	**1**	130	0.13	68.7	0.2	289	0.06
Potassium	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--
Selenium	1.37	**5**	83	0.1	10.6	**1**	2.7	**3**	0.63	**11**	1.3	**5**	2.8	**3**	5.78	**1**	NSL	--
Silver	10.4	--	930	--	73.5	--	1500	--	14	--	54.7	--	990	--	243	--	2.9	--
Sodium	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--	NUT	--
Thallium[$]	1.66	--	48	--	12.7	--	1.2	--	0.42	--	0.065	--	5	--	0.29	--	NSL	--
Uranium [@]	NSL	--	14000	0.01	NSL	--	1000	0.1	480	0.2	NSL	--	4800	0.02	NSL	--	NSL	--
Vanadium[$]	1.6	**60**	140	**1**	12.5	**8**	1300	0.1	280	0.4	37.8	**3**	580	0.2	168.0	**1**	289	0.3
Zinc	313	0.2	30000	0.002	2410	0.02	6800	0.008	79	**1**	685	0.08	10000	0.005	3050	0.02	2890	0.02

Bold values indicate concentrations that exceed ecological screening level; bold and shading indicates HQ exceeds unity (based on one significant figure). Thick border around HQ>1 indicates maximum concentration also exceeds background.

COPEC = chemical of potential environmental concern.

HQ = hazard quotient = maximum concentration / screening level.

max = maximum concentration.

NSL = no screening level.

NUT = essential nutrient; no screening level.

[a] Average concentration, New Mexico, Background Soil Concentration Database, EcoSSL Attachment 1-4, Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs), Review of Background Concentrations for Metals, OSWER Directive 92857-55, Revised July 2007. https://www.epa.gov/sites/production/files/2015-09/documents/ecossl_attachment_1-4.pdf. Average for cadmium is value for "not specified".

[b] Mean for Western US (Shacklette, H.T. and J.G. Boernren. 1984. Element Concentrations in Soil and Other Surface Materials of the Counterminous United States. USGS Professional Paper 1270).

[c] EPA Ecological Soil Screening Levels (EcoSSL) http://www.epa.gov/chemical-research/interim-ecological-soil-screening-level-documents Last updated September 29, 2016.

[$] LANL (2017) ESL Version 4.1; values for avian herbivore (American robin), avian insectivore (American robin), and avian intermediate carnivore (Amercian kestrel); mammalian herbivore (desert cottontail); mammalian insectivore (montane shrew) and mammalian top carnivore (red fox); ESL for plant for antimony, barium, and beryllium and vanadium; ESL for soil invertebrates for arsenic; ESL for birds for barium; avian ground insectivore ESL for chromium.

[@] terrestrial plant value of 250 mg/kg provided in Sheppard et al. (2005, Derivation of ecotoxicity thresholds for uranium, Journal of Environmental Radioactivity, Volume 79 (1), pages 55-83).

^ For mercury, the value for plants from EPA, 2018. March 2018 Update, Region 4 Ecological Risk Assessment Supplemental Guidance (https://www.epa.gov/risk/regional-ecological-risk-assessment-era-supplemental-guidance)

[d] NMED (2017). Risk Assessment Guidance for Site Investigations and Remediation. Volume II -Soil Screening Guidance for Ecological Risk Assessments. March 2017. Tier 1 ecological screening level (ESL).

Includes duplicate sample.

* NMED ESLs are pH dependent; aluminum is identified as a COPC only at sites where the soil pH is less than 5.5 (U.S. EPA. Ecological Soil Screening Level for Aluminum, Interim Final. OSWER Directive 9285.7-6. November 2003).

Appendix H, Table H-6
Refined Ecological Risk Characterization
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

COPEC	Maximum of Detected Concentrations (mg/kg)	Background[a,b]	Plant		Soil invertebrates		Avian herbivore		Avian ground insectivore		Avian carnivore		Mammalian herbivore		Mammalian ground insectivore		Mammalian carnivore	
			Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ
Aluminum	15,000	54,423	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--	NSL	--
Lead	13	18.1	570	0.02	8400	0.002	36	0.4	23	0.6	160	0.08	600	0.02	170	0.08	7000	0.002
Mercury	0.033	0.046	64	0.001	1	0.1	0.67	0.05	0.13	0.3	0.58	0.1	230	0.0001	17	0.002	760	0.00004
Selenium	7.0	0.29	3	**2**	41	0.2	1.9	**4**	1.4	**5**	7.5	0.9	3.4	**2**	1	**7**	130	0.1
Vanadium	98	71.4	80	**1**	NSL	--	13	**8**	9.5	**10**	110	0.9	1500	0.1	610	0.2	6900	0.01
Surface Soil																		
Radium 226 (pCi/g)*	156	1.5	540	0.3	15	**10**	340	0.5	82	**2**	610	0.3	3400	0.0	5100	0.03	3700	0.04
Th-230 (pCi/g)**	156	1.5	2000	0.1	520	0.3	12000	0.01	22000	0.01	170000	0.001	210000	0.001	1100000	0.0001	680000	0.0002
Subsurface Soil																		
Radium 226 (pCi/g)*	319	1.5	540	0.6	15	**21**	340	**1**	82	**4**	610	0.5	3400	0.1	5100	0.06	3700	0.1
Th-230 (pCi/g)**	319	1.5	2000	0.2	520	0.6	12000	0.03	22000	0.01	170000	0.002	210000	0.002	1100000	0.0003	680000	0.000

Bold values indicate concentrations that exceed ecological screening level; bold and shading indicates HQ exceeds unity (based on one significant figure). Thick border around HQ>1 indicates maximum concentration also exceeds background.

COPEC = chemical of potential environmental concern.

HQ = hazard quotient = maximum concentration / screening level.

NSL - no screening level.

[a] Background threshold value for radium-226 as reported in the Central GSA Mine Removal Site Evaluation Report (Weston, July 2019).

[b] Mean for Western US (Shacklette, H.T. and J.G. Boernren. 1984. Element Concentrations in Soil and Other Surface Materials of the Counterminous United States. USGS Professional Paper 1270).

[c] LANL low effect Ecological Screening Level (ESL) Version 4.1; values for avian herbivore (American robin), avian insectivore (American robin), and avian intermediate carnivore (Amercian kestrel); mammalian herbivore (desert cottontail); mammalian insectivore (montane shrew) and mammalian top carnivore (red fox).

* 95% upper confidence limit (95UCL) concentration of radium-226.

** Istope in U-238 decay chain; assumes in secular equilibrium with radium-226.

Appendix H, Table H-7
Refined Ecological Risk Characterization by Geographic Section - Radionuclides
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

COPEC	Average Concentration (mg/kg)^	Background[a]	Plant		Soil invertebrates		Avian herbivore		Avian ground insectivore		Avian carnivore		Mammalian herbivore		Mammalian ground insectivore		Mammalian carnivore	
			Low Effect ESL[b]	Low Effect HQ	Low Effect ESL[b]	Low Effect HQ	Low Effect ESL[b]	Low Effect HQ	Low Effect ESL[b]	Low Effect HQ	Low Effect ESL[b]	Low Effect HQ	Low Effect ESL[b]	Low Effect HQ	Low Effect ESL[b]	Low Effect HQ	Low Effect ESL[b]	Low Effect HQ
Surface Soil																		
Section 17																		
Radium 226 (pCi/g)*	156	1.5	540	0.3	15	**10**	340	0.5	82	**2**	610	0.3	3400	0.05	5100	0.03	3700	0.04
Section 19																		
Radium 226 (pCi/g)*	6.41	1.5	540	0.0	15	0.4	340	0.0	82	0.1	610	0.01	3400	0.002	5100	0.001	3700	0.002
Section 20																		
Radium 226 (pCi/g)*	9.27	1.5	540	0.0	15	0.6	340	0.0	82	0.1	610	0.02	3400	0.003	5100	0.002	3700	0.003
Section 29																		
Radium 226 (pCi/g)*	7.92	1.5	540	0.0	15	0.5	340	0.0	82	0.1	610	0.01	3400	0.002	5100	0.002	3700	0.002
Section 32																		
Radium 226 (pCi/g)*	13.8	1.5	540	0.0	15	0.9	340	0.0	82	0.2	610	0.02	3400	0.004	5100	0.003	3700	0.004
Section 33																		
Radium 226 (pCi/g)*	27.2	1.5	540	0.1	15	**2**	340	0.1	82	0.3	610	0.04	3400	0.008	5100	0.005	3700	0.01
Subsurface Soil																		
Section 17																		
Radium 226 (pCi/g)*	35	1.5	540	0.1	15	**2**	340	0.1	82	0.4	610	0.06	3400	0.01	5100	0.007	3700	0.01
Th-230 (pCi/g)**	1.6	1.5	2000	0.001	520	0.003	12000	0.0001	22000	0.00007	170000	0.00001	210000	0.00001	1100000	0.000001	680000	0.000002
Section 20																		
Radium 226 (pCi/g)*	3.8	1.5	540	0.01	15	0.3	340	0.01	82	0.05	610	0.006	3400	0.001	5100	0.0007	3700	0.001
Th-230 (pCi/g)**	0.2	1.5	2000	0.0001	520	0.0003	12000	0.00001	22000	0.000008	170000	0.000001	210000	0.000001	1100000	0.0000002	680000	0.0000003
Section 29																		
Radium 226 (pCi/g)*	2.0	1.5	540	0.004	15	0.1	340	0.01	82	0.02	610	0.003	3400	0.0006	5100	0.0004	3700	0.001
Section 30																		
Radium 226 (pCi/g)*	63	1.5	540	0.1	15	**4**	340	0.2	82	0.8	610	0.1	3400	0.02	5100	0.01	3700	0.02
Section 32																		
Radium 226 (pCi/g)*	2.9	1.5	540	0.005	15	0.2	340	0.01	82	0.04	610	0.005	3400	0.0009	5100	0.0006	3700	0.001
Section 33																		
Radium 226 (pCi/g)*	23	1.5	540	0.04	15	**2**	340	0.07	82	0.3	610	0.04	3400	0.007	5100	0.005	3700	0.006

Bold values indicate concentrations that exceed ecological screening level; bold and shading indicates HQ exceeds unity (based on one significant figure). Thick border around HQ>1 indicates maximum concentration also exceeds background.

COPEC = chemical of potential environmental concern.

HQ = hazard quotient = maximum concentration / screening level.

[a] Background threshold value for radium-226 as reported in the West GSA Removal Site Evaluation Report (Weston, July 2019).

[b] LANL low effect Ecological Screening Level (ESL) Version 4.1; values for avian herbivore (American robin), avian insectivore (American robin), and avian intermediate carnivore (Amercian kestrel); mammalian herbivore (desert cottontail); mammalian insectivore (montane shrew) and mammalian top carnivore (red fox).

* 95% upper confidence limit (95UCL) concentration of radium-226.

** Istope in U-238 decay chain; assumes in secular equilibrium with radium-226.

^ 95% upper confidence limit (95% UCL) on the mean of soil samples unless otherwise noted; all surface soil locations had 5 or less samples and therefore the maximum concentration was used for surface soil locations.

Appendix H, Table H-8
Refined Ecological Risk Characterization by Geographic Section - Metals
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

COPEC	Average Concentration (mg/kg)^	Background[a,b]	Plant		Soil invertebrates		Avian herbivore		Avian ground insectivore		Avian carnivore		Mammalian herbivore		Mammalian ground insectivore		Mammalian carnivore	
			Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ	Low Effect ESL[c]	Low Effect HQ
Section 17																		
Selenium	ND	0.29	3	--	41	--	1.9	--	1.4	--	7.5	--	3.4	--	1	--	130	--
Vanadium	42	71.4	80	0.5	NSL	--	13	**3**	9.5	**4**	110	0.4	1,500	0.03	610	0.07	6,900	0.006
Section 19																		
Selenium	6.8	0.29	3	**2**	41	0.2	1.9	**4**	1.4	**5**	7.5	0.9	3.4	**2**	1	**7**	130	0.05
Vanadium	82	71.4	80	**1**	NSL	--	13	**6**	9.5	**9**	110	0.7	1,500	0.05	610	0.1	6,900	0.01
Section 30																		
Selenium	ND	0.29	3	--	41	--	1.9	--	1.4	--	7.5	--	3.4	--	1	--	130	--
Vanadium	20	71.4	80	0.2	NSL	--	13	**2**	9.5	**2**	110	0.2	1,500	0.01	610	0.03	6,900	0.003
Section 33																		
Selenium	7.0	0.29	3	**2**	41	0.2	1.9	**4**	1.4	**5**	7.5	0.9	3.4	**2**	1	**7**	130	0.05
Vanadium	41	71.4	80	0.5	NSL	--	13	**3**	9.5	**4**	110	0.4	1,500	0.03	610	0.1	6,900	0.006

Bold values indicate concentrations that exceed ecological screening level; bold and shading indicates HQ exceeds unity (based on one significant figure). Thick border around HQ>1 indicates maximum concentration also exceeds background.

COPEC = chemical of potential environmental concern.

HQ = hazard quotient = maximum concentration / screening level.

ND = non-detect.

NSL - no screening level.

[a] Average concentration, New Mexico, Background Soil Concentration Database, EcoSSL Attachment 1-4, Guidance for Developing Ecological Soil Screening Levels (Eco-SSLs), Review of Background Concentrations for Metals, OSWER Directive 92857-55, Revised July 2007. https://www.epa.gov/sites/production/files/2015-09/documents/ecossl_attachment_1-4.pdf.

[b] Mean for Western US (Shacklette, H.T. and J.G. Boernren. 1984. Element Concentrations in Soil and Other Surface Materials of the Counterminous United States. USGS Professional Paper 1270)

[c] LANL low effect Ecological Screening Level (ESL) Version 4.1; values for avian herbivore (American robin), avian insectivore (American robin), and avian intermediate carnivore (Amercian kestrel); mammalian herbivore (desert cottontail); mammalian insectivore (montane shrew) and mammalian top carnivore (red fox).

^ Average of two samples in Section 17, 19, 30, and average of three samples in Section 33.

Appendix H, Table H-9
Comparison of Plant Tissue Concentrations to Maximum Tolerable Limits for Animals and Normal/ Toxic Limits for Plants
Tronox Navajo Area Uranium Mines, Central GSA Site
McKinley County, New Mexico

Plant Analysis Sample I.D.	Iron ppm	Zinc ppm	Copper ppm	Manganese ppm	Molybdenum ppm	Uranium ppm	Vanadium ppm	Selenium ppm
Minimum within APE	129	0.03	4.4	3	3.0	< 0.10	< 0.10	< 0.10
Average within APE	**506**	32	6.9	34	**12.9**	All < 0.10 except one	1.5	**10.7**
Maximum within APE	**1,193**	**358**	11.2	197	**27.4**	3.9	3.2	**38.1**
Maximum Tolerable Limits (MTL) of Minerals in the Feed (mg/kg dry matter) [a]								
Rodents	500	500	500	2000	7	100 - 400**	NA	5
Poultry	500	500	250	2000	100	NA	25 (<5 laying hens)	3
Swine	3000	1000	250	1000	150	NA	10	4
Horse	500	500	250	400	5*	NA	10	5
Cattle	500	500	40	2000	5*	NA	50	5
Sheep	500	300	15	2000	5*	NA	50	5
Trace Elements in Mature Leaf Tissue* (ppm dry weight) [b]**								
Sufficient/Normal	NA	27 - 150	5 - 30	30 - 300	0.2 - 5	NA	0.2 - 1.5	0.01 - 2
Toxic/Excessive	NA	100 - 400	20 - 100	400 - 1000	10 - 50	NA	5 - 10	5 - 30

Bold indicates concentration exceeds lowest MTL for animals and shading indicates concentration within toxic/excessive range for plants.

* Toxicosis caused by <25 mg/kg is often associated with inadequate available copper; cattle show overt toxicosis when dietary molybdenum level is at 100 mg/kg or higher regardless of dietary copper or sulfur levels (NRC, 2005).

**Maximum tolerable intake for domestic animals is probably between 100 and 400 mg/kg diet (NRC, 2005).

*** Values are not given for very sensitive or highly tolerant plant species (Kabata-Pendias and Pendias, 1992).

[a] Defined as dietary level, that, when fed for a defined period of time, will not impair animal health or performance (NRC, 2005).

ppm = parts per million = millgrams per kilogram (mg/kg)
APE = Area of potential effect.

NA = Not applicable.

References:

[a] National Research Council (NRC). 2005. Mineral Tolerance of Animal. 2nd Revised Edition. The National Academies Press. Washington, D.C.

[b] Kabata-Pendias, Alina and Henryk Pendias. 1992. Trace Elements in Soils and Plants. 2nd Edition. CRC Press. Boca Raton, FL.

* NNV5. 2019a. Natural Resources Evaluation, Tronox NAUM, Section 32 and 36, McKinley County, New Mexico. Prepared for US Environmental Protection Agency Region 6 and Weston Solutions, Inc. June.

Attachment 1
PRG and RSL Calculators Input and Output

Site-specific
Composite Worker Soil Inputs - Secular Equilibrium

Variable	Default Value	Form-input Value
A (PEF Dispersion Constant)	16.2302	14.9421
B (PEF Dispersion Constant)	18.7762	17.9869
City (Climate Zone)	Default	Albuquerque, NM (3)
C (PEF Dispersion Constant)	216.108	205.1782
Cover thickness for GSF_o (gamma shielding factor) cm	0 cm	0 cm
F(x) (function dependent on U_m/U_t) unitless	0.194	0.0553
PEF (particulate emission factor) m^3/kg	1359344438	2573243853.79163
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	31.86507598808449
A_s (acres)	0.5	250
Site area for ACF (area correction factor) m^2	1000029 m^2	1000029 m^2
ED_w (exposure duration - composite worker) yr	25	25
EF_w (exposure frequency - composite worker) day/yr	250	250
ET_w (exposure time - composite worker) hr/day	8	0.8
IRA_w (inhalation rate - composite worker) m^3/day	60	60
IRS_w (soil intake rate - composite worker) mg/day	100	100
t_w (time - composite worker) yr	25	25
TR (target cancer risk) unitless	1.0E-06	1.0E-04
U_m (mean annual wind speed) m/s	4.69	4.02
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

Output generated 15DEC2019:16:28:52

Site-specific

Composite Worker PRGs for Soil - Secular Equilibrium

Isotope	Ingestion PRG TR=0.0001 (pCi/g)	Inhalation PRG TR=0.0001 (pCi/g)	External Exposure PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (pCi/g)
Secular Equilibrium PRG for U-235	*2.91E+02*	*6.55E+04*	*7.51E+01*	*5.97E+01*
Secular Equilibrium PRG for U-238	*6.35E+01*	*1.42E+05*	*2.06E+01*	*1.56E+01*

Site-specific

Indoor Worker Soil Inputs - Secular Equilibrium

Variable	Default Value	Form-input Value
A (PEF Dispersion Constant)	16.2302	14.9421
B (PEF Dispersion Constant)	18.7762	17.9869
City (Climate Zone)	Default	Albuquerque, NM (3)
C (PEF Dispersion Constant)	216.108	205.1782
Cover thickness for GSF_h (gamma shielding factor) cm	0 cm	0 cm
F(x) (function dependent on U_m/U_t) unitless	0.194	0.0553
PEF (particulate emission factor) m^3/kg	1359344438	6609630249.811598
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	81.84858572694108
A_s (acres)	0.5	0.5
Site area for ACF (area correction factor) m^2	1000029 m^2	1000029 m^2
ED_{iw} (exposure duration - indoor worker) yr	25	25
EF_{iw} (exposure frequency - indoor worker) day/yr	250	250
ET_{iw} (exposure time - indoor worker) hr/day	8	0.8
GSF_i (indoor gamma shielding factor) unitless	0.4	0.7
IRA_{iw} (inhalation rate - indoor worker) m^3/day	60	0
IRS_{iw} (soil intake rate - indoor worker) mg/day	50	0
t_{iw} (time - indoor worker) yr	25	25
TR (target cancer risk) unitless	1.0E-06	1.0E-04
U_m (mean annual wind speed) m/s	4.69	4.02
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

Output generated 15DEC2019:16:18:45

Site-specific

Indoor Worker PRGs for Soil - Secular Equilibrium

Isotope	Ingestion PRG TR=0.0001 (pCi/g)	Inhalation PRG TR=0.0001 (pCi/g)	External Exposure PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (pCi/g)
Secular Equilibrium PRG for U-235	-	-	*1.07E+02*	*1.07E+02*
Secular Equilibrium PRG for U-238	-	-	*2.95E+01*	*2.95E+01*

Variable	Farmer Soil Default Value	Form-input Value
A (PEF Dispersion Constant)	16.2302	14.9421
B (PEF Dispersion Constant)	18.7762	17.9869
City (Climate Zone)	Default	Albuquerque, NM (3)
Climate zone	Temperate	Temperate
C (PEF Dispersion Constant)	216.108	205.1782
Cover thickness for GSF_o (gamma shielding factor) cm	0 cm	0 cm
Cover thickness for GSF_b (gamma shielding factor) cm	0 cm	0 cm
$CF_{far-produce}$ (contaminated plant fraction) unitless	1	1
$CF_{far-apple}$ (contaminated apple fraction) unitless	1	1
$CF_{far-asparagus}$ (contaminated asparagus fraction) unitless	1	1
$CF_{far-beef}$ (beef contaminated fraction) unitless	1	0.48
$CF_{far-berry}$ (contaminated berry fraction) unitless	1	1
$CF_{far-broccoli}$ (contaminated broccoli fraction) unitless	1	1
$CF_{far-beet}$ (contaminated beet fraction) unitless	1	1
$CF_{far-cabbage}$ (contaminated cabbage fraction) unitless	1	1
$CF_{far-cereal\ grain}$ (contaminated cereal grain fraction) unitless	1	1
$CF_{far-citrus}$ (contaminated citrus fraction) unitless	1	1
$CF_{far-corn}$ (contaminated corn fraction) unitless	1	1
$CF_{far-carrot}$ (contaminated carrot fraction) unitless	1	1
$CF_{far-cucumber}$ (contaminated cucumber fraction) unitless	1	1
$CF_{far-dairy}$ (dairy contaminated fraction) unitless	1	1
$CF_{far-egg}$ (egg contaminated fraction) unitless	1	1
$CF_{far-fish}$ (fish contaminated fraction) unitless	1	1
$CF_{far-goat\ milk}$ (goat milk contaminated fraction) unitless	1	1
$CF_{far-goat\ meat}$ (goat meat contaminated fraction) unitless	1	1
$CF_{far-lettuce}$ (contaminated lettuce fraction) unitless	1	1
$CF_{far-lima\ bean}$ (contaminated lima bean fraction) unitless	1	1
$CF_{far-okra}$ (contaminated okra fraction) unitless	1	1
$CF_{far-onion}$ (contaminated onion fraction) unitless	1	1
$CF_{far-poultry}$ (poultry contaminated fraction unitless)	1	1
$CF_{far-peach}$ (contaminated peach fraction) unitless	1	1
$CF_{far-pea}$ (contaminated pea fraction) unitless	1	1
$CF_{far-pear}$ (contaminated pear fraction) unitless	1	1
$CF_{far-potato}$ (contaminated potato fraction) unitless	1	1
$CF_{far-pumpkin}$ (contaminated pumpkin fraction) unitless	1	1
$CF_{far-rice}$ (contaminated rice fraction) unitless	1	1
$CF_{far-sheep}$ (sheep contaminated fraction) unitless	1	1
$CF_{far-sheep\ milk}$ (sheep milk contaminated fraction) unitless	1	1
$CF_{far-snap\ bean}$ (contaminated snap bean fraction) unitless	1	1
$CF_{far-strawberry}$ (contaminated strawberry fraction) unitless	1	1
$CF_{far-swine}$ (swine contaminated fraction) unitless	1	1
$CF_{far-tomato}$ (contaminated tomato fraction) unitless	1	1
ED_{far} (exposure duration - farmer) yr	40	25
ED_{far-a} (exposure duration - farmer adult) yr	34	25
ED_{far-c} (exposure duration - farmer child) yr	6	0
EF_{far-a} (exposure frequency - farmer adult) day/yr	350	350
EF_{far-c} (exposure frequency - farmer child) day/yr	350	350
$IFAP_{far-adj}$ (age-adjusted apple ingestion factor) g	1182020	741125
$IFAS_{far-adj}$ (age-adjusted asparagus ingestion factor) g	492870	343875
$IFB_{far-adj}$ (age-adjusted beef ingestion factor) g	2098950	1446375
$IFBE_{far-adj}$ (age-adjusted berry ingestion factor) g	471450	309750
$IFBR_{far-adj}$ (age-adjusted broccoli ingestion factor) g	450310	308875
$IFBT_{far-adj}$ (age-adjusted beet ingestion factor) g	411600	296625
$IFCB_{far-adj}$ (age-adjusted cabbage ingestion factor) g	1043980	749875
$IFCG_{far-adj}$ (age-adjusted cereal grain ingestion factor) g	1190210	1190210
$IFCI_{far-adj}$ (age-adjusted citrus ingestion factor) g	4090100	2707250
$IFCO_{far-adj}$ (age-adjusted corn ingestion factor) g	1044470	717500
$IFCR_{far-adj}$ (age-adjusted carrot ingestion factor) g	318290	213500
$IFCU_{far-adj}$ (age-adjusted cucumber ingestion factor) g	688800	480375
$IFD_{far-adj}$ (age-adjusted dairy ingestion factor) g	10138030	5918500
$IFE_{far-adj}$ (age-adjusted egg ingestion factor) g	775810	521500

Variable	Farmer Soil Default Value	Form-input Value
$IFFI_{far-adj}$ (age-adjusted fish ingestion factor) g	10018960	7278250
$IFLE_{far-adj}$ (age-adjusted lettuce ingestion factor) g	455070	328125
$IFLI_{far-adj}$ (age-adjusted lima bean ingestion factor) g	415870	295750
$IFOK_{far-adj}$ (age-adjusted okra ingestion factor) g	370510	264250
$IFON_{far-adj}$ (age-adjusted onion ingestion factor) g	338800	238000
$IFP_{far-adj}$ (age-adjusted poultry ingestion factor) g	1376550	939750
$IFPC_{far-adj}$ (age-adjusted peach ingestion factor) g	1435420	902125
$IFPE_{far-adj}$ (age-adjusted pea ingestion factor) g	437500	277375
$IFPR_{far-adj}$ (age-adjusted pear ingestion factor) g	874300	524125
$IFPT_{far-adj}$ (age-adjusted potato ingestion factor) g	1807750	1240750
$IFPU_{far-adj}$ (age-adjusted pumpkin ingestion factor) g	866040	567000
$IFRI_{far-adj}$ (age-adjusted rice ingestion factor) g	1126230	774375
$IFSN_{far-adj}$ (age-adjusted snap bean ingestion factor) g	702730	474250
$IFST_{far-adj}$ (age-adjusted strawberry ingestion factor) g	535080	354375
$IFSW_{far-adj}$ (age-adjusted swine ingestion factor) g	1171520	809375
$IFTO_{far-adj}$ (age-adjusted tomato ingestion factor) g	1194270	824250
$IRAP_{far-a}$ (apple ingestion rate - farmer adult) g/day	84.7	84.7
$IRAP_{far-c}$ (apple ingestion rate - farmer child) g/day	82.9	82.9
$IRAS_{far-a}$ (asparagus ingestion rate - farmer adult) g/day	39.3	39.3
$IRAS_{far-c}$ (asparagus ingestion rate - farmer child) g/day	12	12
IRB_{far-a} (beef ingestion rate - farmer adult) g/day	165.3	165.3
IRB_{far-c} (beef ingestion rate - farmer child) g/day	62.8	0
$IRBE_{far-a}$ (berry ingestion rate - farmer adult) g/day	35.4	35.4
$IRBE_{far-c}$ (berry ingestion rate - farmer child) g/day	23.9	23.9
$IRBR_{far-a}$ (broccoli ingestion rate - farmer adult) g/day	35.3	35.3
$IRBR_{far-c}$ (broccoli ingestion rate - farmer child) g/day	14.4	14.4
$IRBT_{far-a}$ (beet ingestion rate - farmer adult) g/day	33.9	33.9
$IRBT_{far-c}$ (beet ingestion rate - farmer child) g/day	3.9	3.9
$IRCB_{far-a}$ (cabbage ingestion rate - farmer adult) g/day	85.7	85.7
$IRCB_{far-c}$ (cabbage ingestion rate - farmer child) g/day	11.5	11.5
$IRCG_{far-a}$ (cereal grain ingestion rate - farmer adult) g/day	91.9	91.9
$IRCG_{far-c}$ (cereal grain ingestion rate - farmer child) g/day	46	46
$IRCI_{far-a}$ (citrus ingestion rate - farmer adult) g/day	309.4	309.4
$IRCI_{far-c}$ (citrus ingestion rate - farmer child) g/day	194.4	194.4
$IRCO_{far-a}$ (corn ingestion rate - farmer adult) g/day	82	82
$IRCO_{far-c}$ (corn ingestion rate - farmer child) g/day	32.7	32.7
$IRCR_{far-a}$ (carrot ingestion rate - farmer adult) g/day	24.4	24.4
$IRCR_{far-c}$ (carrot ingestion rate - farmer child) g/day	13.3	13.3
$IRCU_{far-a}$ (cucumber ingestion rate - farmer adult) g/day	54.9	54.9
$IRCU_{far-c}$ (cucumber ingestion rate - farmer child) g/day	16.9	16.9
IRD_{far-a} (dairy ingestion rate - farmer adult) g/day	676.4	676.4
IRD_{far-c} (dairy ingestion rate - farmer child) g/day	994.7	994.7
IRE_{far-a} (egg ingestion rate - farmer adult) g/day	59.6	59.6
IRE_{far-c} (egg ingestion rate - farmer child) g/day	31.7	31.7
$IRFI_{far-a}$ (fish ingestion rate - farmer adult) g/day	831.8	831.8
$IRFI_{far-c}$ (fish ingestion rate - farmer child) g/day	57.4	57.4
$IRLE_{far-a}$ (lettuce ingestion rate - farmer adult) g/day	37.5	37.5
$IRLE_{far-c}$ (lettuce ingestion rate - farmer child) g/day	4.2	4.2
$IRLI_{far-a}$ (lima bean ingestion rate - farmer adult) g/day	33.8	33.8
$IRLI_{far-c}$ (lima bean ingestion rate - farmer child) g/day	6.5	6.5
$IROK_{far-a}$ (okra ingestion rate - farmer adult) g/day	30.2	30.2
$IROK_{far-c}$ (okra ingestion rate - farmer child) g/day	5.3	5.3
$IRON_{far-a}$ (onion ingestion rate - farmer adult) g/day	27.2	27.2
$IRON_{far-c}$ (onion ingestion rate - farmer child) g/day	7.2	7.2
IRP_{far-a} (poultry ingestion rate - farmer adult) g/day	107.4	107.4
IRP_{far-c} (poultry ingestion rate - farmer child) g/day	46.9	46.9
$IRPC_{far-a}$ (peach ingestion rate - farmer adult) g/day	103.1	103.1
$IRPC_{far-c}$ (peach ingestion rate - farmer child) g/day	99.3	99.3
$IRPE_{far-a}$ (pea ingestion rate - farmer adult) g/day	31.7	31.7
$IRPE_{far-c}$ (pea ingestion rate - farmer child) g/day	28.7	28.7
$IRPR_{far-a}$ (pear ingestion rate - farmer adult) g/day	59.9	59.9

Variable	Farmer Soil Default Value	Form-input Value
$IRPR_{far-c}$ (pear ingestion rate - farmer child) g/day	76.9	76.9
$IRPT_{far-a}$ (potato ingestion rate - farmer adult) g/day	141.8	141.8
$IRPT_{far-c}$ (potato ingestion rate - farmer child) g/day	57.3	57.3
$IRPU_{far-a}$ (pumpkin ingestion rate - farmer adult) g/day	64.8	64.8
$IRPU_{far-c}$ (pumpkin ingestion rate - farmer child) g/day	45.2	45.2
$IRRI_{far-a}$ (rice ingestion rate - farmer adult) g/day	88.5	88.5
$IRRI_{far-c}$ (rice ingestion rate - farmer child) g/day	34.8	34.8
$IRSN_{far-a}$ (snap bean ingestion rate - farmer adult) g/day	54.2	54.2
$IRSN_{far-c}$ (snap bean ingestion rate - farmer child) g/day	27.5	27.5
$IRST_{far-a}$ (strawberry ingestion rate - farmer adult) g/day	40.5	40.5
$IRST_{far-c}$ (strawberry ingestion rate - farmer child) g/day	25.3	25.3
$IRSW_{far-a}$ (swine ingestion rate - farmer adult) g/day	92.5	92.5
$IRSW_{far-c}$ (swine ingestion rate - farmer child) g/day	33.7	33.7
$IRTO_{far-a}$ (tomato ingestion rate - farmer adult) g/day	94.2	94.2
$IRTO_{far-c}$ (tomato ingestion rate - farmer child) g/day	34.9	34.9
MLF_{apple} (apple mass loading factor) unitless	0.00016	0.00016
$MLF_{asparagus}$ (asparagus mass loading factor) unitless	0.000079	0.000079
MLF_{berry} (berry mass loading factor) unitless	0.000166	0.000166
$MLF_{broccoli}$ (broccoli mass loading factor) unitless	0.00101	0.00101
MLF_{beet} (beet mass loading factor) unitless	0.000138	0.000138
$MLF_{cabbage}$ (cabbage mass loading factor) unitless	0.000105	0.000105
$MLF_{cereal\ grain}$ (cereal grain mass loading factor) unitless	0.25	0.25
MLF_{citrus} (citrus mass loading factor) unitless	0.000157	0.000157
MLF_{corn} (corn mass loading factor) unitless	0.000145	0.000145
MLF_{carrot} (carrot mass loading factor) unitless	0.000097	0.000097
$MLF_{cucumber}$ (cucumber mass loading factor) unitless	0.00004	0.00004
$MLF_{lettuce}$ (lettuce mass loading factor) unitless	0.0135	0.0135
$MLF_{lima\ bean}$ (lima bean mass loading factor) unitless	0.00383	0.00383
MLF_{okra} (okra mass loading factor) unitless	0.00008	0.00008
MLF_{onion} (onion mass loading factor) unitless	0.000097	0.000097
MLF_{peach} (peach mass loading factor) unitless	0.00015	0.00015
MLF_{pea} (pea mass loading factor) unitless	0.000178	0.000178
MLF_{pear} (pear mass loading factor) unitless	0.00016	0.00016
MLF_{potato} (potato mass loading factor) unitless	0.00021	0.00021
$MLF_{pumpkin}$ (pumpkin mass loading factor) unitless	0.000058	0.000058
MLF_{rice} (rice mass loading factor) unitless	0.25	0.25
$MLF_{snap\ bean}$ (snap bean mass loading factor) unitless	0.005	0.005
$MLF_{strawberry}$ (strawberry mass loading factor) unitless	0.00008	0.00008
MLF_{tomato} (tomato mass loading factor) unitless	0.00159	0.00159
p_m (density of milk) kg/L	1.03	1.03
t_{far} (time - farmer) yr	40	25
TR (target cancer risk) unitless	0.000001	0.0001
F(x) (function dependent on U_m/U_t) unitless	0.194	0.0553
PEF (particulate emission factor) m^3/kg	1359344438	2370938159
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	29.3598776
A_s (acres)	0.5	500
Slab size for ACF (area correction factor) m^2	1000029 m^2	1000029 m^2
ED_{far} (exposure duration - farmer) yr	40	25
ED_{far-a} (exposure duration - farmer adult) yr	34	25
ED_{far-c} (exposure duration - farmer child) yr	6	0
EF_{far} (exposure frequency) day/yr	350	350
EF_{far-a} (exposure frequency - farmer adult) day/yr	350	350
EF_{far-c} (exposure frequency - farmer child) day/yr	350	0
ET_{far} (exposure time - farmer) hr/day	24	0
ET_{far-a} (exposure time - farmer adult) hr/day	24	0
ET_{far-c} (exposure time - farmer child) hr/day	24	0
ET_{far-i} (indoor exposure time fraction) hr/day	10.008	10.008
ET_{far-o} (outdoor exposure time fraction) hr/day	12.168	12.168
f_{p-beef} (animal on-site fraction) unitless	1	0.375
$f_{p-dairy}$ (animal on-site fraction) unitless	1	1
$f_{p-goat\ milk}$ (animal on-site fraction) unitless	1	1

Variable	Farmer Soil Default Value	Form-input Value
$f_{p\text{-}goat}$ (animal on-site fraction) unitless	1	1
$f_{p\text{-}poultry}$ (animal on-site fraction) unitless	1	1
$f_{p\text{-}sheep}$ (animal on-site fraction) unitless	1	1
$f_{p\text{-}sheep\ milk}$ (animal on-site fraction) unitless	1	1
$f_{p\text{-}swine}$ (animal on-site fraction) unitless	1	1
$f_{s\text{-}beef}$ (fraction of year animal on site) unitless	1	1
$f_{s\text{-}dairy}$ (fraction of year animal on site) unitless	1	1
$f_{s\text{-}goat\ milk}$ (fraction of year animal on site) unitless	1	1
$f_{s\text{-}goat}$ (fraction of year animal on site) unitless	1	1
$f_{s\text{-}poultry}$ (fraction of year animal on site) unitless	1	1
$f_{s\text{-}sheep}$ (fraction of year animal on site) unitless	1	1
$f_{s\text{-}sheep\ milk}$ (fraction of year animal on site) unitless	1	1
$f_{s\text{-}swine}$ (fraction of year animal on site) unitless	1	1
GSF_i (gamma shielding factor - indoor)	0.4	0
$IFA_{far\text{-}adj}$ (age-adjusted soil inhalation factor) m^3	259000	0
$IFS_{far\text{-}adj}$ (age-adjusted soil ingestion factor) mg	1610000	875000
$IRA_{far\text{-}a}$ (inhalation rate - farmer adult) m^3/day	20	20
$IRA_{far\text{-}c}$ (inhalation rate - farmer child) m^3/day	10	0
$IRS_{far\text{-}a}$ (soil ingestion rate - farmer adult) mg/day	100	100
$IRS_{far\text{-}c}$ (soil ingestion rate - farmer child) mg/day	200	0
$MLF_{pasture}$ (pasture plant mass loading factor) unitless	0.25	0.25
$Q_{p\text{-}beef}$ (beef fodder intake rate) kg/day	11.77	11.77
$Q_{p\text{-}dairy}$ (dairy fodder intake rate) kg/day	20.3	20.3
$Q_{p\text{-}goat\ milk}$ (goat milk fodder intake rate) kg/day	1.59	1.59
$Q_{p\text{-}goat}$ (goat fodder intake rate) kg/day	1.27	1.27
$Q_{p\text{-}poultry}$ (poultry fodder intake rate) kg/day	0.2	0.2
$Q_{p\text{-}sheep}$ (sheep fodder intake rate) kg/day	1.75	1.75
$Q_{p\text{-}sheep\ milk}$ (sheep milk fodder intake rate) kg/day	3.15	3.15
$Q_{p\text{-}swine}$ (swine fodder intake rate) kg/day	4.7	4.7
$Q_{s\text{-}beef}$ (beef soil intake rate) kg/day	0.5	0.5
$Q_{s\text{-}dairy}$ (dairy soil intake rate) kg/day	0.4	0.4
$Q_{s\text{-}goat\ milk}$ (goat milk soil intake rate) kg/day	0.29	0.29
$Q_{s\text{-}goat}$ (goat soil intake rate) kg/day	0.23	0.23
$Q_{s\text{-}poultry}$ (poultry soil intake rate) kg/day	0.022	0.022
$Q_{s\text{-}sheep}$ (sheep soil intake rate) kg/day	0.32	0.32
$Q_{s\text{-}sheep\ milk}$ (sheep milk soil intake rate) kg/day	0.57	0.57
$Q_{s\text{-}swine}$ (swine soil intake rate) kg/day	0.37	0.37
t_{far} (time - farmer) yr	40	25
TR (target cancer risk) unitless	0.000001	0.0001
Default	Default	Default
U_m (mean annual wind speed) m/s	4.69	4.02
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

Site-specific
Farmer PRGs for Soil - Secular Equilibrium

Isotope	Beef Consumption PRG TR=0.0001 (pCi/g)
Secular Equilibrium PRG for U-235	*1.63E+02*
Secular Equilibrium PRG for U-238	*8.43E+00*

Appendix H, Attachment 1: Table H 1-1
Site-Specific Equation Inputs for Soil Chemicals - Meat Consumption
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Intake Equation/Exposure Parameter	**Rancher - Adult**	
Target Hazard Quotient (THQ, unitless)	1	
Target Risk (TR, unitless)	1E-06	
Body Weight (BW, kg)	80	a
Exposure Frequency (EF, days/yr) - home grown meat	350	a
Exposure Duration (ED, yrs)	25	a
Averaging Time (ATnc)- noncarcinogens (yrs)	ED	a
Averaging Time (ATc)- carcinogens (yrs)	70	a
Ingestion Rate (IR_c, mg/day) - homegrown meat	165300	b
Fraction ingested (FI) - home grown meat	0.48	c
Fraction onsite	0.38	d
Meat Intake Factor - noncancer (MIF nc)	5.0E+02	
Meat Intake Factor - cancer (MIF c)	1.41E-03	

EXPOSURE ALGORITHMS for

SL meat-nc = THQ x AT nc x BW / (EF x ED x 1/RfD x IR meat x FI x 10^{-6} kg/mg) = MIF nc x 1/RfD

SL meat-c = TR x AT c x BW / (EF x ED x SF x IR meat x FI x 10^{-6} kg/mg) = (MIF c /(FI * SF)

a - Default value (USEPA, 2014)

b - default value for beef (USEPA, 2020a)

c - USEPA, 2011.

d - Hurd et al, 2007

Appendix H, Attachment 1: Table H 1-2
Site-Specific Screening Levels and Hazard Indexes for Soil-to-Meat Consumption
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Chemical	Reference Dose (mg/kg-day)	Screening Level-Meat - noncancer	Beef Transfer Coefficient (day/kg)[a]	Soil-to-Dry Plant Uptake[a]	Screening Level Soil to Meat - noncancer	Soil Concentration (mg/kg)	Noncancer Hazard Quotient
Uranium (Soluble Salts)	2.0E-04	0.21	2.0E-04	8.5E-03	4629	77	0.02

a ORNL RAIS

SL meat-nc = THQ x AT nc x BW / (EF x ED x 1/RfD x IR meat x FI x 10^6 kg/mg) = (MIFnc / FI *1/RfD) * 1/ (1/RfD) = 500 / (0.48 x (1/RfD)

SL-res-meat-nc-ing (mg/kg) = SL-meat-nc / {BTF x ([Forage Intake * PUFdry] + Soil intake)}

Hazard quotient (HQ) = Concentration/SL-nc

Forage intake = 11.77 kg/day *0.375 (fraction onsite) = 4.41375 kg/day

Soil intake = 0.5 kg/day *0.375 (fraction onsite) = 0.1875 kg/day

Appendix H, Attachment 1: Table H 1-3
Chemical-Specific Parameters
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

ANALYSIS	Beef Transfer Coefficient (day/kg)	Soil-to-Dry Plant Uptake	Soil-to-Wet Plant Uptake	BTF, BV Dry and BV Wet Reference
Uranium (Soluble Salts)	0.0002	0.0085	0.002125	Baes, C. F., III, Sharp, R. D., Sjoreen, A. L., and Shor, R. W. 1984. A Review and Analysis of Parameters for Assessing Transport

Source: ORNL RAIS

Site-specific
Composite Worker Equation Inputs for Soil

*** Inputted values different from Composite Worker defaults are highlighted.**

Variable	Composite Worker Soil Default Value	Form-input Value
A (PEF Dispersion Constant)	16.2302	14.9421
A (VF Dispersion Constant)	11.911	14.9421
A (VF Dispersion Constant - mass limit)	11.911	11.911
B (PEF Dispersion Constant)	18.7762	17.9869
B (VF Dispersion Constant)	18.4385	17.9869
B (VF Dispersion Constant - mass limit)	18.4385	18.4385
City (PEF Climate Zone) Selection	Default	Albuquerque, NM
City (VF Climate Zone) Selection	Default	Albuquerque, NM
C (PEF Dispersion Constant)	216.108	205.1782
C (VF Dispersion Constant)	209.7845	205.1782
C (VF Dispersion Constant - mass limit)	209.7845	209.7845
foc (fraction organic carbon in soil) g/g	0.006	0.006
F(x) (function dependent on U_m/U_t) unitless	0.194	0.0553
n (total soil porosity) L_{pore}/L_{soil}	0.43396	0.43396
p_b (dry soil bulk density) g/cm^3	1.5	1.5
p_b (dry soil bulk density - mass limit) g/cm^3	1.5	1.5
PEF (particulate emission factor) m^3/kg	1359344438	6609630249.8115
p_s (soil particle density) g/cm^3	2.65	2.65
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	81.848585726941
Q/C_{vol} (g/m^2-s per kg/m^3)	68.18	81.848585726941
Q/C_{vol} (g/m^2-s per kg/m^3 - mass limit)	68.18	68.18
A_s (PEF acres)	0.5	0.5
A_s (VF acres)	0.5	0.5
A_s (VF mass-limit acres)	0.5	0.5
AF_w (skin adherence factor - composite worker) mg/cm^2	0.12	0.12
AT_w (averaging time - composite worker)	365	365
BW_w (body weight - composite worker)	80	80
ED_w (exposure duration - composite worker) yr	25	25
EF_w (exposure frequency - composite worker) day/yr	250	250

Output generated 29MAY2020:12:47:40

Site-specific
Composite Worker Equation Inputs for Soil

*** Inputted values different from Composite Worker defaults are highlighted.**

Variable	Composite Worker Soil Default Value	Form-input Value
ET_w (exposure time - composite worker) hr	8	1.6
THQ (target hazard quotient) unitless	1	1
IRS_w (soil ingestion rate - composite worker) mg/day	100	100
LT (lifetime) yr	70	70
SA_w (surface area - composite worker) cm^2/day	3527	3527
TR (target risk) unitless	1.0E-04	1.0E-04
T_w (groundwater temperature) Celsius	25	25
$Theta_a$ (air-filled soil porosity) L_{air}/L_{soil}	0.28396	0.28396
$Theta_w$ (water-filled soil porosity) L_{water}/L_{soil}	0.15	0.15
T (exposure interval) s	819936000	819936000
T (exposure interval) yr	26	26
U_m (mean annual wind speed) m/s	4.69	4.02
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5
VF_{ml} (volitization factor - mass limit) m^3/kg	.	0

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Site-specific
Composite Worker Removal Management Levels (RML) for Soil

Key: I = IRIS; P = PPRTV; O = OPP; A = ATSDR; C = Cal EPA; X = PPRTV Screening Level; H = HEAST; D = DWSHA; W = TEF applied; E = RPF applied; G = see user's guide; U = user provided; ca = cancer; nc = noncancer; * = where: nc SL < 100X ca SL; ** = where nc SL < 10X ca SL; SSL values are based on DAF=1; max = ceiling limit exceeded; sat = Csat exceeded.

Chemical	CAS Number	Mutagen?	Volatile?	Chemical Type	SF_o (mg/kg-day)$^{-1}$	SF_o Ref	IUR (ug/m^3)$^{-1}$	IUR Ref	RfD (mg/kg-day)	RfD Ref	RfC (mg/m^3)	RfC Ref	GIABS	ABS	RBA
Uranium	NA	No	No	Inorganics	-		-		2.00E-04	A	4.00E-05	A	1	-	1
Vanadium and Compounds	7440-62-2	No	No	Inorganics	-		-		5.04E-03	G	1.00E-04	A	0.026	-	1

Soil Saturation Concentration (mg/kg)	S (mg/L)	K_{oc} (cm^3/g)	K_d (cm^3/g)	HLC (atm-m^3/mole)	Henry's Law Constant Used in Calcs (unitless)	H` and HLC Ref	Normal Boiling Point BP (K)	BP Ref	Critical Temperature TC (K)	TC Ref	Chemical Type	D_{ia} (cm^2/s)	D_{iw} (cm^2/s)
-	-	-	4.50E+02	-	-		4091.15	CRC89	13712.6	YAWS	INORGANIC	-	-
-	-	-	1.00E+03	-	-		3680.15	CRC89	11325	YAWS	INORGANIC	-	-

D_A (cm^2/s)	Particulate Emission Factor (m³/kg)	Volatilization Factor (m³/kg)	Ingestion SL TR=0.0001 (mg/kg)	Dermal SL TR=0.0001 (mg/kg)	Inhalation SL TR=0.0001 (mg/kg)	Carcinogenic SL TR=0.0001 (mg/kg)	Ingestion SL THQ=1 (mg/kg)	Dermal SL THQ=1 (mg/kg)	Inhalation SL THQ=1 (mg/kg)	Noncarcinogenic SL THI=1 (mg/kg)	Screening Level (mg/kg)
-	6.61E+09	-	-	-	-	-	2.34E+02	-	5.79E+06	2.34E+02	2.34E+02 nc
-	6.61E+09	-	-	-	-	-	5.89E+03	-	1.45E+07	5.88E+03	5.88E+03 nc

Attachment 2
Recommended Shielding Factor for a Pick-up Truck

MEMO

DATE: September 26, 2016

TO: Keith Delhomme

FROM: Rick Haaker

RF Haaker

SUBJECT: Recommended shielding factor for a pick-up truck

Mr. Delhomme directed me to provide a gamma radiation transmission factor for a pick-up truck. A transmission factor in this case may be thought of as the proportion of gamma radiation level measured inside of the cab compared to the level at the same location in the absence of the truck, Equation 1.

$$Eq. 1: \quad Transmission\ Factor = \frac{Gamma\ radiation\ level\ inside\ of\ cab}{Gamma\ radiation\ level\ if\ no\ truck\ is\ present}$$

A 2010 extended cab Honda Ridgeline was chosen for the gamma radiation measurements. The Honda extended cab Ridgeline is considered a comparatively small pickup, having a curb weight of approximately 4,500 pounds. Radiation levels inside and outside a 2014 Toyota Corolla 4-door sedan were also measured to give an estimate of the transmission factor for a rather light vehicle by modern standards. The weights of some selected vehicles are provided in Table 1.

Table 1.

Vehicle	Weight, lbs[1]
2016 Ford F-250 Super Cab	6,200 to 7,460
2016 Ford F-350 Super Cab	6,298 to 7,508
2016 Ford F-450 Crew Cab	8,611
1983 Mazda B-2000 Pickup	2,590[2]
2014 Toyota Corolla 4-door sedan	~2,900 [3]

Measurement Method

Two gamma radiation intensities were measured in the front seats of each vehicle, one in the driver seat and the other in the front passenger seat. The measurements were taken with a Ludlum 44-10 2-inch by 2-inch gamma scintillation detector coupled with a Ludlum 2221 ratemeter/scaler. In each case the detector was held about 15 inches above the seat and about 12 inches toward the dashboard from the seat back, as shown in Figure 1. Once the indoor measurements were made the vehicles were moved and then the gamma radiation intensities were re-measured. The results are summarized in Table 2.

[1] https://www.fleet.ford.com/truckbbas/topics/2016/16_SD_Pickups_SB_Updates.pdf
[2] http://articles.mcall.com/1984-09-01/news/2429550_1_pickup-bed-small-pickup-mazda
[3] https://en.wikipedia.org/wiki/Toyota_Corolla_(E170)

http://articles.mcall.com/1984-09-01/news/2429550_1_pickup-bed-small-pickup-mazda

Table 2. Gamma Transmission Factor

Vehicle	Transmission Factor
2010 Honda Ridgeline extended cab	0.71 (95% CI: 0.69 – 0.73)
2014 Toyota Corolla	0.74 (95% CI: 0.72 – 0.77)

The 95% confidence intervals overlap, thus the gamma radiation transmission results for a Honda Ridgeline and a Toyota Corolla should not be considered significantly different. Most modern pickups are heavier than a 2010 Honda Ridgeline and most likely allow less gamma radiation transmission into the vehicle. Few ranchers are expected to work out of very small sedans or very old small foreign pickups. A gamma radiation transmission value of 0.7 is recommended. Based on the measurements taken, it is not likely to greatly overestimate or underestimate the true gamma transmission factor for pickups.

The specific measurement data is provided in Table 3.

Vehicle	Inside the vehicle (gross counts in 1 minute)		Background after vehicle moved (gross counts in 1 minute)	
	Driver side	Passenger side	Driver side	Passenger side
Honda Ridgeline	10,541	10,732	14,861	15,089
Toyota Corolla	10,732	11,140	14,452	15,058

Ludlum 2221 # 183990 with Ludlum 44-10 #RN19764, cal date June 9, 2016

Attachment 3
ProUCL Output

UCL Statistics for Uncensored Full Data Sets

User Selected Options			
Date/Time of Computation	ProUCL 5.14/21/2020 11:33:38 AM		
From File	Central Table 6-1 & 6-2_tv.xls		
Full Precision	OFF		
Confidence Coefficient	95%		
Number of Bootstrap Operations	2000		

Ra-226_S17

General Statistics

Total Number of Observations	42	Number of Distinct Observations	32
		Number of Missing Observations	3
Minimum	1.4	Mean	14.08
Maximum	177.7	Median	2.8
SD	30.67	Std. Error of Mean	4.733
Coefficient of Variation	2.178	Skewness	4.192

Normal GOF Test

Shapiro Wilk Test Statistic	0.457	**Shapiro Wilk GOF Test**
5% Shapiro Wilk Critical Value	0.942	Data Not Normal at 5% Significance Level
Lilliefors Test Statistic	0.34	**Lilliefors GOF Test**
5% Lilliefors Critical Value	0.135	Data Not Normal at 5% Significance Level

Data Not Normal at 5% Significance Level

Assuming Normal Distribution

95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	22.05	95% Adjusted-CLT UCL (Chen-1995)	25.14
		95% Modified-t UCL (Johnson-1978)	22.56

Gamma GOF Test

A-D Test Statistic	5.269	**Anderson-Darling Gamma GOF Test**
5% A-D Critical Value	0.805	Data Not Gamma Distributed at 5% Significance Level
K-S Test Statistic	0.346	**Kolmogorov-Smirnov Gamma GOF Test**
5% K-S Critical Value	0.143	Data Not Gamma Distributed at 5% Significance Level

Data Not Gamma Distributed at 5% Significance Level

Gamma Statistics

k hat (MLE)	0.584	k star (bias corrected MLE)	0.558
Theta hat (MLE)	24.12	Theta star (bias corrected MLE)	25.23
nu hat (MLE)	49.05	nu star (bias corrected)	46.88
MLE Mean (bias corrected)	14.08	MLE Sd (bias corrected)	18.85
		Approximate Chi Square Value (0.05)	32.17
Adjusted Level of Significance	0.0443	Adjusted Chi Square Value	31.73

Assuming Gamma Distribution

95% Approximate Gamma UCL (use when n>=50))	20.52	95% Adjusted Gamma UCL (use when n<50)	20.81

Lognormal GOF Test

Shapiro Wilk Test Statistic	0.763	**Shapiro Wilk Lognormal GOF Test**
5% Shapiro Wilk Critical Value	0.942	Data Not Lognormal at 5% Significance Level
Lilliefors Test Statistic	0.294	**Lilliefors Lognormal GOF Test**
5% Lilliefors Critical Value	0.135	Data Not Lognormal at 5% Significance Level

Data Not Lognormal at 5% Significance Level

	A	B	C	D	E	F	G	H	I	J	K	L
58	Lognormal Statistics											
59	Minimum of Logged Data					0.336	Mean of logged Data					1.583
60	Maximum of Logged Data					5.18	SD of logged Data					1.257
61												
62	Assuming Lognormal Distribution											
63	95% H-UCL					18.08	90% Chebyshev (MVUE) UCL					17.89
64	95% Chebyshev (MVUE) UCL					21.29	97.5% Chebyshev (MVUE) UCL					26.01
65	99% Chebyshev (MVUE) UCL					35.27						
66												
67	Nonparametric Distribution Free UCL Statistics											
68	Data do not follow a Discernible Distribution (0.05)											
69												
70	Nonparametric Distribution Free UCLs											
71	95% CLT UCL					21.87	95% Jackknife UCL					22.05
72	95% Standard Bootstrap UCL					21.83	95% Bootstrap-t UCL					31.22
73	95% Hall's Bootstrap UCL					52.75	95% Percentile Bootstrap UCL					22.37
74	95% BCA Bootstrap UCL					27.51						
75	90% Chebyshev(Mean, Sd) UCL					28.28	95% Chebyshev(Mean, Sd) UCL					34.71
76	97.5% Chebyshev(Mean, Sd) UCL					43.64	99% Chebyshev(Mean, Sd) UCL					61.18
77												
78	Suggested UCL to Use											
79	95% Chebyshev (Mean, Sd) UCL					34.71						
80												
81	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
82	Recommendations are based upon data size, data distribution, and skewness.											
83	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
84	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
85												
86												

Ra-226_S20			
General Statistics			
Total Number of Observations	16	Number of Distinct Observations	13
		Number of Missing Observations	2
Minimum	1.8	Mean	3.169
Maximum	7.8	Median	2.8
SD	1.443	Std. Error of Mean	0.361
Coefficient of Variation	0.455	Skewness	2.351
Normal GOF Test			
Shapiro Wilk Test Statistic	0.758	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.887	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.181	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.213	Data appear Normal at 5% Significance Level	
Data appear Approximate Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	3.801	95% Adjusted-CLT UCL (Chen-1995)	3.988
		95% Modified-t UCL (Johnson-1978)	3.836
Gamma GOF Test			
A-D Test Statistic	0.582	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.74	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.184	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.216	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	7.088	k star (bias corrected MLE)	5.801
Theta hat (MLE)	0.447	Theta star (bias corrected MLE)	0.546
nu hat (MLE)	226.8	nu star (bias corrected)	185.6
MLE Mean (bias corrected)	3.169	MLE Sd (bias corrected)	1.316
		Approximate Chi Square Value (0.05)	155.1
Adjusted Level of Significance	0.0335	Adjusted Chi Square Value	151.9
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	3.792	95% Adjusted Gamma UCL (use when n<50)	3.871
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.918	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.887	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.172	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.213	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	0.588	Mean of logged Data	1.081
Maximum of Logged Data	2.054	SD of logged Data	0.37
Assuming Lognormal Distribution			
95% H-UCL	3.797	90% Chebyshev (MVUE) UCL	4.032
95% Chebyshev (MVUE) UCL	4.434	97.5% Chebyshev (MVUE) UCL	4.993
99% Chebyshev (MVUE) UCL	6.091		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			

	A-E	F	G-K	L
146	Nonparametric Distribution Free UCLs			
147	95% CLT UCL	3.762	95% Jackknife UCL	3.801
148	95% Standard Bootstrap UCL	3.732	95% Bootstrap-t UCL	4.188
149	95% Hall's Bootstrap UCL	6.441	95% Percentile Bootstrap UCL	3.775
150	95% BCA Bootstrap UCL	3.988		
151	90% Chebyshev(Mean, Sd) UCL	4.251	95% Chebyshev(Mean, Sd) UCL	4.741
152	97.5% Chebyshev(Mean, Sd) UCL	5.421	99% Chebyshev(Mean, Sd) UCL	6.757
153				
154	Suggested UCL to Use			
155	95% Student's-t UCL	3.801		
156				
157	When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test			
158	When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL			
159				
160	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.			
161	Recommendations are based upon data size, data distribution, and skewness.			
162	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).			
163	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.			
164				
165				

Ra-226_S29

General Statistics			
Total Number of Observations	37	Number of Distinct Observations	18
		Number of Missing Observations	5
Minimum	1.17	Mean	1.903
Maximum	2.7	Median	1.8
SD	0.444	Std. Error of Mean	0.073
Coefficient of Variation	0.233	Skewness	0.489
Normal GOF Test			
Shapiro Wilk Test Statistic	0.919	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.936	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.131	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.144	Data appear Normal at 5% Significance Level	
Data appear Approximate Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.026	95% Adjusted-CLT UCL (Chen-1995)	2.029
		95% Modified-t UCL (Johnson-1978)	2.027
Gamma GOF Test			
A-D Test Statistic	0.699	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.747	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.125	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.145	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	19.42	k star (bias corrected MLE)	17.86
Theta hat (MLE)	0.098	Theta star (bias corrected MLE)	0.107
nu hat (MLE)	1437	nu star (bias corrected)	1322
MLE Mean (bias corrected)	1.903	MLE Sd (bias corrected)	0.45
		Approximate Chi Square Value (0.05)	1239
Adjusted Level of Significance	0.0431	Adjusted Chi Square Value	1235
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	2.031	95% Adjusted Gamma UCL (use when n<50)	2.037
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.945	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.936	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.117	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.144	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	0.157	Mean of logged Data	0.617
Maximum of Logged Data	0.993	SD of logged Data	0.23
Assuming Lognormal Distribution			
95% H-UCL	2.036	90% Chebyshev (MVUE) UCL	2.121
95% Chebyshev (MVUE) UCL	2.22	97.5% Chebyshev (MVUE) UCL	2.357
99% Chebyshev (MVUE) UCL	2.627		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			

	A	B	C	D	E	F	G	H	I	J	K	L
225	Nonparametric Distribution Free UCLs											
226					95% CLT UCL	2.023					95% Jackknife UCL	2.026
227					95% Standard Bootstrap UCL	2.02					95% Bootstrap-t UCL	2.028
228					95% Hall's Bootstrap UCL	2.022					95% Percentile Bootstrap UCL	2.017
229					95% BCA Bootstrap UCL	2.022						
230					90% Chebyshev(Mean, Sd) UCL	2.122					95% Chebyshev(Mean, Sd) UCL	2.221
231					97.5% Chebyshev(Mean, Sd) UCL	2.359					99% Chebyshev(Mean, Sd) UCL	2.629
232												
233	Suggested UCL to Use											
234					95% Student's-t UCL	2.026						
235												
236	When a data set follows an approximate (e.g., normal) distribution passing one of the GOF test											
237	When applicable, it is suggested to use a UCL based upon a distribution (e.g., gamma) passing both GOF tests in ProUCL											
238												
239	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
240	Recommendations are based upon data size, data distribution, and skewness.											
241	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
242	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
243												
244												

Ra-226_S30

General Statistics			
Total Number of Observations	50	Number of Distinct Observations	39
		Number of Missing Observations	5
Minimum	1.4	Mean	28.19
Maximum	319	Median	3.6
SD	57.23	Std. Error of Mean	8.094
Coefficient of Variation	2.03	Skewness	3.383
Normal GOF Test			
Shapiro Wilk Test Statistic	0.536	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.947	Data Not Normal at 5% Significance Level	
Lilliefors Test Statistic	0.32	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.125	Data Not Normal at 5% Significance Level	
Data Not Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	41.76	95% Adjusted-CLT UCL (Chen-1995)	45.64
		95% Modified-t UCL (Johnson-1978)	42.4
Gamma GOF Test			
A-D Test Statistic	4.809	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.818	Data Not Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.261	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.133	Data Not Gamma Distributed at 5% Significance Level	
Data Not Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	0.483	k star (bias corrected MLE)	0.467
Theta hat (MLE)	58.38	Theta star (bias corrected MLE)	60.33
nu hat (MLE)	48.28	nu star (bias corrected)	46.72
MLE Mean (bias corrected)	28.19	MLE Sd (bias corrected)	41.24
		Approximate Chi Square Value (0.05)	32.03
Adjusted Level of Significance	0.0452	Adjusted Chi Square Value	31.67
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	41.11	95% Adjusted Gamma UCL (use when n<50)	41.58
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.838	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.947	Data Not Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.227	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.125	Data Not Lognormal at 5% Significance Level	
Data Not Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	0.336	Mean of logged Data	2.016
Maximum of Logged Data	5.765	SD of logged Data	1.519
Assuming Lognormal Distribution			
95% H-UCL	45.32	90% Chebyshev (MVUE) UCL	42.23
95% Chebyshev (MVUE) UCL	51.07	97.5% Chebyshev (MVUE) UCL	63.33
99% Chebyshev (MVUE) UCL	87.43		
Nonparametric Distribution Free UCL Statistics			
Data do not follow a Discernible Distribution (0.05)			

	A	B	C	D	E	F	G	H	I	J	K	L
304	Nonparametric Distribution Free UCLs											
305	95% CLT UCL					41.5	95% Jackknife UCL					41.76
306	95% Standard Bootstrap UCL					41.7	95% Bootstrap-t UCL					50.12
307	95% Hall's Bootstrap UCL					50.83	95% Percentile Bootstrap UCL					43.29
308	95% BCA Bootstrap UCL					46.14						
309	90% Chebyshev(Mean, Sd) UCL					52.47	95% Chebyshev(Mean, Sd) UCL					63.47
310	97.5% Chebyshev(Mean, Sd) UCL					78.73	99% Chebyshev(Mean, Sd) UCL					108.7
311												
312	Suggested UCL to Use											
313	95% Chebyshev (Mean, Sd) UCL					63.47						
314												
315	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
316	Recommendations are based upon data size, data distribution, and skewness.											
317	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
318	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
319												
320												

Ra-226_S32

General Statistics			
Total Number of Observations	27	Number of Distinct Observations	22
		Number of Missing Observations	3
Minimum	1.34	Mean	2.655
Maximum	4.6	Median	2.4
SD	0.887	Std. Error of Mean	0.171
Coefficient of Variation	0.334	Skewness	0.537
Normal GOF Test			
Shapiro Wilk Test Statistic	0.947	**Shapiro Wilk GOF Test**	
5% Shapiro Wilk Critical Value	0.923	Data appear Normal at 5% Significance Level	
Lilliefors Test Statistic	0.137	**Lilliefors GOF Test**	
5% Lilliefors Critical Value	0.167	Data appear Normal at 5% Significance Level	
Data appear Normal at 5% Significance Level			
Assuming Normal Distribution			
95% Normal UCL		**95% UCLs (Adjusted for Skewness)**	
95% Student's-t UCL	2.946	95% Adjusted-CLT UCL (Chen-1995)	2.954
		95% Modified-t UCL (Johnson-1978)	2.949
Gamma GOF Test			
A-D Test Statistic	0.31	**Anderson-Darling Gamma GOF Test**	
5% A-D Critical Value	0.744	Detected data appear Gamma Distributed at 5% Significance Level	
K-S Test Statistic	0.107	**Kolmogorov-Smirnov Gamma GOF Test**	
5% K-S Critical Value	0.168	Detected data appear Gamma Distributed at 5% Significance Level	
Detected data appear Gamma Distributed at 5% Significance Level			
Gamma Statistics			
k hat (MLE)	9.44	k star (bias corrected MLE)	8.416
Theta hat (MLE)	0.281	Theta star (bias corrected MLE)	0.315
nu hat (MLE)	509.7	nu star (bias corrected)	454.4
MLE Mean (bias corrected)	2.655	MLE Sd (bias corrected)	0.915
		Approximate Chi Square Value (0.05)	406
Adjusted Level of Significance	0.0401	Adjusted Chi Square Value	403.1
Assuming Gamma Distribution			
95% Approximate Gamma UCL (use when n>=50))	2.971	95% Adjusted Gamma UCL (use when n<50)	2.993
Lognormal GOF Test			
Shapiro Wilk Test Statistic	0.968	**Shapiro Wilk Lognormal GOF Test**	
5% Shapiro Wilk Critical Value	0.923	Data appear Lognormal at 5% Significance Level	
Lilliefors Test Statistic	0.0863	**Lilliefors Lognormal GOF Test**	
5% Lilliefors Critical Value	0.167	Data appear Lognormal at 5% Significance Level	
Data appear Lognormal at 5% Significance Level			
Lognormal Statistics			
Minimum of Logged Data	0.293	Mean of logged Data	0.922
Maximum of Logged Data	1.526	SD of logged Data	0.337
Assuming Lognormal Distribution			
95% H-UCL	3.008	90% Chebyshev (MVUE) UCL	3.184
95% Chebyshev (MVUE) UCL	3.422	97.5% Chebyshev (MVUE) UCL	3.754
99% Chebyshev (MVUE) UCL	4.405		
Nonparametric Distribution Free UCL Statistics			
Data appear to follow a Discernible Distribution at 5% Significance Level			

	A	B	C	D	E	F	G	H	I	J	K	L
380	Nonparametric Distribution Free UCLs											
381					95% CLT UCL	2.936					95% Jackknife UCL	2.946
382					95% Standard Bootstrap UCL	2.93					95% Bootstrap-t UCL	2.979
383					95% Hall's Bootstrap UCL	2.953					95% Percentile Bootstrap UCL	2.925
384					95% BCA Bootstrap UCL	2.931						
385					90% Chebyshev(Mean, Sd) UCL	3.167					95% Chebyshev(Mean, Sd) UCL	3.399
386					97.5% Chebyshev(Mean, Sd) UCL	3.721					99% Chebyshev(Mean, Sd) UCL	4.353
387												
388	Suggested UCL to Use											
389					95% Student's-t UCL	2.946						
390												
391	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
392	Recommendations are based upon data size, data distribution, and skewness.											
393	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
394	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											
395												
396												

	A–E	F	G–K	L
397	Ra-226_S33			
398				
399		**General Statistics**		
400	Total Number of Observations	62	Number of Distinct Observations	32
401			Number of Missing Observations	7
402	Minimum	1.01	Mean	9.734
403	Maximum	134.6	Median	2.515
404	SD	24.02	Std. Error of Mean	3.05
405	Coefficient of Variation	2.468	Skewness	3.819
406				
407		**Normal GOF Test**		
408	Shapiro Wilk Test Statistic	0.376	**Shapiro Wilk GOF Test**	
409	5% Shapiro Wilk P Value	0	Data Not Normal at 5% Significance Level	
410	Lilliefors Test Statistic	0.469	**Lilliefors GOF Test**	
411	5% Lilliefors Critical Value	0.112	Data Not Normal at 5% Significance Level	
412		**Data Not Normal at 5% Significance Level**		
413				
414		**Assuming Normal Distribution**		
415	**95% Normal UCL**		**95% UCLs (Adjusted for Skewness)**	
416	95% Student's-t UCL	14.83	95% Adjusted-CLT UCL (Chen-1995)	16.33
417			95% Modified-t UCL (Johnson-1978)	15.08
418				
419		**Gamma GOF Test**		
420	A-D Test Statistic	13.84	**Anderson-Darling Gamma GOF Test**	
421	5% A-D Critical Value	0.805	Data Not Gamma Distributed at 5% Significance Level	
422	K-S Test Statistic	0.445	**Kolmogorov-Smirnov Gamma GOF Test**	
423	5% K-S Critical Value	0.119	Data Not Gamma Distributed at 5% Significance Level	
424		**Data Not Gamma Distributed at 5% Significance Level**		
425				
426		**Gamma Statistics**		
427	k hat (MLE)	0.612	k star (bias corrected MLE)	0.593
428	Theta hat (MLE)	15.9	Theta star (bias corrected MLE)	16.4
429	nu hat (MLE)	75.92	nu star (bias corrected)	73.58
430	MLE Mean (bias corrected)	9.734	MLE Sd (bias corrected)	12.64
431			Approximate Chi Square Value (0.05)	54.83
432	Adjusted Level of Significance	0.0461	Adjusted Chi Square Value	54.44
433				
434		**Assuming Gamma Distribution**		
435	95% Approximate Gamma UCL (use when n>=50))	13.06	95% Adjusted Gamma UCL (use when n<50)	13.16
436				
437		**Lognormal GOF Test**		
438	Shapiro Wilk Test Statistic	0.63	**Shapiro Wilk Lognormal GOF Test**	
439	5% Shapiro Wilk P Value	0	Data Not Lognormal at 5% Significance Level	
440	Lilliefors Test Statistic	0.346	**Lilliefors Lognormal GOF Test**	
441	5% Lilliefors Critical Value	0.112	Data Not Lognormal at 5% Significance Level	
442		**Data Not Lognormal at 5% Significance Level**		
443				

	A	B	C	D	E	F	G	H	I	J	K	L
444	**Lognormal Statistics**											
445	Minimum of Logged Data					0.00995	Mean of logged Data					1.27
446	Maximum of Logged Data					4.902	SD of logged Data					1.037
447												
448	**Assuming Lognormal Distribution**											
449	95% H-UCL					8.231	90% Chebyshev (MVUE) UCL					8.854
450	95% Chebyshev (MVUE) UCL					10.14	97.5% Chebyshev (MVUE) UCL					11.93
451	99% Chebyshev (MVUE) UCL					15.44						
452												
453	**Nonparametric Distribution Free UCL Statistics**											
454	**Data do not follow a Discernible Distribution (0.05)**											
455												
456	**Nonparametric Distribution Free UCLs**											
457	95% CLT UCL					14.75	95% Jackknife UCL					14.83
458	95% Standard Bootstrap UCL					14.73	95% Bootstrap-t UCL					18.63
459	95% Hall's Bootstrap UCL					15.2	95% Percentile Bootstrap UCL					14.88
460	95% BCA Bootstrap UCL					16.08						
461	90% Chebyshev(Mean, Sd) UCL					18.89	95% Chebyshev(Mean, Sd) UCL					23.03
462	97.5% Chebyshev(Mean, Sd) UCL					28.78	99% Chebyshev(Mean, Sd) UCL					40.09
463												
464	**Suggested UCL to Use**											
465	95% Chebyshev (Mean, Sd) UCL					23.03						
466												
467	Note: Suggestions regarding the selection of a 95% UCL are provided to help the user to select the most appropriate 95% UCL.											
468	Recommendations are based upon data size, data distribution, and skewness.											
469	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).											
470	However, simulations results will not cover all Real World data sets; for additional insight the user may want to consult a statistician.											

APPENDIX I

PRG CALCULATOR OUTPUT, DCGL AND RA-226 RISK CONTRIBUTION CALCULATIONS, AND RESRAD OUTPUT

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PRG CALCULATOR OUTPUT

Site-specific
Composite Worker Soil Inputs

Variable	Composite Worker Soil Default Value	Form-input Value
A (PEF Dispersion Constant)	16.2302	14.9421
B (PEF Dispersion Constant)	18.7762	17.9869
City (Climate Zone)	Default	Albuquerque, NM (3)
C (PEF Dispersion Constant)	216.108	205.1782
Cover thickness for GSF_o (gamma shielding factor) cm	0 cm	0 cm
F(x) (function dependent on U_m/U_t) unitless	0.194	0.0553
PEF (particulate emission factor) m^3/kg	1359344438	2370938158.760359
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	29.359877603759233
A_s (acres)	0.5	500
Site area for ACF (area correction factor) m^2	1000029 m^2	1000029 m^2
ED_w (exposure duration - composite worker) yr	25	25
EF_w (exposure frequency - composite worker) day/yr	250	250
ET_w (exposure time - composite worker) hr/day	8	0.8
IRA_w (inhalation rate - composite worker) m^3/day	60	60
IRS_w (soil intake rate - composite worker) mg/day	100	100
t_w (time - composite worker) yr	25	25
TR (target cancer risk) unitless	1.0E-06	1.0E-04
U_m (mean annual wind speed) m/s	4.69	4.02
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

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Site-specific
Composite Worker PRGs for Soil - Secular Equilibrium

Isotope	Ingestion PRG TR=0.0001 (pCi/g)	Inhalation PRG TR=0.0001 (pCi/g)	External Exposure PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (pCi/g)
Secular Equilibrium PRG for U-235	*2.91E+02*	*6.03E+04*	*7.51E+01*	*5.97E+01*
Secular Equilibrium PRG for U-238	*6.35E+01*	*1.31E+05*	*2.06E+01*	*1.56E+01*

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Site-specific
Composite Worker Individual Contribution PRGs for Soil - Secular Equilibrium

Isotope	Parent	Fractional Contribution of Progeny	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Adult Soil Ingestion Slope Factor (risk/pCi)	Particulate Emission Factor (m³/kg)	Lambda (1/yr)	Halflife (yr)
Secular Equilibrium PRG for U-235	***U-235***	-		-	-	-	-	-	-
Ac-227	U-235	1.00E+00	S	1.49E-07	1.98E-10	2.01E-10	2.37E+09	3.18E-02	2.18E+01
At-219	U-235	8.28E-07	-	0.00E+00	0.00E+00	0.00E+00	2.37E+09	3.90E+05	1.78E-06
Bi-211	U-235	1.00E+00	-	0.00E+00	1.90E-07	0.00E+00	2.37E+09	1.70E+05	4.07E-06
Bi-215	U-235	8.03E-07	-	0.00E+00	1.08E-06	0.00E+00	2.37E+09	4.79E+04	1.45E-05
Fr-223	U-235	1.38E-02	S	4.07E-11	1.35E-07	4.88E-12	2.37E+09	1.66E+04	4.19E-05
Pa-231	U-235	1.00E+00	F	7.62E-08	1.27E-07	1.54E-10	2.37E+09	2.12E-05	3.28E+04
Pb-211	U-235	1.00E+00	S	4.03E-11	2.91E-07	2.63E-13	2.37E+09	1.01E+04	6.87E-05
Po-211	U-235	2.76E-03	-	0.00E+00	3.76E-08	0.00E+00	2.37E+09	4.24E+07	1.64E-08
Po-215	U-235	1.00E+00	-	0.00E+00	7.48E-10	0.00E+00	2.37E+09	1.23E+10	5.65E-11
Ra-223	U-235	1.00E+00	S	2.92E-08	4.55E-07	1.23E-10	2.37E+09	2.21E+01	3.13E-02
Rn-219	U-235	1.00E+00	-	0.00E+00	2.35E-07	0.00E+00	2.37E+09	5.52E+06	1.26E-07
Th-227	U-235	9.86E-01	S	3.50E-08	4.45E-07	2.06E-11	2.37E+09	1.35E+01	5.12E-02
Th-231	U-235	1.00E+00	S	1.50E-12	2.49E-08	9.07E-13	2.37E+09	2.38E+02	2.91E-03
Tl-207	U-235	9.97E-01	-	0.00E+00	1.59E-08	0.00E+00	2.37E+09	7.64E+04	9.08E-06
U-235	U-235	1.00E+00	S	2.50E-08	5.51E-07	4.92E-11	2.37E+09	9.84E-10	7.04E+08
Secular Equilibrium PRG for U-238	***U-238***	-		-	-	-	-	-	-
At-218	U-238	2.00E-04	-	0.00E+00	2.74E-11	0.00E+00	2.37E+09	1.46E+07	4.76E-08
Bi-210	U-238	1.00E+00	S	4.55E-10	2.77E-09	3.74E-12	2.37E+09	5.05E+01	1.37E-02
Bi-214	U-238	1.00E+00	S	6.18E-11	7.34E-06	1.47E-13	2.37E+09	1.83E+04	3.79E-05
Hg-206	U-238	1.90E-08	-	0.00E+00	4.83E-07	0.00E+00	2.37E+09	4.47E+04	1.55E-05
Pa-234	U-238	1.60E-03	S	1.20E-12	6.62E-06	9.66E-13	2.37E+09	9.06E+02	7.65E-04
Pa-234m	U-238	1.00E+00	-	0.00E+00	9.06E-08	0.00E+00	2.37E+09	3.11E+05	2.23E-06
Pb-210	U-238	1.00E+00	S	1.59E-08	1.48E-09	5.99E-10	2.37E+09	3.12E-02	2.22E+01
Pb-214	U-238	1.00E+00	S	7.77E-11	9.94E-07	2.21E-13	2.37E+09	1.36E+04	5.10E-05
Po-210	U-238	1.00E+00	S	1.45E-08	4.51E-11	1.44E-09	2.37E+09	1.83E+00	3.79E-01
Po-214	U-238	1.00E+00	-	0.00E+00	3.85E-10	0.00E+00	2.37E+09	1.33E+11	5.21E-12
Po-218	U-238	1.00E+00	-	1.39E-11	6.84E-15	0.00E+00	2.37E+09	1.17E+05	5.90E-06
Ra-226	U-238	1.00E+00	S	2.82E-08	2.50E-08	2.95E-10	2.37E+09	4.33E-04	1.60E+03
Rn-218	U-238	2.00E-07	-	0.00E+00	3.39E-09	0.00E+00	2.37E+09	6.24E+08	1.11E-09
Rn-222	U-238	1.00E+00	-	2.28E-12	1.69E-09	0.00E+00	2.37E+09	6.62E+01	1.05E-02

Site-specific
Composite Worker Individual Contribution PRGs for Soil - Secular Equilibrium

Isotope	1000029 m² Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Ingestion PRG TR=0.0001 (pCi/g)	Inhalation PRG TR=0.0001 (pCi/g)	External Exposure PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (mg/kg)
Secular Equilibrium PRG for U-235	-	-	***2.91E+02***	***6.03E+04***	***7.51E+01***	***5.97E+01***	-
Ac-227	1.00E+00	1.00E+00	7.95E+02	1.27E+05	8.83E+05	**7.89E+02**	1.75E-11
At-219	9.00E-01	1.00E+00	-	-	-	**-**	-
Bi-211	1.00E+00	1.00E+00	-	-	9.21E+02	**9.21E+02**	2.61E-18
Bi-215	1.00E+00	1.00E+00	-	-	2.01E+08	**2.01E+08**	4.32E-23
Fr-223	1.00E+00	1.00E+00	2.37E+06	3.38E+10	9.37E+04	**9.02E+04**	2.90E-19
Pa-231	1.00E+00	1.00E+00	1.04E+03	2.49E+05	1.38E+03	**5.90E+02**	3.59E-08
Pb-211	1.00E+00	1.00E+00	6.09E+05	4.70E+08	6.03E+02	**6.02E+02**	6.74E-17
Po-211	1.00E+00	1.00E+00	-	-	1.69E+06	**1.69E+06**	5.73E-24
Po-215	1.00E+00	1.00E+00	-	-	2.34E+05	**2.34E+05**	1.45E-25
Ra-223	1.00E+00	1.00E+00	1.30E+03	6.50E+05	3.85E+02	**2.97E+02**	6.59E-14
Rn-219	1.00E+00	1.00E+00	-	-	7.47E+02	**7.47E+02**	1.03E-19
Th-227	1.00E+00	1.00E+00	7.87E+03	5.49E+05	3.99E+02	**3.80E+02**	8.56E-14
Th-231	1.00E+00	1.00E+00	1.77E+05	1.26E+10	7.04E+03	**6.77E+03**	2.78E-16
Tl-207	1.00E+00	1.00E+00	-	-	1.11E+04	**1.11E+04**	4.75E-19
U-235	1.00E+00	1.00E+00	3.25E+03	7.58E+05	3.18E+02	**2.89E+02**	1.60E-03
Secular Equilibrium PRG for U-238	-	-	***6.35E+01***	***1.31E+05***	***2.06E+01***	***1.56E+01***	-
At-218	9.00E-01	1.00E+00	-	-	3.55E+10	**3.55E+10**	8.18E-28
Bi-210	1.00E+00	1.00E+00	4.28E+04	4.17E+07	6.33E+04	**2.55E+04**	3.16E-16
Bi-214	1.00E+00	1.00E+00	1.09E+06	3.07E+08	2.39E+01	**2.39E+01**	9.51E-16
Hg-206	1.00E+00	1.00E+00	-	-	1.91E+10	**1.91E+10**	4.69E-25
Pa-234	1.00E+00	1.00E+00	1.04E+08	9.89E+12	1.65E+04	**1.65E+04**	3.03E-17
Pa-234m	1.00E+00	1.00E+00	-	-	1.93E+03	**1.93E+03**	7.54E-19
Pb-210	1.00E+00	1.00E+00	2.67E+02	1.19E+06	1.18E+05	**2.66E+02**	4.90E-11
Pb-214	1.00E+00	1.00E+00	7.26E+05	2.44E+08	1.76E+02	**1.76E+02**	1.73E-16
Po-210	1.00E+00	1.00E+00	1.11E+02	1.31E+06	3.89E+06	**1.11E+02**	2.00E-12
Po-214	1.00E+00	1.00E+00	-	-	4.55E+05	**4.55E+05**	6.86E-27
Po-218	9.00E-01	1.00E+00	-	1.36E+09	2.85E+10	**1.30E+09**	2.76E-24
Ra-226	1.00E+00	1.00E+00	5.43E+02	6.74E+05	7.01E+03	**5.04E+02**	2.01E-09
Rn-218	1.00E+00	1.00E+00	-	-	2.59E+11	**2.59E+11**	2.62E-30
Rn-222	1.00E+00	1.00E+00	-	8.32E+09	1.03E+05	**1.03E+05**	6.29E-17

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Site-specific

Composite Worker Individual Contribution PRGs for Soil - Secular Equilibrium

Isotope	Parent	Fractional Contribution of Progeny	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Adult Soil Ingestion Slope Factor (risk/pCi)	Particulate Emission Factor (m^3/kg)	Lambda (1/yr)	Halflife (yr)
Th-230	U-238	1.00E+00	F	3.41E-08	8.45E-10	7.73E-11	2.37E+09	9.19E-06	7.54E+04
Th-234	U-238	1.00E+00	S	3.08E-11	1.77E-08	9.51E-12	2.37E+09	1.05E+01	6.60E-02
Tl-206	U-238	1.34E-06	-	0.00E+00	6.11E-09	0.00E+00	2.37E+09	8.67E+04	7.99E-06
Tl-210	U-238	2.10E-04	-	0.00E+00	1.34E-05	0.00E+00	2.37E+09	2.80E+05	2.47E-06
U-234	U-238	1.00E+00	S	2.78E-08	2.53E-10	5.11E-11	2.37E+09	2.82E-06	2.46E+05
U-238	U-238	1.00E+00	S	2.36E-08	1.24E-10	4.66E-11	2.37E+09	1.55E-10	4.47E+09

Site-specific
Composite Worker Individual Contribution PRGs for Soil - Secular Equilibrium

Isotope	1000029 m² Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Ingestion PRG TR=0.0001 (pCi/g)	Inhalation PRG TR=0.0001 (pCi/g)	External Exposure PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (mg/kg)
Th-230	1.00E+00	1.00E+00	2.07E+03	5.57E+05	2.07E+05	**2.04E+03**	2.38E-08
Th-234	1.00E+00	1.00E+00	1.68E+04	6.16E+08	9.87E+03	**6.22E+03**	6.95E-15
Tl-206	1.00E+00	1.00E+00	-	-	2.14E+10	**2.14E+10**	2.15E-25
Tl-210	1.00E+00	1.00E+00	-	-	6.21E+04	**6.21E+04**	2.34E-20
U-234	1.00E+00	1.00E+00	3.13E+03	6.82E+05	6.91E+05	**3.11E+03**	5.18E-08
U-238	1.00E+00	1.00E+00	3.43E+03	8.02E+05	1.42E+06	**3.41E+03**	8.73E-04

Composite Worker Risk for Soil - Secular Equilibrium

Isotope	Ingestion Risk	Inhalation Risk	External Exposure Risk	Total Risk
Secular Equilibrium Risk for U-235	***1.37E-08***	***6.63E-11***	***5.32E-08***	***6.70E-08***
Secular Equilibrium Risk for U-238	***1.57E-06***	***7.63E-10***	***4.85E-06***	***6.42E-06***
*Total Risk	1.59E-06	8.29E-10	4.90E-06	**6.49E-06**

Isotope	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Adult Soil Ingestion Slope Factor (risk/pCi)	Concentration (pCi/g)	Particulate Emission Factor (m³/kg)	Lambda (1/yr)	Halflife (yr)	1000029 m² Soil Volume Area Correction Factor
Secular Equilibrium Risk for U-235		-	-	-	-	-	-	-	-
Ac-227	S	1.49E-07	1.98E-10	2.01E-10	0.04	2.37E+09	3.18E-02	2.18E+01	1.00E+00
At-219	-	0.00E+00	0.00E+00	0.00E+00	0.04	2.37E+09	3.90E+05	1.78E-06	9.00E-01
Bi-211	-	0.00E+00	1.90E-07	0.00E+00	0.04	2.37E+09	1.70E+05	4.07E-06	1.00E+00
Bi-215	-	0.00E+00	1.08E-06	0.00E+00	0.04	2.37E+09	4.79E+04	1.45E-05	1.00E+00
Fr-223	S	4.07E-11	1.35E-07	4.88E-12	0.04	2.37E+09	1.66E+04	4.19E-05	1.00E+00
Pa-231	F	7.62E-08	1.27E-07	1.54E-10	0.04	2.37E+09	2.12E-05	3.28E+04	1.00E+00
Pb-211	S	4.03E-11	2.91E-07	2.63E-13	0.04	2.37E+09	1.01E+04	6.87E-05	1.00E+00
Po-211	-	0.00E+00	3.76E-08	0.00E+00	0.04	2.37E+09	4.24E+07	1.64E-08	1.00E+00
Po-215	-	0.00E+00	7.48E-10	0.00E+00	0.04	2.37E+09	1.23E+10	5.65E-11	1.00E+00
Ra-223	S	2.92E-08	4.55E-07	1.23E-10	0.04	2.37E+09	2.21E+01	3.13E-02	1.00E+00
Rn-219	-	0.00E+00	2.35E-07	0.00E+00	0.04	2.37E+09	5.52E+06	1.26E-07	1.00E+00
Th-227	S	3.50E-08	4.45E-07	2.06E-11	0.04	2.37E+09	1.35E+01	5.12E-02	1.00E+00
Th-231	S	1.50E-12	2.49E-08	9.07E-13	0.04	2.37E+09	2.38E+02	2.91E-03	1.00E+00
Tl-207	-	0.00E+00	1.59E-08	0.00E+00	0.04	2.37E+09	7.64E+04	9.08E-06	1.00E+00
U-235	S	2.50E-08	5.51E-07	4.92E-11	0.04	2.37E+09	9.84E-10	7.04E+08	1.00E+00
Secular Equilibrium Risk for U-238		-	-	-	-	-	-	-	-
At-218	-	0.00E+00	2.74E-11	0.00E+00	1	2.37E+09	1.46E+07	4.76E-08	9.00E-01
Bi-210	S	4.55E-10	2.77E-09	3.74E-12	1	2.37E+09	5.05E+01	1.37E-02	1.00E+00
Bi-214	S	6.18E-11	7.34E-06	1.47E-13	1	2.37E+09	1.83E+04	3.79E-05	1.00E+00
Hg-206	-	0.00E+00	4.83E-07	0.00E+00	1	2.37E+09	4.47E+04	1.55E-05	1.00E+00
Pa-234	S	1.20E-12	6.62E-06	9.66E-13	1	2.37E+09	9.06E+02	7.65E-04	1.00E+00
Pa-234m	-	0.00E+00	9.06E-08	0.00E+00	1	2.37E+09	3.11E+05	2.23E-06	1.00E+00
Pb-210	S	1.59E-08	1.48E-09	5.99E-10	1	2.37E+09	3.12E-02	2.22E+01	1.00E+00
Pb-214	S	7.77E-11	9.94E-07	2.21E-13	1	2.37E+09	1.36E+04	5.10E-05	1.00E+00
Po-210	S	1.45E-08	4.51E-11	1.44E-09	1	2.37E+09	1.83E+00	3.79E-01	1.00E+00
Po-214	-	0.00E+00	3.85E-10	0.00E+00	1	2.37E+09	1.33E+11	5.21E-12	1.00E+00
Po-218	-	1.39E-11	6.84E-15	0.00E+00	1	2.37E+09	1.17E+05	5.90E-06	9.00E-01
Ra-226	S	2.82E-08	2.50E-08	2.95E-10	1	2.37E+09	4.33E-04	1.60E+03	1.00E+00
Rn-218	-	0.00E+00	3.39E-09	0.00E+00	1	2.37E+09	6.24E+08	1.11E-09	1.00E+00
Rn-222	-	2.28E-12	1.69E-09	0.00E+00	1	2.37E+09	6.62E+01	1.05E-02	1.00E+00

Composite Worker Individual Risk Contributions for Soil - Secular Equilibrium

Isotope	0 cm Soil Volume Gamma Shielding Factor	Ingestion CDI (pCi)	Inhalation CDI (pCi)	External Exposure CDI (pCi)	Ingestion Risk	Inhalation Risk	External Exposure Risk	Total Risk
****Secular Equilibrium Risk for U-235***	-	-	-	-	***1.37E-08***	***6.63E-11***	***5.32E-08***	***6.70E-08***
Ac-227	1.00E+00	2.50E+01	2.11E-04	2.28E-02	5.03E-09	3.15E-11	4.53E-12	**5.07E-09**
At-219	1.00E+00	2.50E+01	2.11E-04	2.05E-02	0.00E+00	0.00E+00	0.00E+00	**0.00E+00**
Bi-211	1.00E+00	2.50E+01	2.11E-04	2.28E-02	0.00E+00	0.00E+00	4.35E-09	**4.35E-09**
Bi-215	1.00E+00	2.50E+01	2.11E-04	2.28E-02	0.00E+00	0.00E+00	1.99E-14	**1.99E-14**
Fr-223	1.00E+00	2.50E+01	2.11E-04	2.28E-02	1.68E-12	1.18E-16	4.27E-11	**4.44E-11**
Pa-231	1.00E+00	2.50E+01	2.11E-04	2.28E-02	3.86E-09	1.61E-11	2.91E-09	**6.78E-09**
Pb-211	1.00E+00	2.50E+01	2.11E-04	2.28E-02	6.57E-12	8.51E-15	6.64E-09	**6.64E-09**
Po-211	1.00E+00	2.50E+01	2.11E-04	2.28E-02	0.00E+00	0.00E+00	2.37E-12	**2.37E-12**
Po-215	1.00E+00	2.50E+01	2.11E-04	2.28E-02	0.00E+00	0.00E+00	1.71E-11	**1.71E-11**
Ra-223	1.00E+00	2.50E+01	2.11E-04	2.28E-02	3.08E-09	6.16E-12	1.04E-08	**1.35E-08**
Rn-219	1.00E+00	2.50E+01	2.11E-04	2.28E-02	0.00E+00	0.00E+00	5.36E-09	**5.36E-09**
Th-227	1.00E+00	2.50E+01	2.11E-04	2.28E-02	5.08E-10	7.28E-12	1.00E-08	**1.05E-08**
Th-231	1.00E+00	2.50E+01	2.11E-04	2.28E-02	2.27E-11	3.17E-16	5.68E-10	**5.90E-10**
Tl-207	1.00E+00	2.50E+01	2.11E-04	2.28E-02	0.00E+00	0.00E+00	3.62E-10	**3.62E-10**
U-235	1.00E+00	2.50E+01	2.11E-04	2.28E-02	1.23E-09	5.27E-12	1.26E-08	**1.38E-08**
****Secular Equilibrium Risk for U-238***	-	-	-	-	***1.57E-06***	***7.63E-10***	***4.85E-06***	***6.42E-06***
At-218	1.00E+00	6.25E+02	5.27E-03	5.14E-01	0.00E+00	0.00E+00	2.82E-15	**2.82E-15**
Bi-210	1.00E+00	6.25E+02	5.27E-03	5.71E-01	2.34E-09	2.40E-12	1.58E-09	**3.92E-09**
Bi-214	1.00E+00	6.25E+02	5.27E-03	5.71E-01	9.20E-11	3.26E-13	4.19E-06	**4.19E-06**
Hg-206	1.00E+00	6.25E+02	5.27E-03	5.71E-01	0.00E+00	0.00E+00	5.24E-15	**5.24E-15**
Pa-234	1.00E+00	6.25E+02	5.27E-03	5.71E-01	9.66E-13	1.01E-17	6.05E-09	**6.05E-09**
Pa-234m	1.00E+00	6.25E+02	5.27E-03	5.71E-01	0.00E+00	0.00E+00	5.17E-08	**5.17E-08**
Pb-210	1.00E+00	6.25E+02	5.27E-03	5.71E-01	3.75E-07	8.37E-11	8.46E-10	**3.76E-07**
Pb-214	1.00E+00	6.25E+02	5.27E-03	5.71E-01	1.38E-10	4.10E-13	5.67E-07	**5.67E-07**
Po-210	1.00E+00	6.25E+02	5.27E-03	5.71E-01	8.97E-07	7.65E-11	2.57E-11	**8.97E-07**
Po-214	1.00E+00	6.25E+02	5.27E-03	5.71E-01	0.00E+00	0.00E+00	2.20E-10	**2.20E-10**
Po-218	1.00E+00	6.25E+02	5.27E-03	5.14E-01	0.00E+00	7.33E-14	3.51E-15	**7.68E-14**
Ra-226	1.00E+00	6.25E+02	5.27E-03	5.71E-01	1.84E-07	1.48E-10	1.43E-08	**1.98E-07**
Rn-218	1.00E+00	6.25E+02	5.27E-03	5.71E-01	0.00E+00	0.00E+00	3.87E-16	**3.87E-16**
Rn-222	1.00E+00	6.25E+02	5.27E-03	5.71E-01	0.00E+00	1.20E-14	9.66E-10	**9.66E-10**

Composite Worker Individual Risk Contributions for Soil - Secular Equilibrium

Isotope	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Adult Soil Ingestion Slope Factor (risk/pCi)	Concentration (pCi/g)	Particulate Emission Factor (m^3/kg)	Lambda (1/yr)	Halflife (yr)	1000029 m^2 Soil Volume Area Correction Factor
Th-230	F	3.41E-08	8.45E-10	7.73E-11	1	2.37E+09	9.19E-06	7.54E+04	1.00E+00
Th-234	S	3.08E-11	1.77E-08	9.51E-12	1	2.37E+09	1.05E+01	6.60E-02	1.00E+00
Tl-206	-	0.00E+00	6.11E-09	0.00E+00	1	2.37E+09	8.67E+04	7.99E-06	1.00E+00
Tl-210	-	0.00E+00	1.34E-05	0.00E+00	1	2.37E+09	2.80E+05	2.47E-06	1.00E+00
U-234	S	2.78E-08	2.53E-10	5.11E-11	1	2.37E+09	2.82E-06	2.46E+05	1.00E+00
U-238	S	2.36E-08	1.24E-10	4.66E-11	1	2.37E+09	1.55E-10	4.47E+09	1.00E+00

Site-specific

Composite Worker Individual Risk Contributions for Soil - Secular Equilibrium

Isotope	0 cm Soil Volume Gamma Shielding Factor	Ingestion CDI (pCi)	Inhalation CDI (pCi)	External Exposure CDI (pCi)	Ingestion Risk	Inhalation Risk	External Exposure Risk	Total Risk
Th-230	1.00E+00	6.25E+02	5.27E-03	5.71E-01	4.83E-08	1.80E-10	4.83E-10	**4.90E-08**
Th-234	1.00E+00	6.25E+02	5.27E-03	5.71E-01	5.94E-09	1.62E-13	1.01E-08	**1.61E-08**
Tl-206	1.00E+00	6.25E+02	5.27E-03	5.71E-01	0.00E+00	0.00E+00	4.67E-15	**4.67E-15**
Tl-210	1.00E+00	6.25E+02	5.27E-03	5.71E-01	0.00E+00	0.00E+00	1.61E-09	**1.61E-09**
U-234	1.00E+00	6.25E+02	5.27E-03	5.71E-01	3.19E-08	1.47E-10	1.45E-10	**3.22E-08**
U-238	1.00E+00	6.25E+02	5.27E-03	5.71E-01	2.91E-08	1.25E-10	7.06E-11	**2.93E-08**

Site-specific

Indoor Worker Soil Inputs

Variable	Indoor Worker Soil Default Value	Form-input Value
A (PEF Dispersion Constant)	16.2302	14.9421
B (PEF Dispersion Constant)	18.7762	17.9869
City (Climate Zone)	Default	Albuquerque, NM (3)
C (PEF Dispersion Constant)	216.108	205.1782
Cover thickness for GSF_h (gamma shielding factor) cm	0 cm	0 cm
F(x) (function dependent on U_m/U_t) unitless	0.194	0.0553
PEF (particulate emission factor) m^3/kg	1359344438	2370938158.760359
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	29.359877603759233
A_s (acres)	0.5	500
Site area for ACF (area correction factor) m^2	1000029 m^2	1000029 m^2
ED_{iw} (exposure duration - indoor worker) yr	25	25
EF_{iw} (exposure frequency - indoor worker) day/yr	250	250
ET_{iw} (exposure time - indoor worker) hr/day	8	0.8
GSF_i (indoor gamma shielding factor) unitless	0.4	0.7
t_{iw} (time - indoor worker) yr	25	25
TR (target cancer risk) unitless	1.0E-06	1.0E-04
U_m (mean annual wind speed) m/s	4.69	4.02
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

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Site-specific
Indoor Worker PRGs for Soil - Secular Equilibrium

Isotope	Ingestion PRG TR=0.0001 (pCi/g)	Inhalation PRG TR=0.0001 (pCi/g)	External Exposure PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (pCi/g)
Secular Equilibrium PRG for U-235	-	-	*1.07E+02*	*1.07E+02*
Secular Equilibrium PRG for U-238	-	-	*2.95E+01*	*2.95E+01*

Site-specific

Indoor Worker Individual Contribution PRGs for Soil - Secular Equilibrium

Isotope	Parent	Fractional Contribution of Progeny	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Adult Soil Ingestion Slope Factor (risk/pCi)	Particulate Emission Factor (m^3/kg)	Lambda (1/yr)	Halflife (yr)
Secular Equilibrium PRG for U-235	***U-235***	-		-	-	-	-	-	-
Ac-227	U-235	1.00E+00	S	1.49E-07	1.98E-10	2.01E-10	2.37E+09	3.18E-02	2.18E+01
At-219	U-235	8.28E-07	-	0.00E+00	0.00E+00	0.00E+00	2.37E+09	3.90E+05	1.78E-06
Bi-211	U-235	1.00E+00	-	0.00E+00	1.90E-07	0.00E+00	2.37E+09	1.70E+05	4.07E-06
Bi-215	U-235	8.03E-07	-	0.00E+00	1.08E-06	0.00E+00	2.37E+09	4.79E+04	1.45E-05
Fr-223	U-235	1.38E-02	S	4.07E-11	1.35E-07	4.88E-12	2.37E+09	1.66E+04	4.19E-05
Pa-231	U-235	1.00E+00	F	7.62E-08	1.27E-07	1.54E-10	2.37E+09	2.12E-05	3.28E+04
Pb-211	U-235	1.00E+00	S	4.03E-11	2.91E-07	2.63E-13	2.37E+09	1.01E+04	6.87E-05
Po-211	U-235	2.76E-03	-	0.00E+00	3.76E-08	0.00E+00	2.37E+09	4.24E+07	1.64E-08
Po-215	U-235	1.00E+00	-	0.00E+00	7.48E-10	0.00E+00	2.37E+09	1.23E+10	5.65E-11
Ra-223	U-235	1.00E+00	S	2.92E-08	4.55E-07	1.23E-10	2.37E+09	2.21E+01	3.13E-02
Rn-219	U-235	1.00E+00	-	0.00E+00	2.35E-07	0.00E+00	2.37E+09	5.52E+06	1.26E-07
Th-227	U-235	9.86E-01	S	3.50E-08	4.45E-07	2.06E-11	2.37E+09	1.35E+01	5.12E-02
Th-231	U-235	1.00E+00	S	1.50E-12	2.49E-08	9.07E-13	2.37E+09	2.38E+02	2.91E-03
Tl-207	U-235	9.97E-01	-	0.00E+00	1.59E-08	0.00E+00	2.37E+09	7.64E+04	9.08E-06
U-235	U-235	1.00E+00	S	2.50E-08	5.51E-07	4.92E-11	2.37E+09	9.84E-10	7.04E+08
Secular Equilibrium PRG for U-238	***U-238***	-		-	-	-	-	-	-
At-218	U-238	2.00E-04	-	0.00E+00	2.74E-11	0.00E+00	2.37E+09	1.46E+07	4.76E-08
Bi-210	U-238	1.00E+00	S	4.55E-10	2.77E-09	3.74E-12	2.37E+09	5.05E+01	1.37E-02
Bi-214	U-238	1.00E+00	S	6.18E-11	7.34E-06	1.47E-13	2.37E+09	1.83E+04	3.79E-05
Hg-206	U-238	1.90E-08	-	0.00E+00	4.83E-07	0.00E+00	2.37E+09	4.47E+04	1.55E-05
Pa-234	U-238	1.60E-03	S	1.20E-12	6.62E-06	9.66E-13	2.37E+09	9.06E+02	7.65E-04
Pa-234m	U-238	1.00E+00	-	0.00E+00	9.06E-08	0.00E+00	2.37E+09	3.11E+05	2.23E-06
Pb-210	U-238	1.00E+00	S	1.59E-08	1.48E-09	5.99E-10	2.37E+09	3.12E-02	2.22E+01
Pb-214	U-238	1.00E+00	S	7.77E-11	9.94E-07	2.21E-13	2.37E+09	1.36E+04	5.10E-05
Po-210	U-238	1.00E+00	S	1.45E-08	4.51E-11	1.44E-09	2.37E+09	1.83E+00	3.79E-01
Po-214	U-238	1.00E+00	-	0.00E+00	3.85E-10	0.00E+00	2.37E+09	1.33E+11	5.21E-12
Po-218	U-238	1.00E+00	-	1.39E-11	6.84E-15	0.00E+00	2.37E+09	1.17E+05	5.90E-06
Ra-226	U-238	1.00E+00	S	2.82E-08	2.50E-08	2.95E-10	2.37E+09	4.33E-04	1.60E+03
Rn-218	U-238	2.00E-07	-	0.00E+00	3.39E-09	0.00E+00	2.37E+09	6.24E+08	1.11E-09
Rn-222	U-238	1.00E+00	-	2.28E-12	1.69E-09	0.00E+00	2.37E+09	6.62E+01	1.05E-02

Isotope	1000029 m² Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Ingestion PRG TR=0.0001 (pCi/g)	Inhalation PRG TR=0.0001 (pCi/g)	External Exposure PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (mg/kg)
Secular Equilibrium PRG for U-235	-	-	-	-	-	***1.07E+02***	***1.07E+02***	-
Ac-227	1.00E+00	1.00E+00	7.00E-01	-	-	1.26E+06	**1.26E+06**	1.10E-14
At-219	9.00E-01	1.00E+00	7.00E-01	-	-	-	**-**	-
Bi-211	1.00E+00	1.00E+00	7.00E-01	-	-	1.32E+03	**1.32E+03**	1.83E-18
Bi-215	1.00E+00	1.00E+00	7.00E-01	-	-	2.88E+08	**2.88E+08**	3.03E-23
Fr-223	1.00E+00	1.00E+00	7.00E-01	-	-	1.34E+05	**1.34E+05**	1.95E-19
Pa-231	1.00E+00	1.00E+00	7.00E-01	-	-	1.97E+03	**1.97E+03**	1.08E-08
Pb-211	1.00E+00	1.00E+00	7.00E-01	-	-	8.61E+02	**8.61E+02**	4.71E-17
Po-211	1.00E+00	1.00E+00	7.00E-01	-	-	2.41E+06	**2.41E+06**	4.01E-24
Po-215	1.00E+00	1.00E+00	7.00E-01	-	-	3.34E+05	**3.34E+05**	1.02E-25
Ra-223	1.00E+00	1.00E+00	7.00E-01	-	-	5.50E+02	**5.50E+02**	3.56E-14
Rn-219	1.00E+00	1.00E+00	7.00E-01	-	-	1.07E+03	**1.07E+03**	7.22E-20
Th-227	1.00E+00	1.00E+00	7.00E-01	-	-	5.70E+02	**5.70E+02**	5.70E-14
Th-231	1.00E+00	1.00E+00	7.00E-01	-	-	1.01E+04	**1.01E+04**	1.87E-16
Tl-207	1.00E+00	1.00E+00	7.00E-01	-	-	1.58E+04	**1.58E+04**	3.33E-19
U-235	1.00E+00	1.00E+00	7.00E-01	-	-	4.54E+02	**4.54E+02**	1.02E-03
Secular Equilibrium PRG for U-238	-	-	-	-	-	***2.95E+01***	***2.95E+01***	-
At-218	9.00E-01	1.00E+00	7.00E-01	-	-	5.07E+10	**5.07E+10**	5.73E-28
Bi-210	1.00E+00	1.00E+00	7.00E-01	-	-	9.04E+04	**9.04E+04**	8.93E-17
Bi-214	1.00E+00	1.00E+00	7.00E-01	-	-	3.41E+01	**3.41E+01**	6.66E-16
Hg-206	1.00E+00	1.00E+00	7.00E-01	-	-	2.73E+10	**2.73E+10**	3.28E-25
Pa-234	1.00E+00	1.00E+00	7.00E-01	-	-	2.36E+04	**2.36E+04**	2.12E-17
Pa-234m	1.00E+00	1.00E+00	7.00E-01	-	-	2.76E+03	**2.76E+03**	5.28E-19
Pb-210	1.00E+00	1.00E+00	7.00E-01	-	-	1.69E+05	**1.69E+05**	7.73E-14
Pb-214	1.00E+00	1.00E+00	7.00E-01	-	-	2.52E+02	**2.52E+02**	1.21E-16
Po-210	1.00E+00	1.00E+00	7.00E-01	-	-	5.55E+06	**5.55E+06**	4.01E-17
Po-214	1.00E+00	1.00E+00	7.00E-01	-	-	6.50E+05	**6.50E+05**	4.81E-27
Po-218	9.00E-01	1.00E+00	7.00E-01	-	-	4.06E+10	**4.06E+10**	8.86E-26
Ra-226	1.00E+00	1.00E+00	7.00E-01	-	-	1.00E+04	**1.00E+04**	1.01E-10
Rn-218	1.00E+00	1.00E+00	7.00E-01	-	-	3.70E+11	**3.70E+11**	1.83E-30
Rn-222	1.00E+00	1.00E+00	7.00E-01	-	-	1.48E+05	**1.48E+05**	4.40E-17

Site-specific
Indoor Worker Individual Contribution PRGs for Soil - Secular Equilibrium

Isotope	Parent	Fractional Contribution of Progeny	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Adult Soil Ingestion Slope Factor (risk/pCi)	Particulate Emission Factor (m^3/kg)	Lambda (1/yr)	Halflife (yr)
Th-230	U-238	1.00E+00	F	3.41E-08	8.45E-10	7.73E-11	2.37E+09	9.19E-06	7.54E+04
Th-234	U-238	1.00E+00	S	3.08E-11	1.77E-08	9.51E-12	2.37E+09	1.05E+01	6.60E-02
Tl-206	U-238	1.34E-06	-	0.00E+00	6.11E-09	0.00E+00	2.37E+09	8.67E+04	7.99E-06
Tl-210	U-238	2.10E-04	-	0.00E+00	1.34E-05	0.00E+00	2.37E+09	2.80E+05	2.47E-06
U-234	U-238	1.00E+00	S	2.78E-08	2.53E-10	5.11E-11	2.37E+09	2.82E-06	2.46E+05
U-238	U-238	1.00E+00	S	2.36E-08	1.24E-10	4.66E-11	2.37E+09	1.55E-10	4.47E+09

Site-specific

Indoor Worker Individual Contribution PRGs for Soil - Secular Equilibrium

Isotope	1000029 m² Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Ingestion PRG TR=0.0001 (pCi/g)	Inhalation PRG TR=0.0001 (pCi/g)	External Exposure PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (mg/kg)
Th-230	1.00E+00	1.00E+00	7.00E-01	-	-	2.96E+05	**2.96E+05**	1.64E-10
Th-234	1.00E+00	1.00E+00	7.00E-01	-	-	1.41E+04	**1.41E+04**	3.07E-15
Tl-206	1.00E+00	1.00E+00	7.00E-01	-	-	3.06E+10	**3.06E+10**	1.51E-25
Tl-210	1.00E+00	1.00E+00	7.00E-01	-	-	8.88E+04	**8.88E+04**	1.64E-20
U-234	1.00E+00	1.00E+00	7.00E-01	-	-	9.88E+05	**9.88E+05**	1.63E-10
U-238	1.00E+00	1.00E+00	7.00E-01	-	-	2.02E+06	**2.02E+06**	1.47E-06

Site-specific

Indoor Worker Risk for Soil - Secular Equilibrium

Isotope	Ingestion Risk	Inhalation Risk	External Exposure Risk	Total Risk
Secular Equilibrium Risk for U-235	***-***	***-***	***3.73E-08***	***3.73E-08***
Secular Equilibrium Risk for U-238	***-***	***-***	***3.39E-06***	***3.39E-06***
*Total Risk	-	-	3.43E-06	**3.43E-06**

Isotope	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Adult Soil Ingestion Slope Factor (risk/pCi)	Concentration (pCi/g)	Particulate Emission Factor (m^3/kg)	Lambda (1/yr)	Halflife (yr)	1000029 m^2 Soil Volume Area Correction Factor
**Secular Equilibrium Risk for U-235*		-	-	-	-	-	-	-	-
Ac-227	S	1.49E-07	1.98E-10	2.01E-10	0.04	2.37E+09	3.18E-02	2.18E+01	1.00E+00
At-219	-	0.00E+00	0.00E+00	0.00E+00	0.04	2.37E+09	3.90E+05	1.78E-06	9.00E-01
Bi-211	-	0.00E+00	1.90E-07	0.00E+00	0.04	2.37E+09	1.70E+05	4.07E-06	1.00E+00
Bi-215	-	0.00E+00	1.08E-06	0.00E+00	0.04	2.37E+09	4.79E+04	1.45E-05	1.00E+00
Fr-223	S	4.07E-11	1.35E-07	4.88E-12	0.04	2.37E+09	1.66E+04	4.19E-05	1.00E+00
Pa-231	F	7.62E-08	1.27E-07	1.54E-10	0.04	2.37E+09	2.12E-05	3.28E+04	1.00E+00
Pb-211	S	4.03E-11	2.91E-07	2.63E-13	0.04	2.37E+09	1.01E+04	6.87E-05	1.00E+00
Po-211	-	0.00E+00	3.76E-08	0.00E+00	0.04	2.37E+09	4.24E+07	1.64E-08	1.00E+00
Po-215	-	0.00E+00	7.48E-10	0.00E+00	0.04	2.37E+09	1.23E+10	5.65E-11	1.00E+00
Ra-223	S	2.92E-08	4.55E-07	1.23E-10	0.04	2.37E+09	2.21E+01	3.13E-02	1.00E+00
Rn-219	-	0.00E+00	2.35E-07	0.00E+00	0.04	2.37E+09	5.52E+06	1.26E-07	1.00E+00
Th-227	S	3.50E-08	4.45E-07	2.06E-11	0.04	2.37E+09	1.35E+01	5.12E-02	1.00E+00
Th-231	S	1.50E-12	2.49E-08	9.07E-13	0.04	2.37E+09	2.38E+02	2.91E-03	1.00E+00
Tl-207	-	0.00E+00	1.59E-08	0.00E+00	0.04	2.37E+09	7.64E+04	9.08E-06	1.00E+00
U-235	S	2.50E-08	5.51E-07	4.92E-11	0.04	2.37E+09	9.84E-10	7.04E+08	1.00E+00
**Secular Equilibrium Risk for U-238*		-	-	-	-	-	-	-	-
At-218	-	0.00E+00	2.74E-11	0.00E+00	1	2.37E+09	1.46E+07	4.76E-08	9.00E-01
Bi-210	S	4.55E-10	2.77E-09	3.74E-12	1	2.37E+09	5.05E+01	1.37E-02	1.00E+00
Bi-214	S	6.18E-11	7.34E-06	1.47E-13	1	2.37E+09	1.83E+04	3.79E-05	1.00E+00
Hg-206	-	0.00E+00	4.83E-07	0.00E+00	1	2.37E+09	4.47E+04	1.55E-05	1.00E+00
Pa-234	S	1.20E-12	6.62E-06	9.66E-13	1	2.37E+09	9.06E+02	7.65E-04	1.00E+00
Pa-234m	-	0.00E+00	9.06E-08	0.00E+00	1	2.37E+09	3.11E+05	2.23E-06	1.00E+00
Pb-210	S	1.59E-08	1.48E-09	5.99E-10	1	2.37E+09	3.12E-02	2.22E+01	1.00E+00
Pb-214	S	7.77E-11	9.94E-07	2.21E-13	1	2.37E+09	1.36E+04	5.10E-05	1.00E+00
Po-210	S	1.45E-08	4.51E-11	1.44E-09	1	2.37E+09	1.83E+00	3.79E-01	1.00E+00
Po-214	-	0.00E+00	3.85E-10	0.00E+00	1	2.37E+09	1.33E+11	5.21E-12	1.00E+00
Po-218	-	1.39E-11	6.84E-15	0.00E+00	1	2.37E+09	1.17E+05	5.90E-06	9.00E-01
Ra-226	S	2.82E-08	2.50E-08	2.95E-10	1	2.37E+09	4.33E-04	1.60E+03	1.00E+00
Rn-218	-	0.00E+00	3.39E-09	0.00E+00	1	2.37E+09	6.24E+08	1.11E-09	1.00E+00
Rn-222	-	2.28E-12	1.69E-09	0.00E+00	1	2.37E+09	6.62E+01	1.05E-02	1.00E+00

Site-specific

Indoor Worker Individual Risk Contributions for Soil - Secular Equilibrium

Isotope	0 cm Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Ingestion CDI (pCi)	Inhalation CDI (pCi)	External Exposure CDI (pCi)	Ingestion Risk	Inhalation Risk	External Exposure Risk	Total Risk
Secular Equilibrium Risk for U-235	**-**	**-**	**-**	**-**	**-**	**-**	**-**	***3.73E-08***	***3.73E-08***
Ac-227	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	3.17E-12	**3.17E-12**
At-219	1.00E+00	7.00E-01	-	-	1.44E-02	-	-	0.00E+00	**0.00E+00**
Bi-211	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	3.04E-09	**3.04E-09**
Bi-215	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	1.39E-14	**1.39E-14**
Fr-223	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	2.99E-11	**2.99E-11**
Pa-231	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	2.03E-09	**2.03E-09**
Pb-211	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	4.65E-09	**4.65E-09**
Po-211	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	1.66E-12	**1.66E-12**
Po-215	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	1.20E-11	**1.20E-11**
Ra-223	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	7.28E-09	**7.28E-09**
Rn-219	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	3.75E-09	**3.75E-09**
Th-227	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	7.01E-09	**7.01E-09**
Th-231	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	3.97E-10	**3.97E-10**
Tl-207	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	2.53E-10	**2.53E-10**
U-235	1.00E+00	7.00E-01	-	-	1.60E-02	-	-	8.81E-09	**8.81E-09**
Secular Equilibrium Risk for U-238	**-**	**-**	**-**	**-**	**-**	**-**	**-**	***3.39E-06***	***3.39E-06***
At-218	1.00E+00	7.00E-01	-	-	3.60E-01	-	-	1.97E-15	**1.97E-15**
Bi-210	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	1.11E-09	**1.11E-09**
Bi-214	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	2.93E-06	**2.93E-06**
Hg-206	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	3.67E-15	**3.67E-15**
Pa-234	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	4.23E-09	**4.23E-09**
Pa-234m	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	3.62E-08	**3.62E-08**
Pb-210	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	5.92E-10	**5.92E-10**
Pb-214	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	3.97E-07	**3.97E-07**
Po-210	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	1.80E-11	**1.80E-11**
Po-214	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	1.54E-10	**1.54E-10**
Po-218	1.00E+00	7.00E-01	-	-	3.60E-01	-	-	2.46E-15	**2.46E-15**
Ra-226	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	9.98E-09	**9.98E-09**
Rn-218	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	2.71E-16	**2.71E-16**
Rn-222	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	6.76E-10	**6.76E-10**

Indoor Worker Individual Risk Contributions for Soil - Secular Equilibrium

Isotope	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Adult Soil Ingestion Slope Factor (risk/pCi)	Concentration (pCi/g)	Particulate Emission Factor (m^3/kg)	Lambda (1/yr)	Halflife (yr)	1000029 m^2 Soil Volume Area Correction Factor
Th-230	F	3.41E-08	8.45E-10	7.73E-11	1	2.37E+09	9.19E-06	7.54E+04	1.00E+00
Th-234	S	3.08E-11	1.77E-08	9.51E-12	1	2.37E+09	1.05E+01	6.60E-02	1.00E+00
Tl-206	-	0.00E+00	6.11E-09	0.00E+00	1	2.37E+09	8.67E+04	7.99E-06	1.00E+00
Tl-210	-	0.00E+00	1.34E-05	0.00E+00	1	2.37E+09	2.80E+05	2.47E-06	1.00E+00
U-234	S	2.78E-08	2.53E-10	5.11E-11	1	2.37E+09	2.82E-06	2.46E+05	1.00E+00
U-238	S	2.36E-08	1.24E-10	4.66E-11	1	2.37E+09	1.55E-10	4.47E+09	1.00E+00

Site-specific

Indoor Worker Individual Risk Contributions for Soil - Secular Equilibrium

Isotope	0 cm Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Ingestion CDI (pCi)	Inhalation CDI (pCi)	External Exposure CDI (pCi)	Ingestion Risk	Inhalation Risk	External Exposure Risk	Total Risk
Th-230	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	3.38E-10	**3.38E-10**
Th-234	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	7.09E-09	**7.09E-09**
Tl-206	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	3.27E-15	**3.27E-15**
Tl-210	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	1.13E-09	**1.13E-09**
U-234	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	1.01E-10	**1.01E-10**
U-238	1.00E+00	7.00E-01	-	-	4.00E-01	-	-	4.95E-11	**4.95E-11**

Site-specific
Farmer Soil Inputs

Variable	Farmer Soil Default Value	Form-input Value
A (PEF Dispersion Constant)	16.2302	14.9421
B (PEF Dispersion Constant)	18.7762	17.9869
City (Climate Zone)	Default	Albuquerque, NM (3)
Climate zone	Temperate	Temperate
C (PEF Dispersion Constant)	216.108	205.1782
Cover thickness for GSF_{a} (gamma shielding factor) cm	0 cm	0 cm
Cover thickness for GSF_{b} (gamma shielding factor) cm	0 cm	0 cm
$CF_{far-produce}$ (contaminated plant fraction) unitless	1	1
$CF_{far-apple}$ (contaminated apple fraction) unitless	1	1
$CF_{far-asparagus}$ (contaminated asparagus fraction) unitless	1	1
$CF_{far-beef}$ (beef contaminated fraction) unitless	1	.48
$CF_{far-berry}$ (contaminated berry fraction) unitless	1	1
$CF_{far-broccoli}$ (contaminated broccoli fraction) unitless	1	1
$CF_{far-beet}$ (contaminated beet fraction) unitless	1	1
$CF_{far-cabbage}$ (contaminated cabbage fraction) unitless	1	1
$CF_{far-cereal grain}$ (contaminated cereal grain fraction) unitless	1	1
$CF_{far-citrus}$ (contaminated citrus fraction) unitless	1	1
$CF_{far-corn}$ (contaminated corn fraction) unitless	1	1
$CF_{far-carrot}$ (contaminated carrot fraction) unitless	1	1
$CF_{far-cucumber}$ (contaminated cucumber fraction) unitless	1	1
$CF_{far-dairy}$ (dairy contaminated fraction) unitless	1	1
$CF_{far-egg}$ (egg contaminated fraction) unitless	1	1
$CF_{far-fish}$ (fish contaminated fraction) unitless	1	1
$CF_{far-goat milk}$ (goat milk contaminated fraction) unitless	1	1
$CF_{far-goat meat}$ (goat meat contaminated fraction) unitless	1	1
$CF_{far-lettuce}$ (contaminated lettuce fraction) unitless	1	1
$CF_{far-lima bean}$ (contaminated lima bean fraction) unitless	1	1
$CF_{far-okra}$ (contaminated okra fraction) unitless	1	1
$CF_{far-onion}$ (contaminated onion fraction) unitless	1	1
$CF_{far-poultry}$ (poultry contaminated fraction unitless)	1	1
$CF_{far-peach}$ (contaminated peach fraction) unitless	1	1
$CF_{far-pea}$ (contaminated pea fraction) unitless	1	1

Site-specific

Farmer Soil Inputs

Variable	Farmer Soil Default Value	Form-input Value
$CF_{far-pear}$ (contaminated pear fraction) unitless	1	1
$CF_{far-potato}$ (contaminated potato fraction) unitless	1	1
$CF_{far-pumpkin}$ (contaminated pumpkin fraction) unitless	1	1
$CF_{far-rice}$ (contaminated rice fraction) unitless	1	1
$CF_{far-sheep}$ (sheep contaminated fraction) unitless	1	1
$CF_{far-sheep\ milk}$ (sheep milk contaminated fraction) unitless	1	1
$CF_{far-snap\ bean}$ (contaminated snap bean fraction) unitless	1	1
$CF_{far-strawberry}$ (contaminated strawberry fraction) unitless	1	1
$CF_{far-swine}$ (swine contaminated fraction) unitless	1	1
$CF_{far-tomato}$ (contaminated tomato fraction) unitless	1	1
ED_{far} (exposure duration - farmer) yr	40	25
ED_{far-a} (exposure duration - farmer adult) yr	34	25
ED_{far-c} (exposure duration - farmer child) yr	6	0
EF_{far-a} (exposure frequency - farmer adult) day/yr	350	350
EF_{far-c} (exposure frequency - farmer child) day/yr	350	350
$IFAP_{far-adj}$ (age-adjusted apple ingestion factor) g	1182020	741125
$IFAS_{far-adj}$ (age-adjusted asparagus ingestion factor) g	492870	343874.99999999994
$IFB_{far-adj}$ (age-adjusted beef ingestion factor) g	2098950	1446375
$IFBE_{far-adj}$ (age-adjusted berry ingestion factor) g	471450	309750
$IFBR_{far-adj}$ (age-adjusted broccoli ingestion factor) g	450310	308874.99999999994
$IFBT_{far-adj}$ (age-adjusted beet ingestion factor) g	411600	296625
$IFCB_{far-adj}$ (age-adjusted cabbage ingestion factor) g	1043980	749875
$IFCG_{far-adj}$ (age-adjusted cereal grain ingestion factor) g	1190210	1190210
$IFCI_{far-adj}$ (age-adjusted citrus ingestion factor) g	4090100	2707249.9999999995
$IFCO_{far-adj}$ (age-adjusted corn ingestion factor) g	1044470	717500
$IFCR_{far-adj}$ (age-adjusted carrot ingestion factor) g	318290	213500
$IFCU_{far-adj}$ (age-adjusted cucumber ingestion factor) g	688800	480375
$IFD_{far-adj}$ (age-adjusted dairy ingestion factor) g	10138030	5918500
$IFE_{far-adj}$ (age-adjusted egg ingestion factor) g	775810	521500
$IFFI_{far-adj}$ (age-adjusted fish ingestion factor) g	10018960	7278250
$IFLE_{far-adj}$ (age-adjusted lettuce ingestion factor) g	455070	328125
$IFLI_{far-adj}$ (age-adjusted lima bean ingestion factor) g	415870	295749.99999999994

Variable	Farmer Soil Default Value	Form-input Value
$IFOK_{far-adj}$ (age-adjusted okra ingestion factor) g	370510	264250
$IFON_{far-adj}$ (age-adjusted onion ingestion factor) g	338800	238000
$IFP_{far-adj}$ (age-adjusted poultry ingestion factor) g	1376550	939750
$IFPC_{far-adj}$ (age-adjusted peach ingestion factor) g	1435420	902125
$IFPE_{far-adj}$ (age-adjusted pea ingestion factor) g	437500	277375
$IFPR_{far-adj}$ (age-adjusted pear ingestion factor) g	874300	524125
$IFPT_{far-adj}$ (age-adjusted potato ingestion factor) g	1807750	1240750.0000000002
$IFPU_{far-adj}$ (age-adjusted pumpkin ingestion factor) g	866040	567000
$IFRI_{far-adj}$ (age-adjusted rice ingestion factor) g	1126230	774375
$IFSN_{far-adj}$ (age-adjusted snap bean ingestion factor) g	702730	474250
$IFST_{far-adj}$ (age-adjusted strawberry ingestion factor) g	535080	354375
$IFSW_{far-adj}$ (age-adjusted swine ingestion factor) g	1171520	809375
$IFTO_{far-adj}$ (age-adjusted tomato ingestion factor) g	1194270	824250
$IRAP_{far-a}$ (apple ingestion rate - farmer adult) g/day	84.7	84.7
$IRAP_{far-c}$ (apple ingestion rate - farmer child) g/day	82.9	82.9
$IRAS_{far-a}$ (asparagus ingestion rate - farmer adult) g/day	39.3	39.3
$IRAS_{far-c}$ (asparagus ingestion rate - farmer child) g/day	12.0	12.0
IRB_{far-a} (beef ingestion rate - farmer adult) g/day	165.3	165.3
IRB_{far-c} (beef ingestion rate - farmer child) g/day	62.8	0
$IRBE_{far-a}$ (berry ingestion rate - farmer adult) g/day	35.4	35.4
$IRBE_{far-c}$ (berry ingestion rate - farmer child) g/day	23.9	23.9
$IRBR_{far-a}$ (broccoli ingestion rate - farmer adult) g/day	35.3	35.3
$IRBR_{far-c}$ (broccoli ingestion rate - farmer child) g/day	14.4	14.4
$IRBT_{far-a}$ (beet ingestion rate - farmer adult) g/day	33.9	33.9
$IRBT_{far-c}$ (beet ingestion rate - farmer child) g/day	3.9	3.9
$IRCB_{far-a}$ (cabbage ingestion rate - farmer adult) g/day	85.7	85.7
$IRCB_{far-c}$ (cabbage ingestion rate - farmer child) g/day	11.5	11.5
$IRCG_{far-a}$ (cereal grain ingestion rate - farmer adult) g/day	91.9	91.9
$IRCG_{far-c}$ (cereal grain ingestion rate - farmer child) g/day	46.0	46.0
$IRCI_{far-a}$ (citrus ingestion rate - farmer adult) g/day	309.4	309.4
$IRCI_{far-c}$ (citrus ingestion rate - farmer child) g/day	194.4	194.4
$IRCO_{far-a}$ (corn ingestion rate - farmer adult) g/day	82.0	82.0

Variable	Farmer Soil Default Value	Form-input Value
$IRCO_{far-c}$ (corn ingestion rate - farmer child) g/day	32.7	32.7
$IRCR_{far-a}$ (carrot ingestion rate - farmer adult) g/day	24.4	24.4
$IRCR_{far-c}$ (carrot ingestion rate - farmer child) g/day	13.3	13.3
$IRCU_{far-a}$ (cucumber ingestion rate - farmer adult) g/day	54.9	54.9
$IRCU_{far-c}$ (cucumber ingestion rate - farmer child) g/day	16.9	16.9
IRD_{far-a} (dairy ingestion rate - farmer adult) g/day	676.4	676.4
IRD_{far-c} (dairy ingestion rate - farmer child) g/day	994.7	994.7
IRE_{far-a} (egg ingestion rate - farmer adult) g/day	59.6	59.6
IRE_{far-c} (egg ingestion rate - farmer child) g/day	31.7	31.7
$IRFI_{far-a}$ (fish ingestion rate - farmer adult) g/day	831.8	831.8
$IRFI_{far-c}$ (fish ingestion rate - farmer child) g/day	57.4	57.4
$IRLE_{far-a}$ (lettuce ingestion rate - farmer adult) g/day	37.5	37.5
$IRLE_{far-c}$ (lettuce ingestion rate - farmer child) g/day	4.2	4.2
$IRLI_{far-a}$ (lima bean ingestion rate - farmer adult) g/day	33.8	33.8
$IRLI_{far-c}$ (lima bean ingestion rate - farmer child) g/day	6.5	6.5
$IROK_{far-a}$ (okra ingestion rate - farmer adult) g/day	30.2	30.2
$IROK_{far-c}$ (okra ingestion rate - farmer child) g/day	5.3	5.3
$IRON_{far-a}$ (onion ingestion rate - farmer adult) g/day	27.2	27.2
$IRON_{far-c}$ (onion ingestion rate - farmer child) g/day	7.2	7.2
IRP_{far-a} (poultry ingestion rate - farmer adult) g/day	107.4	107.4
IRP_{far-c} (poultry ingestion rate - farmer child) g/day	46.9	46.9
$IRPC_{far-a}$ (peach ingestion rate - farmer adult) g/day	103.1	103.1
$IRPC_{far-c}$ (peach ingestion rate - farmer child) g/day	99.3	99.3
$IRPE_{far-a}$ (pea ingestion rate - farmer adult) g/day	31.7	31.7
$IRPE_{far-c}$ (pea ingestion rate - farmer child) g/day	28.7	28.7
$IRPR_{far-a}$ (pear ingestion rate - farmer adult) g/day	59.9	59.9
$IRPR_{far-c}$ (pear ingestion rate - farmer child) g/day	76.9	76.9
$IRPT_{far-a}$ (potato ingestion rate - farmer adult) g/day	141.8	141.8
$IRPT_{far-c}$ (potato ingestion rate - farmer child) g/day	57.3	57.3
$IRPU_{far-a}$ (pumpkin ingestion rate - farmer adult) g/day	64.8	64.8
$IRPU_{far-c}$ (pumpkin ingestion rate - farmer child) g/day	45.2	45.2
$IRRI_{far-a}$ (rice ingestion rate - farmer adult) g/day	88.5	88.5

Variable	Farmer Soil Default Value	Form-input Value
$IRRI_{far\text{-}c}$ (rice ingestion rate - farmer child) g/day	34.8	34.8
$IRSN_{far\text{-}a}$ (snap bean ingestion rate - farmer adult) g/day	54.2	54.2
$IRSN_{far\text{-}c}$ (snap bean ingestion rate - farmer child) g/day	27.5	27.5
$IRST_{far\text{-}a}$ (strawberry ingestion rate - farmer adult) g/day	40.5	40.5
$IRST_{far\text{-}c}$ (strawberry ingestion rate - farmer child) g/day	25.3	25.3
$IRSW_{far\text{-}a}$ (swine ingestion rate - farmer adult) g/day	92.5	92.5
$IRSW_{far\text{-}c}$ (swine ingestion rate - farmer child) g/day	33.7	33.7
$IRTO_{far\text{-}a}$ (tomato ingestion rate - farmer adult) g/day	94.2	94.2
$IRTO_{far\text{-}c}$ (tomato ingestion rate - farmer child) g/day	34.9	34.9
MLF_{apple} (apple mass loading factor) unitless	0.000160	0.000160
$MLF_{asparagus}$ (asparagus mass loading factor) unitless	0.0000790	0.0000790
MLF_{berry} (berry mass loading factor) unitless	0.000166	0.000166
$MLF_{broccoli}$ (broccoli mass loading factor) unitless	0.00101	0.00101
MLF_{beet} (beet mass loading factor) unitless	0.000138	0.000138
$MLF_{cabbage}$ (cabbage mass loading factor) unitless	0.000105	0.000105
$MLF_{cereal\ grain}$ (cereal grain mass loading factor) unitless	0.250	0.250
MLF_{citrus} (citrus mass loading factor) unitless	0.000157	0.000157
MLF_{corn} (corn mass loading factor) unitless	0.000145	0.000145
MLF_{carrot} (carrot mass loading factor) unitless	0.0000970	0.0000970
$MLF_{cucumber}$ (cucumber mass loading factor) unitless	0.0000400	0.0000400
$MLF_{lettuce}$ (lettuce mass loading factor) unitless	0.0135	0.0135
$MLF_{lima\ bean}$ (lima bean mass loading factor) unitless	0.00383	0.00383
MLF_{okra} (okra mass loading factor) unitless	0.0000800	0.0000800
MLF_{onion} (onion mass loading factor) unitless	0.0000970	0.0000970
MLF_{peach} (peach mass loading factor) unitless	0.000150	0.000150
MLF_{pea} (pea mass loading factor) unitless	0.000178	0.000178
MLF_{pear} (pear mass loading factor) unitless	0.000160	0.000160
MLF_{potato} (potato mass loading factor) unitless	0.000210	0.000210
$MLF_{pumpkin}$ (pumpkin mass loading factor) unitless	0.0000580	0.0000580
MLF_{rice} (rice mass loading factor) unitless	0.250	0.250
$MLF_{snap\ bean}$ (snap bean mass loading factor) unitless	0.00500	0.00500
$MLF_{strawberry}$ (strawberry mass loading factor) unitless	0.0000800	0.0000800

Variable	Farmer Soil Default Value	Form-input Value
MLF_{tomato} (tomato mass loading factor) unitless	0.00159	0.00159
p_m (density of milk) kg/L	1.03	1.03
t_{far} (time - farmer) yr	40	25
TR (target cancer risk) unitless	1.0E-06	1.0E-04
F(x) (function dependent on U_m/U_t) unitless	0.194	0.0553
PEF (particulate emission factor) m^3/kg	1359344438	2370938158.760359
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	29.359877603759233
A_s (acres)	0.5	500
Slab size for ACF (area correction factor) m^2	1000029 m^2	1000029 m^2
ED_{far} (exposure duration - farmer) yr	40	25
ED_{far-a} (exposure duration - farmer adult) yr	34	25
ED_{far-c} (exposure duration - farmer child) yr	6	0
EF_{far} (exposure frequency) day/yr	350	350
EF_{far-a} (exposure frequency - farmer adult) day/yr	350	350
EF_{far-c} (exposure frequency - farmer child) day/yr	350	350
ET_{far} (exposure time - farmer) hr/day	24	24
ET_{far-a} (exposure time - farmer adult) hr/day	24	24
ET_{far-c} (exposure time - farmer child) hr/day	24	24
ET_{far-i} (indoor exposure time fraction) hr/day	10.008	0
ET_{far-o} (outdoor exposure time fraction) hr/day	12.168	0
f_{p-beef} (animal on-site fraction) unitless	1	.375
$f_{p-dairy}$ (animal on-site fraction) unitless	1	1
$f_{p-goat\ milk}$ (animal on-site fraction) unitless	1	1
f_{p-goat} (animal on-site fraction) unitless	1	1
$f_{p-poultry}$ (animal on-site fraction) unitless	1	1
$f_{p-sheep}$ (animal on-site fraction) unitless	1	1
$f_{p-sheep\ milk}$ (animal on-site fraction) unitless	1	1
$f_{p-swine}$ (animal on-site fraction) unitless	1	1
f_{s-beef} (fraction of year animal on site) unitless	1	1
$f_{s-dairy}$ (fraction of year animal on site) unitless	1	1
$f_{s-goat\ milk}$ (fraction of year animal on site) unitless	1	1
f_{s-goat} (fraction of year animal on site) unitless	1	1

Variable	Farmer Soil Default Value	Form-input Value
$f_{s\text{-}poultry}$ (fraction of year animal on site) unitless	1	1
$f_{s\text{-}sheep}$ (fraction of year animal on site) unitless	1	1
$f_{s\text{-}sheep\ milk}$ (fraction of year animal on site) unitless	1	1
$f_{s\text{-}swine}$ (fraction of year animal on site) unitless	1	1
GSF_i (gamma shielding factor - indoor)	0.4	0
$IFA_{far\text{-}adj}$ (age-adjusted soil inhalation factor) m^3	259000	0
$IFS_{far\text{-}adj}$ (age-adjusted soil ingestion factor) mg	1610000	0
$IRA_{far\text{-}a}$ (inhalation rate - farmer adult) m^3/day	20	0
$IRA_{far\text{-}c}$ (inhalation rate - farmer child) m^3/day	10	0
$IRS_{far\text{-}a}$ (soil ingestion rate - farmer adult) mg/day	100	0
$IRS_{far\text{-}c}$ (soil ingestion rate - farmer child) mg/day	200	0
$MLF_{pasture}$ (pasture plant mass loading factor) unitless	0.25	0.25
$Q_{p\text{-}beef}$ (beef fodder intake rate) kg/day	11.77	11.77
$Q_{p\text{-}dairy}$ (dairy fodder intake rate) kg/day	20.3	20.3
$Q_{p\text{-}goat\ milk}$ (goat milk fodder intake rate) kg/day	1.59	1.59
$Q_{p\text{-}goat}$ (goat fodder intake rate) kg/day	1.27	1.27
$Q_{p\text{-}poultry}$ (poultry fodder intake rate) kg/day	0.2	0.2
$Q_{p\text{-}sheep}$ (sheep fodder intake rate) kg/day	1.75	1.75
$Q_{p\text{-}sheep\ milk}$ (sheep milk fodder intake rate) kg/day	3.15	3.15
$Q_{p\text{-}swine}$ (swine fodder intake rate) kg/day	4.7	4.7
$Q_{s\text{-}beef}$ (beef soil intake rate) kg/day	0.5	0.5
$Q_{s\text{-}dairy}$ (dairy soil intake rate) kg/day	0.4	0.4
$Q_{s\text{-}goat\ milk}$ (goat milk soil intake rate) kg/day	0.29	0.29
$Q_{s\text{-}goat}$ (goat soil intake rate) kg/day	0.23	0.23
$Q_{s\text{-}poultry}$ (poultry soil intake rate) kg/day	0.022	0.022
$Q_{s\text{-}sheep}$ (sheep soil intake rate) kg/day	0.32	0.32
$Q_{s\text{-}sheep\ milk}$ (sheep milk soil intake rate) kg/day	0.57	0.57
$Q_{s\text{-}swine}$ (swine soil intake rate) kg/day	0.37	0.37
t_{far} (time - farmer) yr	40	25
TR (target cancer risk) unitless	1.0E-06	1.0E-04
Default	Default	Default
U_m (mean annual wind speed) m/s	4.69	4.02

Site-specific

Farmer Soil Inputs

Variable	Farmer Soil Default Value	Form-input Value
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

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Site-specific

Farmer PRGs for Soil - Secular Equilibrium

Isotope	Ingestion PRG TR=0.0001 (pCi/g)	Inhalation PRG TR=0.0001 (pCi/g)	External Exposure PRG TR=0.0001 (pCi/g)	Produce Consumption PRG TR=0.0001 (pCi/g)	Beef Consumption PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (pCi/g)
Secular Equilibrium PRG for U-235	-	-	-	-	*1.63E+02*	*1.63E+02*
Secular Equilibrium PRG for U-238	-	-	-	-	*8.42E+00*	*8.42E+00*

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Isotope	Parent	Fractional Contribution of Progeny	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Food Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor (risk/pCi)	Plant to Beef Transfer Factor (pCi/kg per pCi/d)	Particulate Emission Factor (m³/kg)	Lambda (1/yr)	Halflife (yr)	1000029 m² Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor
Secular Equilibrium PRG for U-235	***U-235***	-		-	-	-	-	-	-	-	-	-	-
Ac-227	U-235	1.00E+00	S	1.49E-07	1.98E-10	2.45E-10	2.90E-10	2.00E-05	2.37E+09	3.18E-02	2.18E+01	1.00E+00	1.00E+00
At-219	U-235	8.28E-07	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-02	2.37E+09	3.90E+05	1.78E-06	9.00E-01	1.00E+00
Bi-211	U-235	1.00E+00	-	0.00E+00	1.90E-07	0.00E+00	0.00E+00	2.00E-03	2.37E+09	1.70E+05	4.07E-06	1.00E+00	1.00E+00
Bi-215	U-235	8.03E-07	-	0.00E+00	1.08E-06	0.00E+00	0.00E+00	2.00E-03	2.37E+09	4.79E+04	1.45E-05	1.00E+00	1.00E+00
Fr-223	U-235	1.38E-02	S	4.07E-11	1.35E-07	1.01E-11	1.69E-11	3.00E-02	2.37E+09	1.66E+04	4.19E-05	1.00E+00	1.00E+00
Pa-231	U-235	1.00E+00	F	7.62E-08	1.27E-07	2.26E-10	2.98E-10	5.00E-06	2.37E+09	2.12E-05	3.28E+04	1.00E+00	1.00E+00
Pb-211	U-235	1.00E+00	S	4.03E-11	2.91E-07	5.81E-13	9.55E-13	7.00E-04	2.37E+09	1.01E+04	6.87E-05	1.00E+00	1.00E+00
Po-211	U-235	2.76E-03	-	0.00E+00	3.76E-08	0.00E+00	0.00E+00	5.00E-03	2.37E+09	4.24E+07	1.64E-08	1.00E+00	1.00E+00
Po-215	U-235	1.00E+00	-	0.00E+00	7.48E-10	0.00E+00	0.00E+00	5.00E-03	2.37E+09	1.23E+10	5.65E-11	1.00E+00	1.00E+00
Ra-223	U-235	1.00E+00	S	2.92E-08	4.55E-07	3.39E-10	5.99E-10	1.70E-03	2.37E+09	2.21E+01	3.13E-02	1.00E+00	1.00E+00
Rn-219	U-235	1.00E+00	-	0.00E+00	2.35E-07	0.00E+00	0.00E+00	0.00E+00	2.37E+09	5.52E+06	1.26E-07	1.00E+00	1.00E+00
Th-227	U-235	9.86E-01	S	3.50E-08	4.45E-07	7.03E-11	1.29E-10	2.30E-04	2.37E+09	1.35E+01	5.12E-02	1.00E+00	1.00E+00
Th-231	U-235	1.00E+00	S	1.50E-12	2.49E-08	3.22E-12	5.96E-12	2.30E-04	2.37E+09	2.38E+02	2.91E-03	1.00E+00	1.00E+00
Tl-207	U-235	9.97E-01	-	0.00E+00	1.59E-08	0.00E+00	0.00E+00	2.00E-02	2.37E+09	7.64E+04	9.08E-06	1.00E+00	1.00E+00
U-235	U-235	1.00E+00	S	2.50E-08	5.51E-07	9.44E-11	1.48E-10	3.90E-04	2.37E+09	9.84E-10	7.04E+08	1.00E+00	1.00E+00
Secular Equilibrium PRG for U-238	***U-238***	-		-	-	-	-	-	-	-	-	-	-
At-218	U-238	2.00E-04	-	0.00E+00	2.74E-11	0.00E+00	0.00E+00	1.00E-02	2.37E+09	1.46E+07	4.76E-08	9.00E-01	1.00E+00
Bi-210	U-238	1.00E+00	S	4.55E-10	2.77E-09	1.30E-11	2.40E-11	2.00E-03	2.37E+09	5.05E+01	1.37E-02	1.00E+00	1.00E+00
Bi-214	U-238	1.00E+00	S	6.18E-11	7.34E-06	2.65E-13	4.03E-13	2.00E-03	2.37E+09	1.83E+04	3.79E-05	1.00E+00	1.00E+00
Hg-206	U-238	1.90E-08	-	0.00E+00	4.83E-07	0.00E+00	0.00E+00	1.00E-02	2.37E+09	4.47E+04	1.55E-05	1.00E+00	1.00E+00
Pa-234	U-238	1.60E-03	S	1.20E-12	6.62E-06	3.00E-12	5.37E-12	5.00E-06	2.37E+09	9.06E+02	7.65E-04	1.00E+00	1.00E+00
Pa-234m	U-238	1.00E+00	-	0.00E+00	9.06E-08	0.00E+00	0.00E+00	5.00E-06	2.37E+09	3.11E+05	2.23E-06	1.00E+00	1.00E+00
Pb-210	U-238	1.00E+00	S	1.59E-08	1.48E-09	1.18E-09	1.72E-09	7.00E-04	2.37E+09	3.12E-02	2.22E+01	1.00E+00	1.00E+00
Pb-214	U-238	1.00E+00	S	7.77E-11	9.94E-07	4.85E-13	7.92E-13	7.00E-04	2.37E+09	1.36E+04	5.10E-05	1.00E+00	1.00E+00
Po-210	U-238	1.00E+00	S	1.45E-08	4.51E-11	2.25E-09	3.27E-09	5.00E-03	2.37E+09	1.83E+00	3.79E-01	1.00E+00	1.00E+00

Site-specific

Farmer Individual Contribution PRGs for Soil - Secular Equilibrium

Isotope	Total Indoor GSF Soil Volume	Dry Soil-to-plant transfer factor (pCi/g-fresh plant per pCi/g-dry soil)	K_d Distribution coefficient (L/kg)	Ingestion PRG TR=0.0001 (pCi/g)	Inhalation PRG TR=0.0001 (pCi/g)	External Exposure PRG TR=0.0001 (pCi/g)	Produce Consumption PRG TR=0.0001 (pCi/g)	Beef Consumption PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (mg/kg)
Secular Equilibrium PRG for U-235	-	-	-	-	-	-	-	***1.63E+02***	***1.63E+02***	-
Ac-227	0.00E+00	1.00E-01	1.70E+03	-	-	-	-	1.69E+04	**1.69E+04**	8.17E-13
At-219	0.00E+00	9.00E-01	1.00E+01	-	-	-	-	-	**-**	-
Bi-211	0.00E+00	5.00E-01	4.80E+02	-	-	-	-	-	**-**	-
Bi-215	0.00E+00	5.00E-01	4.80E+02	-	-	-	-	-	**-**	-
Fr-223	0.00E+00	1.00E-01	2.50E+02	-	-	-	-	1.99E+04	**1.99E+04**	1.31E-18
Pa-231	0.00E+00	1.00E-01	2.00E+03	-	-	-	-	7.37E+04	**7.37E+04**	2.88E-10
Pb-211	0.00E+00	1.26E-02	1.50E+02	-	-	-	-	2.63E+05	**2.63E+05**	1.54E-19
Po-211	0.00E+00	2.76E-04	2.10E+02	-	-	-	-	-	**-**	-
Po-215	0.00E+00	2.76E-04	2.10E+02	-	-	-	-	-	**-**	-
Ra-223	0.00E+00	1.95E-02	1.00E+00	-	-	-	-	1.82E+02	**1.82E+02**	1.08E-13
Rn-219	0.00E+00	0.00E+00	0.00E+00	-	-	-	-	-	**-**	-
Th-227	0.00E+00	2.41E-03	2.00E+01	-	-	-	-	6.94E+03	**6.94E+03**	4.69E-15
Th-231	0.00E+00	2.41E-03	2.00E+01	-	-	-	-	1.50E+05	**1.50E+05**	1.26E-17
Tl-207	0.00E+00	6.00E-01	1.50E+03	-	-	-	-	-	**-**	-
U-235	0.00E+00	7.13E-03	4.00E-01	-	-	-	-	2.96E+03	**2.96E+03**	1.56E-04
Secular Equilibrium PRG for U-238	-	-	-	-	-	-	-	***8.42E+00***	***8.42E+00***	-
At-218	0.00E+00	9.00E-01	1.00E+01	-	-	-	-	-	**-**	-
Bi-210	0.00E+00	5.00E-01	4.80E+02	-	-	-	-	1.58E+03	**1.58E+03**	5.11E-15
Bi-214	0.00E+00	5.00E-01	4.80E+02	-	-	-	-	7.76E+04	**7.76E+04**	2.92E-19
Hg-206	0.00E+00	1.00E+00	6.30E+03	-	-	-	-	-	**-**	-
Pa-234	0.00E+00	1.00E-01	2.00E+03	-	-	-	-	3.46E+09	**3.46E+09**	1.45E-22
Pa-234m	0.00E+00	1.00E-01	2.00E+03	-	-	-	-	-	**-**	-
Pb-210	0.00E+00	1.26E-02	1.50E+02	-	-	-	-	1.30E+02	**1.30E+02**	1.01E-10
Pb-214	0.00E+00	1.26E-02	1.50E+02	-	-	-	-	3.15E+05	**3.15E+05**	9.69E-20
Po-210	0.00E+00	2.76E-04	2.10E+02	-	-	-	-	9.89E+00	**9.89E+00**	2.25E-11

Farmer Individual Contribution PRGs for Soil - Secular Equilibrium

Isotope	Parent	Fractional Contribution of Progeny	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Food Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor (risk/pCi)	Plant to Beef Transfer Factor (pCi/kg per pCi/d)	Particulate Emission Factor (m³/kg)	Lambda (1/yr)	Halflife (yr)	1000029 m² Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor
Po-214	U-238	1.00E+00	-	0.00E+00	3.85E-10	0.00E+00	0.00E+00	5.00E-03	2.37E+09	1.33E+11	5.21E-12	1.00E+00	1.00E+00
Po-218	U-238	1.00E+00	-	1.39E-11	6.84E-15	0.00E+00	0.00E+00	5.00E-03	2.37E+09	1.17E+05	5.90E-06	9.00E-01	1.00E+00
Ra-226	U-238	1.00E+00	S	2.82E-08	2.50E-08	5.14E-10	6.77E-10	1.70E-03	2.37E+09	4.33E-04	1.60E+03	1.00E+00	1.00E+00
Rn-218	U-238	2.00E-07	-	0.00E+00	3.39E-09	0.00E+00	0.00E+00	0.00E+00	2.37E+09	6.24E+08	1.11E-09	1.00E+00	1.00E+00
Rn-222	U-238	1.00E+00	-	2.28E-12	1.69E-09	0.00E+00	0.00E+00	0.00E+00	2.37E+09	6.62E+01	1.05E-02	1.00E+00	1.00E+00
Th-230	U-238	1.00E+00	F	3.41E-08	8.45E-10	1.19E-10	1.66E-10	2.30E-04	2.37E+09	9.19E-06	7.54E+04	1.00E+00	1.00E+00
Th-234	U-238	1.00E+00	S	3.08E-11	1.77E-08	3.39E-11	6.25E-11	2.30E-04	2.37E+09	1.05E+01	6.60E-02	1.00E+00	1.00E+00
Tl-206	U-238	1.34E-06	-	0.00E+00	6.11E-09	0.00E+00	0.00E+00	2.00E-02	2.37E+09	8.67E+04	7.99E-06	1.00E+00	1.00E+00
Tl-210	U-238	2.10E-04	-	0.00E+00	1.34E-05	0.00E+00	0.00E+00	2.00E-02	2.37E+09	2.80E+05	2.47E-06	1.00E+00	1.00E+00
U-234	U-238	1.00E+00	S	2.78E-08	2.53E-10	9.55E-11	1.48E-10	3.90E-04	2.37E+09	2.82E-06	2.46E+05	1.00E+00	1.00E+00
U-238	U-238	1.00E+00	S	2.36E-08	1.24E-10	8.66E-11	1.34E-10	3.90E-04	2.37E+09	1.55E-10	4.47E+09	1.00E+00	1.00E+00

Isotope	Total Indoor GSF Soil Volume	Dry Soil-to-plant transfer factor (pCi/g-fresh plant per pCi/g-dry soil)	K_d Distribution coefficient (L/kg)	Ingestion PRG TR=0.0001 (pCi/g)	Inhalation PRG TR=0.0001 (pCi/g)	External Exposure PRG TR=0.0001 (pCi/g)	Produce Consumption PRG TR=0.0001 (pCi/g)	Beef Consumption PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (pCi/g)	Total PRG TR=0.0001 (mg/kg)
Po-214	0.00E+00	2.76E-04	2.10E+02	-	-	-	-	-	**-**	-
Po-218	0.00E+00	2.76E-04	2.10E+02	-	-	-	-	-	**-**	-
Ra-226	0.00E+00	1.95E-02	1.00E+00	-	-	-	-	1.20E+02	**1.20E+02**	8.46E-09
Rn-218	0.00E+00	0.00E+00	0.00E+00	-	-	-	-	-	**-**	-
Rn-222	0.00E+00	0.00E+00	0.00E+00	-	-	-	-	-	**-**	-
Th-230	0.00E+00	2.41E-03	2.00E+01	-	-	-	-	4.04E+03	**4.04E+03**	1.20E-08
Th-234	0.00E+00	2.41E-03	2.00E+01	-	-	-	-	1.42E+04	**1.42E+04**	3.05E-15
Tl-206	0.00E+00	6.00E-01	1.50E+03	-	-	-	-	-	**-**	-
Tl-210	0.00E+00	6.00E-01	1.50E+03	-	-	-	-	-	**-**	-
U-234	0.00E+00	7.13E-03	4.00E-01	-	-	-	-	2.93E+03	**2.93E+03**	5.50E-08
U-238	0.00E+00	7.13E-03	4.00E-01	-	-	-	-	3.23E+03	**3.23E+03**	9.23E-04

Farmer Risk for Soil - Secular Equilibrium

Isotope	Ingestion Risk	Inhalation Risk	External Exposure Risk	Produce Consumption Risk	Beef Risk	Total Risk
***Secular Equilibrium Risk for U-235**	***0.00E+00***	***0.00E+00***	***0.00E+00***	***-***	***2.45E-08***	***2.45E-08***
***Secular Equilibrium Risk for U-238**	***0.00E+00***	***0.00E+00***	***0.00E+00***	***-***	***1.19E-05***	***1.19E-05***
*Total Risk	0.00E+00	0.00E+00	0.00E+00	-	1.19E-05	**1.19E-05**

Farmer Individual Risk Contributions for Soil - Secular Equilibrium

Isotope	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Food Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor (risk/pCi)	Plant to Beef Transfer Factor (pCi/kg per pCi/d)	Concentration (pCi/g)	Particulate Emission Factor (m³/kg)	Lambda (1/yr)
**Secular Equilibrium Risk for U-235*		-	-	-	-	-	-	-	-
Ac-227	S	1.49E-07	1.98E-10	2.45E-10	2.90E-10	2.00E-05	0.04	2.37E+09	3.18E-02
At-219	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	1.00E-02	0.04	2.37E+09	3.90E+05
Bi-211	-	0.00E+00	1.90E-07	0.00E+00	0.00E+00	2.00E-03	0.04	2.37E+09	1.70E+05
Bi-215	-	0.00E+00	1.08E-06	0.00E+00	0.00E+00	2.00E-03	0.04	2.37E+09	4.79E+04
Fr-223	S	4.07E-11	1.35E-07	1.01E-11	1.69E-11	3.00E-02	0.04	2.37E+09	1.66E+04
Pa-231	F	7.62E-08	1.27E-07	2.26E-10	2.98E-10	5.00E-06	0.04	2.37E+09	2.12E-05
Pb-211	S	4.03E-11	2.91E-07	5.81E-13	9.55E-13	7.00E-04	0.04	2.37E+09	1.01E+04
Po-211	-	0.00E+00	3.76E-08	0.00E+00	0.00E+00	5.00E-03	0.04	2.37E+09	4.24E+07
Po-215	-	0.00E+00	7.48E-10	0.00E+00	0.00E+00	5.00E-03	0.04	2.37E+09	1.23E+10
Ra-223	S	2.92E-08	4.55E-07	3.39E-10	5.99E-10	1.70E-03	0.04	2.37E+09	2.21E+01
Rn-219	-	0.00E+00	2.35E-07	0.00E+00	0.00E+00	0.00E+00	0.04	2.37E+09	5.52E+06
Th-227	S	3.50E-08	4.45E-07	7.03E-11	1.29E-10	2.30E-04	0.04	2.37E+09	1.35E+01
Th-231	S	1.50E-12	2.49E-08	3.22E-12	5.96E-12	2.30E-04	0.04	2.37E+09	2.38E+02
Tl-207	-	0.00E+00	1.59E-08	0.00E+00	0.00E+00	2.00E-02	0.04	2.37E+09	7.64E+04
U-235	S	2.50E-08	5.51E-07	9.44E-11	1.48E-10	3.90E-04	0.04	2.37E+09	9.84E-10
**Secular Equilibrium Risk for U-238*		-	-	-	-	-	-	-	-
At-218	-	0.00E+00	2.74E-11	0.00E+00	0.00E+00	1.00E-02	1	2.37E+09	1.46E+07
Bi-210	S	4.55E-10	2.77E-09	1.30E-11	2.40E-11	2.00E-03	1	2.37E+09	5.05E+01
Bi-214	S	6.18E-11	7.34E-06	2.65E-13	4.03E-13	2.00E-03	1	2.37E+09	1.83E+04
Hg-206	-	0.00E+00	4.83E-07	0.00E+00	0.00E+00	1.00E-02	1	2.37E+09	4.47E+04
Pa-234	S	1.20E-12	6.62E-06	3.00E-12	5.37E-12	5.00E-06	1	2.37E+09	9.06E+02
Pa-234m	-	0.00E+00	9.06E-08	0.00E+00	0.00E+00	5.00E-06	1	2.37E+09	3.11E+05
Pb-210	S	1.59E-08	1.48E-09	1.18E-09	1.72E-09	7.00E-04	1	2.37E+09	3.12E-02
Pb-214	S	7.77E-11	9.94E-07	4.85E-13	7.92E-13	7.00E-04	1	2.37E+09	1.36E+04
Po-210	S	1.45E-08	4.51E-11	2.25E-09	3.27E-09	5.00E-03	1	2.37E+09	1.83E+00
Po-214	-	0.00E+00	3.85E-10	0.00E+00	0.00E+00	5.00E-03	1	2.37E+09	1.33E+11
Po-218	-	1.39E-11	6.84E-15	0.00E+00	0.00E+00	5.00E-03	1	2.37E+09	1.17E+05
Ra-226	S	2.82E-08	2.50E-08	5.14E-10	6.77E-10	1.70E-03	1	2.37E+09	4.33E-04

Isotope	Halflife (yr)	1000029 m² Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Dry Soil-to-plant transfer factor (pCi/g-fresh plant per pCi/g-dry soil)	K_d Distribution coefficient (L/kg)	Ingestion CDI (pCi)	Inhalation CDI (pCi)	External Exposure CDI (pCi)
**Secular Equilibrium Risk for U-235*	-	-	-	-	-	-	-	-	-
Ac-227	2.18E+01	1.00E+00	1.00E+00	0.00E+00	1.00E-01	1.70E+03	0.00E+00	0.00E+00	0.00E+00
At-219	1.78E-06	9.00E-01	1.00E+00	0.00E+00	9.00E-01	1.00E+01	0.00E+00	0.00E+00	0.00E+00
Bi-211	4.07E-06	1.00E+00	1.00E+00	0.00E+00	5.00E-01	4.80E+02	0.00E+00	0.00E+00	0.00E+00
Bi-215	1.45E-05	1.00E+00	1.00E+00	0.00E+00	5.00E-01	4.80E+02	0.00E+00	0.00E+00	0.00E+00
Fr-223	4.19E-05	1.00E+00	1.00E+00	0.00E+00	1.00E-01	2.50E+02	0.00E+00	0.00E+00	0.00E+00
Pa-231	3.28E+04	1.00E+00	1.00E+00	0.00E+00	1.00E-01	2.00E+03	0.00E+00	0.00E+00	0.00E+00
Pb-211	6.87E-05	1.00E+00	1.00E+00	0.00E+00	1.26E-02	1.50E+02	0.00E+00	0.00E+00	0.00E+00
Po-211	1.64E-08	1.00E+00	1.00E+00	0.00E+00	2.76E-04	2.10E+02	0.00E+00	0.00E+00	0.00E+00
Po-215	5.65E-11	1.00E+00	1.00E+00	0.00E+00	2.76E-04	2.10E+02	0.00E+00	0.00E+00	0.00E+00
Ra-223	3.13E-02	1.00E+00	1.00E+00	0.00E+00	1.95E-02	1.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-219	1.26E-07	1.00E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-227	5.12E-02	1.00E+00	1.00E+00	0.00E+00	2.41E-03	2.00E+01	0.00E+00	0.00E+00	0.00E+00
Th-231	2.91E-03	1.00E+00	1.00E+00	0.00E+00	2.41E-03	2.00E+01	0.00E+00	0.00E+00	0.00E+00
Tl-207	9.08E-06	1.00E+00	1.00E+00	0.00E+00	6.00E-01	1.50E+03	0.00E+00	0.00E+00	0.00E+00
U-235	7.04E+08	1.00E+00	1.00E+00	0.00E+00	7.13E-03	4.00E-01	0.00E+00	0.00E+00	0.00E+00
**Secular Equilibrium Risk for U-238*	-	-	-	-	-	-	-	-	-
At-218	4.76E-08	9.00E-01	1.00E+00	0.00E+00	9.00E-01	1.00E+01	0.00E+00	0.00E+00	0.00E+00
Bi-210	1.37E-02	1.00E+00	1.00E+00	0.00E+00	5.00E-01	4.80E+02	0.00E+00	0.00E+00	0.00E+00
Bi-214	3.79E-05	1.00E+00	1.00E+00	0.00E+00	5.00E-01	4.80E+02	0.00E+00	0.00E+00	0.00E+00
Hg-206	1.55E-05	1.00E+00	1.00E+00	0.00E+00	1.00E+00	6.30E+03	0.00E+00	0.00E+00	0.00E+00
Pa-234	7.65E-04	1.00E+00	1.00E+00	0.00E+00	1.00E-01	2.00E+03	0.00E+00	0.00E+00	0.00E+00
Pa-234m	2.23E-06	1.00E+00	1.00E+00	0.00E+00	1.00E-01	2.00E+03	0.00E+00	0.00E+00	0.00E+00
Pb-210	2.22E+01	1.00E+00	1.00E+00	0.00E+00	1.26E-02	1.50E+02	0.00E+00	0.00E+00	0.00E+00
Pb-214	5.10E-05	1.00E+00	1.00E+00	0.00E+00	1.26E-02	1.50E+02	0.00E+00	0.00E+00	0.00E+00
Po-210	3.79E-01	1.00E+00	1.00E+00	0.00E+00	2.76E-04	2.10E+02	0.00E+00	0.00E+00	0.00E+00
Po-214	5.21E-12	1.00E+00	1.00E+00	0.00E+00	2.76E-04	2.10E+02	0.00E+00	0.00E+00	0.00E+00
Po-218	5.90E-06	9.00E-01	1.00E+00	0.00E+00	2.76E-04	2.10E+02	0.00E+00	0.00E+00	0.00E+00
Ra-226	1.60E+03	1.00E+00	1.00E+00	0.00E+00	1.95E-02	1.00E+00	0.00E+00	0.00E+00	0.00E+00

Isotope	Produce Consumption CDI (pCi)	Beef CDI (pCi)	Ingestion Risk	Inhalation Risk	External Exposure Risk	Produce Consumption Risk	Beef Risk	Total Risk
***Secular Equilibrium Risk for U-235**	**-**	**-**	***0.00E+00***	***0.00E+00***	***0.00E+00***	**-**	***2.45E-08***	***2.45E-08***
Ac-227	-	9.62E-01	0.00E+00	0.00E+00	0.00E+00	-	2.36E-10	**2.36E-10**
At-219	-	1.46E+03	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Bi-211	-	1.94E+02	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Bi-215	-	1.94E+02	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Fr-223	-	1.44E+03	0.00E+00	0.00E+00	0.00E+00	-	2.01E-10	**2.01E-10**
Pa-231	-	2.41E-01	0.00E+00	0.00E+00	0.00E+00	-	5.43E-11	**5.43E-11**
Pb-211	-	2.62E+01	0.00E+00	0.00E+00	0.00E+00	-	1.52E-11	**1.52E-11**
Po-211	-	1.79E+02	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Po-215	-	1.79E+02	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Ra-223	-	6.50E+01	0.00E+00	0.00E+00	0.00E+00	-	2.20E-08	**2.20E-08**
Rn-219	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Th-227	-	8.31E+00	0.00E+00	0.00E+00	0.00E+00	-	5.76E-10	**5.76E-10**
Th-231	-	8.31E+00	0.00E+00	0.00E+00	0.00E+00	-	2.67E-11	**2.67E-11**
Tl-207	-	2.19E+03	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
U-235	-	1.43E+01	0.00E+00	0.00E+00	0.00E+00	-	1.35E-09	**1.35E-09**
***Secular Equilibrium Risk for U-238**	**-**	**-**	***0.00E+00***	***0.00E+00***	***0.00E+00***	**-**	***1.19E-05***	***1.19E-05***
At-218	-	3.65E+04	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Bi-210	-	4.86E+03	0.00E+00	0.00E+00	0.00E+00	-	6.33E-08	**6.33E-08**
Bi-214	-	4.86E+03	0.00E+00	0.00E+00	0.00E+00	-	1.29E-09	**1.29E-09**
Hg-206	-	3.96E+04	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Pa-234	-	6.01E+00	0.00E+00	0.00E+00	0.00E+00	-	2.89E-14	**2.89E-14**
Pa-234m	-	6.01E+00	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Pb-210	-	6.54E+02	0.00E+00	0.00E+00	0.00E+00	-	7.70E-07	**7.70E-07**
Pb-214	-	6.54E+02	0.00E+00	0.00E+00	0.00E+00	-	3.17E-10	**3.17E-10**
Po-210	-	4.49E+03	0.00E+00	0.00E+00	0.00E+00	-	1.01E-05	**1.01E-05**
Po-214	-	4.49E+03	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Po-218	-	4.49E+03	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Ra-226	-	1.63E+03	0.00E+00	0.00E+00	0.00E+00	-	8.36E-07	**8.36E-07**

Farmer Individual Risk Contributions for Soil - Secular Equilibrium

Isotope	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Food Ingestion Slope Factor (risk/pCi)	Soil Ingestion Slope Factor (risk/pCi)	Plant to Beef Transfer Factor (pCi/kg per pCi/d)	Concentration (pCi/g)	Particulate Emission Factor (m^3/kg)	Lambda (1/yr)
Rn-218	-	0.00E+00	3.39E-09	0.00E+00	0.00E+00	0.00E+00	1	2.37E+09	6.24E+08
Rn-222	-	2.28E-12	1.69E-09	0.00E+00	0.00E+00	0.00E+00	1	2.37E+09	6.62E+01
Th-230	F	3.41E-08	8.45E-10	1.19E-10	1.66E-10	2.30E-04	1	2.37E+09	9.19E-06
Th-234	S	3.08E-11	1.77E-08	3.39E-11	6.25E-11	2.30E-04	1	2.37E+09	1.05E+01
Tl-206	-	0.00E+00	6.11E-09	0.00E+00	0.00E+00	2.00E-02	1	2.37E+09	8.67E+04
Tl-210	-	0.00E+00	1.34E-05	0.00E+00	0.00E+00	2.00E-02	1	2.37E+09	2.80E+05
U-234	S	2.78E-08	2.53E-10	9.55E-11	1.48E-10	3.90E-04	1	2.37E+09	2.82E-06
U-238	S	2.36E-08	1.24E-10	8.66E-11	1.34E-10	3.90E-04	1	2.37E+09	1.55E-10

Farmer Individual Risk Contributions for Soil - Secular Equilibrium

Isotope	Halflife (yr)	1000029 m² Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Total Indoor GSF Soil Volume	Dry Soil-to-plant transfer factor (pCi/g-fresh plant per pCi/g-dry soil)	K_d Distribution coefficient (L/kg)	Ingestion CDI (pCi)	Inhalation CDI (pCi)	External Exposure CDI (pCi)
Rn-218	1.11E-09	1.00E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Rn-222	1.05E-02	1.00E+00	1.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Th-230	7.54E+04	1.00E+00	1.00E+00	0.00E+00	2.41E-03	2.00E+01	0.00E+00	0.00E+00	0.00E+00
Th-234	6.60E-02	1.00E+00	1.00E+00	0.00E+00	2.41E-03	2.00E+01	0.00E+00	0.00E+00	0.00E+00
Tl-206	7.99E-06	1.00E+00	1.00E+00	0.00E+00	6.00E-01	1.50E+03	0.00E+00	0.00E+00	0.00E+00
Tl-210	2.47E-06	1.00E+00	1.00E+00	0.00E+00	6.00E-01	1.50E+03	0.00E+00	0.00E+00	0.00E+00
U-234	2.46E+05	1.00E+00	1.00E+00	0.00E+00	7.13E-03	4.00E-01	0.00E+00	0.00E+00	0.00E+00
U-238	4.47E+09	1.00E+00	1.00E+00	0.00E+00	7.13E-03	4.00E-01	0.00E+00	0.00E+00	0.00E+00

Isotope	Produce Consumption CDI (pCi)	Beef CDI (pCi)	Ingestion Risk	Inhalation Risk	External Exposure Risk	Produce Consumption Risk	Beef Risk	Total Risk
Rn-218	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Rn-222	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Th-230	-	2.08E+02	0.00E+00	0.00E+00	0.00E+00	-	2.48E-08	**2.48E-08**
Th-234	-	2.08E+02	0.00E+00	0.00E+00	0.00E+00	-	7.05E-09	**7.05E-09**
Tl-206	-	5.47E+04	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
Tl-210	-	5.47E+04	0.00E+00	0.00E+00	0.00E+00	-	0.00E+00	**0.00E+00**
U-234	-	3.58E+02	0.00E+00	0.00E+00	0.00E+00	-	3.42E-08	**3.42E-08**
U-238	-	3.58E+02	0.00E+00	0.00E+00	0.00E+00	-	3.10E-08	**3.10E-08**

DCGL CALCULATION

DCGL Calculation

	Composite Worker (Outdoor Worker)	Indoor Worker (Inside Truck)	Farmer (Beef Consumption)	
Secular Equilibrium Risk for U-235 and U-238	6.49E-06	3.43E-06	1.19E-05	see pages 7 (Composite and Indoor Workers) and 14 (Farmer) of preceding PRG Calculator Output
Total Secular Equilibrium Risk for U-235 and U-238	**2.18E-05**			

PRG Calculator- Derived DCGL (Derived Concentration Guideline Level) =
Target Cancer Risk (1E-04) ÷ Total Risk(2.18E-05) =
4.6 pCi/g

RA-226 RISK CONTRIBUTION CALCULATION

Ra-226 Risk Contribution Calculation

	Composite Worker (Outdoor Worker)	Indoor Worker (Inside Truck)	Farmer (Beef Consumption)	
Ra-226	1.98E-07	9.98E-09	8.36E-07	see pages 9 (Composite and Indoor Workers) and pages 17-18 (Farmer) of preceding PRG Calculator Output
Rn-222	9.66E-10	6.76E-10	0.00E+00	
At-218	2.82E-15	1.97E-15	0.00E+00	
Po-218	7.68E-14	2.46E-15	0.00E+00	
Rn-218	3.87E-16	2.71E-16	0.00E+00	
Pb-214	5.67E-07	3.97E-07	3.17E-10	
Bi-214	4.19E-06	2.93E-06	1.29E-09	
Po-214	2.20E-10	1.54E-10	0.00E+00	
Secular Equilibrium Risk for Ra-226 through Po-214	4.96E-06	3.34E-06	8.38E-07	
Total Secular Equilibrium Risk for Ra-226 through Po-214	**9.13E-06**			
Total Secular Equilibrium Risk for U-235 and U-238	**2.18E-05**			

% Contribution of Ra-226 through Po-214 Risk to Total Risk = 42 %

RESRAD OUTPUT

Table of Contents

Part III: Intake Quantities and Health Risk Factors

Cancer Risk Slope Factors Summary Table
Risk Library: DCFPAK3.02 Morbidity

Menu	Parameter	Current Value	Base Case*	Parameter Name
Sf-1	Ground external radiation slope factors, 1/yr per (pCi/g):			
Sf-1	Ac-227+D	1.63E-06	1.98E-10	SLPF(1,1)
Sf-1	Pa-231	1.27E-07	1.27E-07	SLPF(2,1)
Sf-1	Pb-210+D	4.25E-09	1.48E-09	SLPF(3,1)
Sf-1	Pb-210+D1	1.72E-08	1.48E-09	SLPF(4,1)
Sf-1	Po-210	4.51E-11	4.51E-11	SLPF(5,1)
Sf-1	Ra-226+D	8.37E-06	2.50E-08	SLPF(6,1)
Sf-1	Th-230	8.45E-10	8.45E-10	SLPF(8,1)
Sf-1	U-234	2.53E-10	2.53E-10	SLPF(10,1)
Sf-1	U-235+D	5.76E-07	5.51E-07	SLPF(12,1)
Sf-1	U-238	1.24E-10	1.24E-10	SLPF(13,1)
Sf-1	U-238+D	1.19E-07	1.24E-10	SLPF(14,1)
Sf-2	Inhalation, slope factors, 1/(pCi):			
Sf-2	Ac-227+D	2.13E-07	1.49E-07	SLPF(1,2)
Sf-2	Pa-231	7.62E-08	7.62E-08	SLPF(2,2)
Sf-2	Pb-210+D	1.63E-08	1.59E-08	SLPF(3,2)
Sf-2	Pb-210+D1	1.63E-08	1.59E-08	SLPF(4,2)
Sf-2	Po-210	1.45E-08	1.45E-08	SLPF(5,2)
Sf-2	Ra-226+D	2.82E-08	2.81E-08	SLPF(6,2)
Sf-2	Th-230	3.41E-08	3.41E-08	SLPF(8,2)
Sf-2	U-234	2.78E-08	2.78E-08	SLPF(10,2)
Sf-2	U-235+D	2.50E-08	2.50E-08	SLPF(12,2)
Sf-2	U-238	2.36E-08	2.36E-08	SLPF(13,2)
Sf-2	U-238+D	2.37E-08	2.36E-08	SLPF(14,2)
Sf-3	Food ingestion, slope factors, 1/(pCi):			
Sf-3	Ac-227+D	6.54E-10	2.45E-10	SLPF(1,3)
Sf-3	Pa-231	2.26E-10	2.26E-10	SLPF(2,3)
Sf-3	Pb-210+D	1.19E-09	1.18E-09	SLPF(3,3)
Sf-3	Pb-210+D1	1.19E-09	1.18E-09	SLPF(4,3)
Sf-3	Po-210	2.25E-09	2.25E-09	SLPF(5,3)
Sf-3	Ra-226+D	5.15E-10	5.14E-10	SLPF(6,3)
Sf-3	Th-230	1.19E-10	1.19E-10	SLPF(8,3)
Sf-3	U-234	9.55E-11	9.55E-11	SLPF(10,3)
Sf-3	U-235+D	9.76E-11	9.43E-11	SLPF(12,3)
Sf-3	U-238	8.66E-11	8.66E-11	SLPF(13,3)
Sf-3	U-238+D	1.21E-10	8.66E-11	SLPF(14,3)
Sf-3	Water ingestion, slope factors, 1/(pCi):			
Sf-3	Ac-227+D	4.87E-10	2.01E-10	SLPF(1,4)
Sf-3	Pa-231	1.72E-10	1.72E-10	SLPF(2,4)
Sf-3	Pb-210+D	8.93E-10	8.84E-10	SLPF(3,4)
Sf-3	Pb-210+D1	8.93E-10	8.84E-10	SLPF(4,4)
Sf-3	Po-210	1.78E-09	1.78E-09	SLPF(5,4)
Sf-3	Ra-226+D	3.85E-10	3.85E-10	SLPF(6,4)
Sf-3	Th-230	9.14E-11	9.14E-11	SLPF(8,4)
Sf-3	U-234	7.07E-11	7.07E-11	SLPF(10,4)
Sf-3	U-235+D	7.17E-11	6.95E-11	SLPF(12,4)
Sf-3	U-238	6.40E-11	6.40E-11	SLPF(13,4)

Cancer Risk Slope Factors Summary Table (continued)

Risk Library: DCFPAK3.02 Morbidity

Menu	Parameter	Current Value	Base Case*	Parameter Name
Sf-3	U-238+D	8.71E-11	6.40E-11	SLPF(14,4)
Sf-3	Soil ingestion, slope factors, 1/(pCi):			
Sf-3	Ac-227+D	6.54E-10	2.45E-10	SLPF(1,5)
Sf-3	Pa-231	2.26E-10	2.26E-10	SLPF(2,5)
Sf-3	Pb-210+D	1.19E-09	1.18E-09	SLPF(3,5)
Sf-3	Pb-210+D1	1.19E-09	1.18E-09	SLPF(4,5)
Sf-3	Po-210	2.25E-09	2.25E-09	SLPF(5,5)
Sf-3	Ra-226+D	5.15E-10	5.14E-10	SLPF(6,5)
Sf-3	Th-230	1.19E-10	1.19E-10	SLPF(8,5)
Sf-3	U-234	9.55E-11	9.55E-11	SLPF(10,5)
Sf-3	U-235+D	9.76E-11	9.43E-11	SLPF(12,5)
Sf-3	U-238	8.66E-11	8.66E-11	SLPF(13,5)
Sf-3	U-238+D	1.21E-10	8.66E-11	SLPF(14,5)
Sf-Rn	Radon Inhalation slope factors, 1/(pCi):			
Sf-Rn	Rn-222	1.80E-12	1.80E-12	SLPFRN(1,1)
Sf-Rn	Po-218	3.70E-12	3.70E-12	SLPFRN(1,2)
Sf-Rn	Pb-214	6.20E-12	6.20E-12	SLPFRN(1,3)
Sf-Rn	Bi-214	1.50E-11	1.50E-11	SLPFRN(1,4)
Sf-Rn	Radon K factors, (mrem/WLM):			
Sf-Rn	Rn-222 Indoor	3.88E+02	3.88E+02	KFACTR(1,1)
Sf-Rn	Rn-222 Outdoor	3.88E+02	3.88E+02	KFACTR(1,2)

*Base Case means Default.Lib w/o Associate Nuclide contributions.

Risk Slope and Environmental Transport Factors for the Ground Pathway

Nuclide (i)	Slope(i)*	ETFG(i,t) At Time in Years (dimensionless) t= 0.000E+00	1.000E+00	3.000E+00	1.000E+01	3.000E+01	1.000E+02	3.000E+02	1.000E+03
Ac-227	1.990E-10	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
At-218	2.740E-11	3.877E-02	3.877E-02	3.877E-02	3.877E-02	3.877E-02	3.877E-02	3.877E-02	3.877E-02
At-219	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Bi-210	2.770E-09	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Bi-211	1.900E-07	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Bi-214	7.340E-06	3.877E-02	3.877E-02	3.877E-02	3.877E-02	3.877E-02	3.877E-02	3.877E-02	3.877E-02
Bi-215	1.080E-06	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Fr-223	1.350E-07	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Hg-206	4.830E-07	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Pa-231	1.270E-07	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Pa-234	6.620E-06	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Pa-234m	9.060E-08	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Pb-210	1.480E-09	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Pb-211	2.910E-07	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Pb-214	9.940E-07	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Po-210	4.510E-11	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Po-211	3.760E-08	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Po-214	3.850E-10	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Po-215	7.480E-10	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Po-218	6.840E-15	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Ra-223	4.550E-07	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Ra-226	2.500E-08	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Rn-218	3.390E-09	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Rn-219	2.350E-07	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Rn-222	1.690E-09	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Th-227	4.450E-07	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Th-230	8.450E-10	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Th-231	2.490E-08	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Th-234	1.780E-08	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Tl-206	6.110E-09	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Tl-207	1.590E-08	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
Tl-210	1.340E-05	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
U-234	2.530E-10	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
U-235	5.510E-07	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02	3.881E-02
U-238	1.240E-10	3.879E-02	3.879E-02	3.879E-02	3.879E-02	3.879E-02	3.879E-02	3.879E-02	3.879E-02

* - Units are 1/yr per (pCi/g) at infinite depth and area. Multiplication by ETFG(i,t) converts to site conditions.

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 0.000E+00 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Ac-227	3.256E-04	0.000E+00	4.422E-03	0.000E+00	4.566E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.008E-02
Pa-231	3.256E-04	0.000E+00	1.290E+00	0.000E+00	4.566E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.336E+00
Pb-210	8.140E-03	0.000E+00	5.160E+00	0.000E+00	1.142E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.301E+00
Po-210	8.140E-03	0.000E+00	2.672E+01	0.000E+00	1.142E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.786E+01
Ra-226	8.140E-03	0.000E+00	1.014E+01	0.000E+00	1.142E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.128E+01
Th-230	8.140E-03	0.000E+00	5.343E-01	0.000E+00	1.142E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.676E+00
U-234	8.140E-03	0.000E+00	1.879E+00	0.000E+00	1.142E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.021E+00
U-235	3.256E-04	0.000E+00	7.518E-02	0.000E+00	4.566E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.208E-01
U-238	8.140E-03	0.000E+00	1.879E+00	0.000E+00	1.142E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.021E+00

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 0.000E+00 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	5.788E-08	0.0058	1.590E-09	0.0002	0.000E+00	0.0000	1.013E-10	0.0000	0.000E+00	0.0000	6.835E-10	0.0001
Pa-231	4.730E-09	0.0005	5.953E-10	0.0001	0.000E+00	0.0000	6.986E-09	0.0007	0.000E+00	0.0000	2.472E-10	0.0000
Pb-210	4.032E-09	0.0004	3.248E-09	0.0003	0.000E+00	0.0000	1.505E-07	0.0152	0.000E+00	0.0000	3.318E-08	0.0033
Po-210	4.246E-11	0.0000	2.863E-09	0.0003	0.000E+00	0.0000	1.404E-06	0.1415	0.000E+00	0.0000	6.238E-08	0.0063
Ra-226	7.873E-06	0.7933	5.577E-09	0.0006	0.000E+00	0.0000	1.267E-07	0.0128	0.000E+00	0.0000	1.427E-08	0.0014
Th-230	8.199E-10	0.0001	6.933E-09	0.0007	0.000E+00	0.0000	1.591E-09	0.0002	0.000E+00	0.0000	3.399E-09	0.0003
U-234	2.356E-10	0.0000	5.433E-09	0.0005	0.000E+00	0.0000	4.305E-09	0.0004	0.000E+00	0.0000	2.614E-09	0.0003
U-235	2.145E-08	0.0022	1.954E-10	0.0000	0.000E+00	0.0000	1.760E-10	0.0000	0.000E+00	0.0000	1.069E-10	0.0000
U-238	1.109E-07	0.0112	4.623E-09	0.0005	0.000E+00	0.0000	5.435E-09	0.0005	0.000E+00	0.0000	3.300E-09	0.0003
Total	8.073E-06	0.8135	3.106E-08	0.0031	0.000E+00	0.0000	1.700E-06	0.1713	0.000E+00	0.0000	1.202E-07	0.0121

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 0.000E+00 years

Water Dependent Pathways

Radio-Nuclide	Water risk	Water fract.	Fish risk	Fish fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	All Pathways** risk	All Pathways** fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.026E-08	0.0061
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.256E-08	0.0013
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.910E-07	0.0192
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.470E-06	0.1481
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.020E-06	0.8081
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.274E-08	0.0013
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.259E-08	0.0013
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.193E-08	0.0022
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.243E-07	0.0125
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.925E-06	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 0.000E+00 years

Radon Pathway	Radionuclides Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 0.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	3.992E-08	0.0040	1.096E-09	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	4.568E-11	0.0000	0.000E+00	0.0000	4.714E-10	0.0000
Pa-231	2.268E-08	0.0023	1.088E-09	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	7.040E-09	0.0007	0.000E+00	0.0000	4.592E-10	0.0000
Pb-210	2.841E-09	0.0003	4.231E-09	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	1.068E-06	0.1076	0.000E+00	0.0000	6.596E-08	0.0066
Po-210	9.484E-13	0.0000	6.395E-11	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.264E-08	0.0033	0.000E+00	0.0000	1.393E-09	0.0001
Ra-226	7.832E-06	0.7891	7.356E-09	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	5.785E-07	0.0583	0.000E+00	0.0000	4.228E-08	0.0043
Th-230	4.372E-08	0.0044	6.970E-09	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	3.991E-09	0.0004	0.000E+00	0.0000	3.583E-09	0.0004
U-234	2.389E-10	0.0000	5.434E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	4.305E-09	0.0004	0.000E+00	0.0000	2.614E-09	0.0003
U-235	2.145E-08	0.0022	1.956E-10	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.778E-10	0.0000	0.000E+00	0.0000	1.070E-10	0.0000
U-238	1.109E-07	0.0112	4.623E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	5.435E-09	0.0005	0.000E+00	0.0000	3.300E-09	0.0003
Total	8.073E-06	0.8135	3.106E-08	0.0031	0.000E+00	0.0000	0.000E+00	0.0000	1.700E-06	0.1713	0.000E+00	0.0000	1.202E-07	0.0121

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 0.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.154E-08	0.0042
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.127E-08	0.0032
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.141E-06	0.1150
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.410E-08	0.0034
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.460E-06	0.8524
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.826E-08	0.0059
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.259E-08	0.0013
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.194E-08	0.0022
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.243E-07	0.0125
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.925E-06	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

DCGL = Target Risk of 1E-04 ÷ Total Risk Across All Pathways of 9.925E-06 = 10.1 pCi/g U-238 and all progeny, including Ra-226.

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 1.000E+00 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Ac-227	3.230E-04	0.000E+00	6.623E-03	0.000E+00	4.529E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.191E-02
Pa-231	3.245E-04	0.000E+00	1.286E+00	0.000E+00	4.551E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.331E+00
Pb-210	8.127E-03	0.000E+00	5.171E+00	0.000E+00	1.140E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.311E+00
Po-210	8.072E-03	0.000E+00	2.548E+01	0.000E+00	1.132E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.661E+01
Ra-226	8.121E-03	0.000E+00	1.011E+01	0.000E+00	1.139E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.125E+01
Th-230	8.140E-03	0.000E+00	5.343E-01	0.000E+00	1.142E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.676E+00
U-234	8.113E-03	0.000E+00	1.874E+00	0.000E+00	1.138E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.011E+00
U-235	3.245E-04	0.000E+00	7.494E-02	0.000E+00	4.551E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.205E-01
U-238	8.113E-03	0.000E+00	1.874E+00	0.000E+00	1.138E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.011E+00

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 1.000E+00 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	5.750E-08	0.0058	1.579E-09	0.0002	0.000E+00	0.0000	1.008E-10	0.0000	0.000E+00	0.0000	6.789E-10	0.0001
Pa-231	4.715E-09	0.0005	5.933E-10	0.0001	0.000E+00	0.0000	6.963E-09	0.0007	0.000E+00	0.0000	2.464E-10	0.0000
Pb-210	4.024E-09	0.0004	3.242E-09	0.0003	0.000E+00	0.0000	1.503E-07	0.0152	0.000E+00	0.0000	3.311E-08	0.0033
Po-210	4.237E-11	0.0000	2.857E-09	0.0003	0.000E+00	0.0000	1.401E-06	0.1415	0.000E+00	0.0000	6.225E-08	0.0063
Ra-226	7.855E-06	0.7933	5.563E-09	0.0006	0.000E+00	0.0000	1.264E-07	0.0128	0.000E+00	0.0000	1.424E-08	0.0014
Th-230	8.199E-10	0.0001	6.933E-09	0.0007	0.000E+00	0.0000	1.591E-09	0.0002	0.000E+00	0.0000	3.399E-09	0.0003
U-234	2.348E-10	0.0000	5.415E-09	0.0005	0.000E+00	0.0000	4.290E-09	0.0004	0.000E+00	0.0000	2.605E-09	0.0003
U-235	2.138E-08	0.0022	1.947E-10	0.0000	0.000E+00	0.0000	1.754E-10	0.0000	0.000E+00	0.0000	1.065E-10	0.0000
U-238	1.105E-07	0.0112	4.607E-09	0.0005	0.000E+00	0.0000	5.417E-09	0.0005	0.000E+00	0.0000	3.289E-09	0.0003
Total	8.054E-06	0.8134	3.098E-08	0.0031	0.000E+00	0.0000	1.697E-06	0.1713	0.000E+00	0.0000	1.199E-07	0.0121

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Plant		Meat		Milk		All Pathways**	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.986E-08	0.0060
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.252E-08	0.0013
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.906E-07	0.0193
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.466E-06	0.1481
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.001E-06	0.8081
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.274E-08	0.0013
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.255E-08	0.0013
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.186E-08	0.0022
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.239E-07	0.0125
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.901E-06	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 1.000E+00 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	3.835E-08	0.0039	1.053E-09	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	4.388E-11	0.0000	0.000E+00	0.0000	4.529E-10	0.0000
Pa-231	2.385E-08	0.0024	1.119E-09	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	7.018E-09	0.0007	0.000E+00	0.0000	4.723E-10	0.0000
Pb-210	2.750E-09	0.0003	4.146E-09	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	1.060E-06	0.1071	0.000E+00	0.0000	6.497E-08	0.0066
Po-210	1.497E-13	0.0000	1.010E-11	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.154E-09	0.0005	0.000E+00	0.0000	2.200E-10	0.0000
Ra-226	7.810E-06	0.7888	7.466E-09	0.0008	0.000E+00	0.0000	0.000E+00	0.0000	6.102E-07	0.0616	0.000E+00	0.0000	4.421E-08	0.0045
Th-230	4.711E-08	0.0048	6.973E-09	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	4.248E-09	0.0004	0.000E+00	0.0000	3.602E-09	0.0004
U-234	2.385E-10	0.0000	5.416E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	4.291E-09	0.0004	0.000E+00	0.0000	2.606E-09	0.0003
U-235	2.138E-08	0.0022	1.950E-10	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.774E-10	0.0000	0.000E+00	0.0000	1.066E-10	0.0000
U-238	1.105E-07	0.0112	4.608E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	5.417E-09	0.0005	0.000E+00	0.0000	3.289E-09	0.0003
Total	8.054E-06	0.8134	3.098E-08	0.0031	0.000E+00	0.0000	0.000E+00	0.0000	1.697E-06	0.1713	0.000E+00	0.0000	1.199E-07	0.0121

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.990E-08	0.0040
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.246E-08	0.0033
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.132E-06	0.1143
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.384E-09	0.0005
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.472E-06	0.8556
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.193E-08	0.0063
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.255E-08	0.0013
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.186E-08	0.0022
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.239E-07	0.0125
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.901E-06	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 3.000E+00 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Ac-227	3.179E-04	0.000E+00	6.540E-03	0.000E+00	4.458E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.112E-02
Pa-231	3.224E-04	0.000E+00	1.277E+00	0.000E+00	4.521E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.323E+00
Pb-210	8.099E-03	0.000E+00	5.154E+00	0.000E+00	1.136E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.289E+00
Po-210	8.035E-03	0.000E+00	2.536E+01	0.000E+00	1.127E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.649E+01
Ra-226	8.082E-03	0.000E+00	1.007E+01	0.000E+00	1.133E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.120E+01
Th-230	8.140E-03	0.000E+00	5.343E-01	0.000E+00	1.142E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.676E+00
U-234	8.060E-03	0.000E+00	1.861E+00	0.000E+00	1.130E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.991E+00
U-235	3.224E-04	0.000E+00	7.445E-02	0.000E+00	4.521E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.197E-01
U-238	8.060E-03	0.000E+00	1.861E+00	0.000E+00	1.130E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.991E+00

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
  and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 3.000E+00 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent   Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	5.675E-08	0.0058	1.559E-09	0.0002	0.000E+00	0.0000	9.976E-11	0.0000	0.000E+00	0.0000	6.702E-10	0.0001
Pa-231	4.683E-09	0.0005	5.894E-10	0.0001	0.000E+00	0.0000	6.917E-09	0.0007	0.000E+00	0.0000	2.448E-10	0.0000
Pb-210	4.009E-09	0.0004	3.230E-09	0.0003	0.000E+00	0.0000	1.497E-07	0.0152	0.000E+00	0.0000	3.299E-08	0.0033
Po-210	4.221E-11	0.0000	2.846E-09	0.0003	0.000E+00	0.0000	1.396E-06	0.1416	0.000E+00	0.0000	6.202E-08	0.0063
Ra-226	7.818E-06	0.7932	5.537E-09	0.0006	0.000E+00	0.0000	1.258E-07	0.0128	0.000E+00	0.0000	1.417E-08	0.0014
Th-230	8.199E-10	0.0001	6.933E-09	0.0007	0.000E+00	0.0000	1.591E-09	0.0002	0.000E+00	0.0000	3.399E-09	0.0003
U-234	2.332E-10	0.0000	5.379E-09	0.0005	0.000E+00	0.0000	4.262E-09	0.0004	0.000E+00	0.0000	2.588E-09	0.0003
U-235	2.124E-08	0.0022	1.934E-10	0.0000	0.000E+00	0.0000	1.742E-10	0.0000	0.000E+00	0.0000	1.058E-10	0.0000
U-238	1.098E-07	0.0111	4.577E-09	0.0005	0.000E+00	0.0000	5.381E-09	0.0005	0.000E+00	0.0000	3.268E-09	0.0003
Total	8.015E-06	0.8133	3.084E-08	0.0031	0.000E+00	0.0000	1.690E-06	0.1715	0.000E+00	0.0000	1.194E-07	0.0121

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Plant		Meat		Milk		All Pathways**	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.908E-08	0.0060
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.243E-08	0.0013
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.899E-07	0.0193
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.461E-06	0.1482
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.963E-06	0.8080
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.274E-08	0.0013
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.246E-08	0.0013
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.171E-08	0.0022
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.230E-07	0.0125
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.856E-06	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 3.000E+00 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+00 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	3.540E-08	0.0036	9.721E-10	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	4.050E-11	0.0000	0.000E+00	0.0000	4.180E-10	0.0000
Pa-231	2.603E-08	0.0026	1.176E-09	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	6.974E-09	0.0007	0.000E+00	0.0000	4.968E-10	0.0001
Pb-210	2.575E-09	0.0003	3.891E-09	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	9.972E-07	0.1012	0.000E+00	0.0000	6.104E-08	0.0062
Po-210	3.732E-15	0.0000	2.517E-13	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.285E-10	0.0000	0.000E+00	0.0000	5.484E-12	0.0000
Ra-226	7.766E-06	0.7880	7.674E-09	0.0008	0.000E+00	0.0000	0.000E+00	0.0000	6.709E-07	0.0681	0.000E+00	0.0000	4.789E-08	0.0049
Th-230	5.385E-08	0.0055	6.979E-09	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	4.803E-09	0.0005	0.000E+00	0.0000	3.642E-09	0.0004
U-234	2.379E-10	0.0000	5.380E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	4.262E-09	0.0004	0.000E+00	0.0000	2.589E-09	0.0003
U-235	2.124E-08	0.0022	1.938E-10	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.765E-10	0.0000	0.000E+00	0.0000	1.059E-10	0.0000
U-238	1.098E-07	0.0111	4.577E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	5.381E-09	0.0005	0.000E+00	0.0000	3.268E-09	0.0003
Total	8.015E-06	0.8133	3.084E-08	0.0031	0.000E+00	0.0000	0.000E+00	0.0000	1.690E-06	0.1715	0.000E+00	0.0000	1.194E-07	0.0121

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+00 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.683E-08	0.0037
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.468E-08	0.0035
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.065E-06	0.1080
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.342E-10	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.493E-06	0.8617
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.928E-08	0.0070
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.247E-08	0.0013
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.172E-08	0.0022
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.230E-07	0.0125
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.856E-06	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 1.000E+01 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Ac-227	3.020E-04	0.000E+00	6.273E-03	0.000E+00	4.235E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.862E-02
Pa-231	3.150E-04	0.000E+00	1.248E+00	0.000E+00	4.417E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.292E+00
Pb-210	7.998E-03	0.000E+00	5.089E+00	0.000E+00	1.122E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	6.211E+00
Po-210	7.935E-03	0.000E+00	2.505E+01	0.000E+00	1.113E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.616E+01
Ra-226	7.950E-03	0.000E+00	9.901E+00	0.000E+00	1.115E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.102E+01
Th-230	8.140E-03	0.000E+00	5.343E-01	0.000E+00	1.142E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.676E+00
U-234	7.874E-03	0.000E+00	1.818E+00	0.000E+00	1.104E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.923E+00
U-235	3.150E-04	0.000E+00	7.274E-02	0.000E+00	4.417E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.169E-01
U-238	7.874E-03	0.000E+00	1.818E+00	0.000E+00	1.104E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.923E+00

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 1.000E+01 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	5.440E-08	0.0056	1.494E-09	0.0002	0.000E+00	0.0000	9.627E-11	0.0000	0.000E+00	0.0000	6.423E-10	0.0001
Pa-231	4.576E-09	0.0005	5.759E-10	0.0001	0.000E+00	0.0000	6.758E-09	0.0007	0.000E+00	0.0000	2.392E-10	0.0000
Pb-210	3.954E-09	0.0004	3.185E-09	0.0003	0.000E+00	0.0000	1.476E-07	0.0152	0.000E+00	0.0000	3.254E-08	0.0034
Po-210	4.163E-11	0.0000	2.807E-09	0.0003	0.000E+00	0.0000	1.377E-06	0.1420	0.000E+00	0.0000	6.117E-08	0.0063
Ra-226	7.690E-06	0.7931	5.447E-09	0.0006	0.000E+00	0.0000	1.238E-07	0.0128	0.000E+00	0.0000	1.394E-08	0.0014
Th-230	8.199E-10	0.0001	6.933E-09	0.0007	0.000E+00	0.0000	1.591E-09	0.0002	0.000E+00	0.0000	3.399E-09	0.0004
U-234	2.279E-10	0.0000	5.256E-09	0.0005	0.000E+00	0.0000	4.164E-09	0.0004	0.000E+00	0.0000	2.529E-09	0.0003
U-235	2.075E-08	0.0021	1.890E-10	0.0000	0.000E+00	0.0000	1.702E-10	0.0000	0.000E+00	0.0000	1.034E-10	0.0000
U-238	1.073E-07	0.0111	4.472E-09	0.0005	0.000E+00	0.0000	5.257E-09	0.0005	0.000E+00	0.0000	3.192E-09	0.0003
Total	7.882E-06	0.8129	3.036E-08	0.0031	0.000E+00	0.0000	1.666E-06	0.1719	0.000E+00	0.0000	1.178E-07	0.0121

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water risk	Water fract.	Fish risk	Fish fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	All Pathways** risk	All Pathways** fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.663E-08	0.0058
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.215E-08	0.0013
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.873E-07	0.0193
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.441E-06	0.1486
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.833E-06	0.8078
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.274E-08	0.0013
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.218E-08	0.0013
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.121E-08	0.0022
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.202E-07	0.0124
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.697E-06	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 1.000E+01 years

Radon Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

(Radionuclides)

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	2.674E-08	0.0028	7.343E-10	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	3.059E-11	0.0000	0.000E+00	0.0000	3.157E-10	0.0000
Pa-231	3.223E-08	0.0033	1.335E-09	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	6.821E-09	0.0007	0.000E+00	0.0000	5.656E-10	0.0001
Pb-210	2.045E-09	0.0002	3.091E-09	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	7.923E-07	0.0817	0.000E+00	0.0000	4.849E-08	0.0050
Po-210	9.126E-21	0.0000	6.154E-19	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.141E-16	0.0000	0.000E+00	0.0000	1.341E-17	0.0000
Ra-226	7.616E-06	0.7854	8.277E-09	0.0009	0.000E+00	0.0000	0.000E+00	0.0000	8.506E-07	0.0877	0.000E+00	0.0000	5.875E-08	0.0061
Th-230	7.717E-08	0.0080	7.003E-09	0.0007	0.000E+00	0.0000	0.000E+00	0.0000	7.122E-09	0.0007	0.000E+00	0.0000	3.804E-09	0.0004
U-234	2.366E-10	0.0000	5.257E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	4.165E-09	0.0004	0.000E+00	0.0000	2.529E-09	0.0003
U-235	2.076E-08	0.0021	1.895E-10	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.734E-10	0.0000	0.000E+00	0.0000	1.036E-10	0.0000
U-238	1.073E-07	0.0111	4.472E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	5.257E-09	0.0005	0.000E+00	0.0000	3.193E-09	0.0003
Total	7.882E-06	0.8129	3.036E-08	0.0031	0.000E+00	0.0000	0.000E+00	0.0000	1.666E-06	0.1719	0.000E+00	0.0000	1.178E-07	0.0121

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+01 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.782E-08	0.0029
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.095E-08	0.0042
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.459E-07	0.0872
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.282E-16	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.533E-06	0.8800
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.510E-08	0.0098
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.219E-08	0.0013
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.123E-08	0.0022
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.202E-07	0.0124
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.697E-06	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 3.000E+01 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Ac-227	2.684E-04	0.000E+00	5.676E-03	0.000E+00	3.763E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.331E-02
Pa-231	2.947E-04	0.000E+00	1.168E+00	0.000E+00	4.133E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.209E+00
Pb-210	7.687E-03	0.000E+00	4.892E+00	0.000E+00	1.078E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.970E+00
Po-210	7.628E-03	0.000E+00	2.408E+01	0.000E+00	1.070E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.515E+01
Ra-226	7.584E-03	0.000E+00	9.446E+00	0.000E+00	1.064E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.051E+01
Th-230	8.139E-03	0.000E+00	5.343E-01	0.000E+00	1.141E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.676E+00
U-234	7.369E-03	0.000E+00	1.702E+00	0.000E+00	1.033E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.735E+00
U-235	2.947E-04	0.000E+00	6.807E-02	0.000E+00	4.133E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.094E-01
U-238	7.369E-03	0.000E+00	1.702E+00	0.000E+00	1.033E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.735E+00

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
  and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 3.000E+01 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent   Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	4.916E-08	0.0053	1.350E-09	0.0001	0.000E+00	0.0000	8.809E-11	0.0000	0.000E+00	0.0000	5.805E-10	0.0001
Pa-231	4.282E-09	0.0005	5.389E-10	0.0001	0.000E+00	0.0000	6.324E-09	0.0007	0.000E+00	0.0000	2.238E-10	0.0000
Pb-210	3.792E-09	0.0004	3.055E-09	0.0003	0.000E+00	0.0000	1.416E-07	0.0153	0.000E+00	0.0000	3.121E-08	0.0034
Po-210	3.993E-11	0.0000	2.693E-09	0.0003	0.000E+00	0.0000	1.321E-06	0.1427	0.000E+00	0.0000	5.867E-08	0.0063
Ra-226	7.338E-06	0.7928	5.198E-09	0.0006	0.000E+00	0.0000	1.181E-07	0.0128	0.000E+00	0.0000	1.330E-08	0.0014
Th-230	8.198E-10	0.0001	6.932E-09	0.0007	0.000E+00	0.0000	1.591E-09	0.0002	0.000E+00	0.0000	3.398E-09	0.0004
U-234	2.133E-10	0.0000	4.918E-09	0.0005	0.000E+00	0.0000	3.897E-09	0.0004	0.000E+00	0.0000	2.366E-09	0.0003
U-235	1.942E-08	0.0021	1.769E-10	0.0000	0.000E+00	0.0000	1.593E-10	0.0000	0.000E+00	0.0000	9.674E-11	0.0000
U-238	1.004E-07	0.0108	4.185E-09	0.0005	0.000E+00	0.0000	4.920E-09	0.0005	0.000E+00	0.0000	2.987E-09	0.0003
Total	7.517E-06	0.8121	2.905E-08	0.0031	0.000E+00	0.0000	1.597E-06	0.1726	0.000E+00	0.0000	1.128E-07	0.0122

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water risk	Water fract.	Fish risk	Fish fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	All Pathways** risk	All Pathways** fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.118E-08	0.0055
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.137E-08	0.0012
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.796E-07	0.0194
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.382E-06	0.1493
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.475E-06	0.8076
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.274E-08	0.0014
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.139E-08	0.0012
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.985E-08	0.0021
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.125E-07	0.0122
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.256E-06	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 3.000E+01 years

Radionuclides

Radon Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+01 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground risk	Ground fract.	Inhalation risk	Inhalation fract.	Radon risk	Radon fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	Soil risk	Soil fract.
Ac-227	1.200E-08	0.0013	3.294E-10	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.372E-11	0.0000	0.000E+00	0.0000	1.416E-10	0.0000
Pa-231	4.142E-08	0.0045	1.558E-09	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	6.393E-09	0.0007	0.000E+00	0.0000	6.622E-10	0.0001
Pb-210	1.060E-09	0.0001	1.601E-09	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	4.104E-07	0.0443	0.000E+00	0.0000	2.512E-08	0.0027
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	7.201E-06	0.7780	9.197E-09	0.0010	0.000E+00	0.0000	0.000E+00	0.0000	1.156E-06	0.1249	0.000E+00	0.0000	7.706E-08	0.0083
Th-230	1.413E-07	0.0153	7.078E-09	0.0008	0.000E+00	0.0000	0.000E+00	0.0000	1.599E-08	0.0017	0.000E+00	0.0000	4.403E-09	0.0005
U-234	2.409E-10	0.0000	4.920E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	3.899E-09	0.0004	0.000E+00	0.0000	2.367E-09	0.0003
U-235	1.944E-08	0.0021	1.779E-10	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.650E-10	0.0000	0.000E+00	0.0000	9.719E-11	0.0000
U-238	1.004E-07	0.0108	4.185E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	4.920E-09	0.0005	0.000E+00	0.0000	2.988E-09	0.0003
Total	7.517E-06	0.8121	2.905E-08	0.0031	0.000E+00	0.0000	0.000E+00	0.0000	1.597E-06	0.1726	0.000E+00	0.0000	1.128E-07	0.0122

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+01 years

Water Dependent Pathways

Radio-Nuclide	Water risk	Water fract.	Fish risk	Fish fract.	Radon risk	Radon fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	All pathways risk	All pathways fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.248E-08	0.0013
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.004E-08	0.0054
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.382E-07	0.0473
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.443E-06	0.9121
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.688E-07	0.0182
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.143E-08	0.0012
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.988E-08	0.0021
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.125E-07	0.0122
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.256E-06	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 1.000E+02 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Ac-227	2.031E-04	0.000E+00	4.369E-03	0.000E+00	2.849E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.285E-02
Pa-231	2.336E-04	0.000E+00	9.258E-01	0.000E+00	3.276E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	9.586E-01
Pb-210	6.582E-03	0.000E+00	4.188E+00	0.000E+00	9.231E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.111E+00
Po-210	6.532E-03	0.000E+00	2.062E+01	0.000E+00	9.160E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.154E+01
Ra-226	6.455E-03	0.000E+00	8.040E+00	0.000E+00	9.053E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	8.945E+00
Th-230	8.137E-03	0.000E+00	5.341E-01	0.000E+00	1.141E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.675E+00
U-234	5.841E-03	0.000E+00	1.349E+00	0.000E+00	8.191E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.168E+00
U-235	2.336E-04	0.000E+00	5.395E-02	0.000E+00	3.276E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	8.672E-02
U-238	5.841E-03	0.000E+00	1.349E+00	0.000E+00	8.191E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	2.168E+00

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 1.000E+02 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent   Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	3.779E-08	0.0048	1.038E-09	0.0001	0.000E+00	0.0000	6.848E-11	0.0000	0.000E+00	0.0000	4.462E-10	0.0001
Pa-231	3.394E-09	0.0004	4.272E-10	0.0001	0.000E+00	0.0000	5.013E-09	0.0006	0.000E+00	0.0000	1.774E-10	0.0000
Pb-210	3.242E-09	0.0004	2.612E-09	0.0003	0.000E+00	0.0000	1.210E-07	0.0154	0.000E+00	0.0000	2.668E-08	0.0034
Po-210	3.414E-11	0.0000	2.302E-09	0.0003	0.000E+00	0.0000	1.129E-06	0.1433	0.000E+00	0.0000	5.016E-08	0.0064
Ra-226	6.253E-06	0.7936	4.429E-09	0.0006	0.000E+00	0.0000	1.006E-07	0.0128	0.000E+00	0.0000	1.133E-08	0.0014
Th-230	8.195E-10	0.0001	6.930E-09	0.0009	0.000E+00	0.0000	1.590E-09	0.0002	0.000E+00	0.0000	3.397E-09	0.0004
U-234	1.690E-10	0.0000	3.898E-09	0.0005	0.000E+00	0.0000	3.089E-09	0.0004	0.000E+00	0.0000	1.876E-09	0.0002
U-235	1.539E-08	0.0020	1.402E-10	0.0000	0.000E+00	0.0000	1.263E-10	0.0000	0.000E+00	0.0000	7.668E-11	0.0000
U-238	7.959E-08	0.0101	3.317E-09	0.0004	0.000E+00	0.0000	3.900E-09	0.0005	0.000E+00	0.0000	2.368E-09	0.0003
Total	6.393E-06	0.8114	2.509E-08	0.0032	0.000E+00	0.0000	1.365E-06	0.1732	0.000E+00	0.0000	9.651E-08	0.0122

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Plant		Meat		Milk		All Pathways**	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.934E-08	0.0050
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.012E-09	0.0011
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.536E-07	0.0195
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.182E-06	0.1500
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.369E-06	0.8083
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.274E-08	0.0016
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.032E-09	0.0011
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.573E-08	0.0020
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.917E-08	0.0113
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.879E-06	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 1.000E+02 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	7.253E-10	0.0001	1.992E-11	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.298E-13	0.0000	0.000E+00	0.0000	8.564E-12	0.0000
Pa-231	4.038E-08	0.0051	1.442E-09	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	5.069E-09	0.0006	0.000E+00	0.0000	6.139E-10	0.0001
Pb-210	1.060E-10	0.0000	1.602E-10	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.107E-08	0.0052	0.000E+00	0.0000	2.513E-09	0.0003
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	5.917E-06	0.7510	8.755E-09	0.0011	0.000E+00	0.0000	0.000E+00	0.0000	1.257E-06	0.1595	0.000E+00	0.0000	8.212E-08	0.0104
Th-230	3.394E-07	0.0431	7.351E-09	0.0009	0.000E+00	0.0000	0.000E+00	0.0000	5.446E-08	0.0069	0.000E+00	0.0000	6.928E-09	0.0009
U-234	3.330E-10	0.0000	3.903E-09	0.0005	0.000E+00	0.0000	0.000E+00	0.0000	3.111E-09	0.0004	0.000E+00	0.0000	1.880E-09	0.0002
U-235	1.547E-08	0.0020	1.431E-10	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.383E-10	0.0000	0.000E+00	0.0000	7.791E-11	0.0000
U-238	7.959E-08	0.0101	3.318E-09	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	3.901E-09	0.0005	0.000E+00	0.0000	2.369E-09	0.0003
Total	6.393E-06	0.8114	2.509E-08	0.0032	0.000E+00	0.0000	0.000E+00	0.0000	1.365E-06	0.1732	0.000E+00	0.0000	9.651E-08	0.0122

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.546E-10	0.0001
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.751E-08	0.0060
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.385E-08	0.0056
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.265E-06	0.9220
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.081E-07	0.0518
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.227E-09	0.0012
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.583E-08	0.0020
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.917E-08	0.0113
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.879E-06	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 3.000E+02 years

Radio-	Water Independent Pathways (Inhalation w/o radon)					Water Dependent Pathways					Total
Nuclide	Inhalation	Plant	Meat	Milk	Soil	Water	Fish	Plant	Meat	Milk	Ingestion*
Ac-227	1.042E-04	0.000E+00	2.244E-03	0.000E+00	1.461E-02	0.000E+00	0.000E+00	0.000E+00	2.759E-04	0.000E+00	1.713E-02
Pa-231	1.203E-04	0.000E+00	4.767E-01	0.000E+00	1.687E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.935E-01
Pb-210	4.271E-03	0.000E+00	2.718E+00	0.000E+00	5.989E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	3.316E+00
Po-210	4.238E-03	0.000E+00	1.338E+01	0.000E+00	5.943E-01	0.000E+00	0.000E+00	0.000E+00	3.308E-14	0.000E+00	1.397E+01
Ra-226	4.221E-03	0.000E+00	5.257E+00	0.000E+00	5.920E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	5.849E+00
Th-230	8.125E-03	0.000E+00	5.334E-01	0.000E+00	1.139E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.673E+00
U-234	3.007E-03	0.000E+00	6.945E-01	0.000E+00	4.217E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.116E+00
U-235	1.203E-04	0.000E+00	2.778E-02	0.000E+00	1.687E-02	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	4.465E-02
U-238	3.007E-03	0.000E+00	6.945E-01	0.000E+00	4.217E-01	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	1.116E+00

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 3.000E+02 years

Radon	Radionuclides							
Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	1.941E-08	0.0038	5.330E-10	0.0001	0.000E+00	0.0000	3.520E-11	0.0000	0.000E+00	0.0000	2.292E-10	0.0000
Pa-231	1.748E-09	0.0003	2.199E-10	0.0000	0.000E+00	0.0000	2.581E-09	0.0005	0.000E+00	0.0000	9.135E-11	0.0000
Pb-210	2.110E-09	0.0004	1.700E-09	0.0003	0.000E+00	0.0000	7.878E-08	0.0153	0.000E+00	0.0000	1.736E-08	0.0034
Po-210	2.222E-11	0.0000	1.498E-09	0.0003	0.000E+00	0.0000	7.348E-07	0.1428	0.000E+00	0.0000	3.264E-08	0.0063
Ra-226	4.104E-06	0.7976	2.907E-09	0.0006	0.000E+00	0.0000	6.605E-08	0.0128	0.000E+00	0.0000	7.437E-09	0.0014
Th-230	8.183E-10	0.0002	6.920E-09	0.0013	0.000E+00	0.0000	1.588E-09	0.0003	0.000E+00	0.0000	3.392E-09	0.0007
U-234	8.704E-11	0.0000	2.007E-09	0.0004	0.000E+00	0.0000	1.590E-09	0.0003	0.000E+00	0.0000	9.658E-10	0.0002
U-235	7.925E-09	0.0015	7.218E-11	0.0000	0.000E+00	0.0000	6.502E-11	0.0000	0.000E+00	0.0000	3.948E-11	0.0000
U-238	4.098E-08	0.0080	1.708E-09	0.0003	0.000E+00	0.0000	2.008E-09	0.0004	0.000E+00	0.0000	1.219E-09	0.0002
Total	4.177E-06	0.8118	1.756E-08	0.0034	0.000E+00	0.0000	8.875E-07	0.1725	0.000E+00	0.0000	6.338E-08	0.0123

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+02 years

Water Dependent Pathways

Radio-Nuclide	Water risk	Water fract.	Fish risk	Fish fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	All Pathways** risk	All Pathways** fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.841E-12	0.0000	0.000E+00	0.0000	2.021E-08	0.0039
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.640E-09	0.0009
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.996E-08	0.0194
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.015E-18	0.0000	0.000E+00	0.0000	7.690E-07	0.1495
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.180E-06	0.8124
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.272E-08	0.0025
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.650E-09	0.0009
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.101E-09	0.0016
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.591E-08	0.0089
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.841E-12	0.0000	0.000E+00	0.0000	5.145E-06	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 3.000E+02 years

Radon Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+02 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	2.394E-13	0.0000	6.573E-15	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.739E-16	0.0000	0.000E+00	0.0000	2.826E-15	0.0000
Pa-231	2.103E-08	0.0041	7.483E-10	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	2.599E-09	0.0005	0.000E+00	0.0000	3.185E-10	0.0001
Pb-210	1.475E-13	0.0000	2.230E-13	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.715E-11	0.0000	0.000E+00	0.0000	3.498E-12	0.0000
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	3.375E-06	0.6560	5.089E-09	0.0010	0.000E+00	0.0000	0.000E+00	0.0000	7.412E-07	0.1441	0.000E+00	0.0000	4.833E-08	0.0094
Th-230	7.304E-07	0.1420	7.922E-09	0.0015	0.000E+00	0.0000	0.000E+00	0.0000	1.398E-07	0.0272	0.000E+00	0.0000	1.249E-08	0.0024
U-234	9.432E-10	0.0002	2.019E-09	0.0004	0.000E+00	0.0000	0.000E+00	0.0000	1.743E-09	0.0003	0.000E+00	0.0000	9.810E-10	0.0002
U-235	8.053E-09	0.0016	7.684E-11	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.223E-11	0.0000	0.000E+00	0.0000	4.146E-11	0.0000
U-238	4.098E-08	0.0080	1.710E-09	0.0003	0.000E+00	0.0000	0.000E+00	0.0000	2.009E-09	0.0004	0.000E+00	0.0000	1.220E-09	0.0002
Total	4.177E-06	0.8118	1.756E-08	0.0034	0.000E+00	0.0000	0.000E+00	0.0000	8.875E-07	0.1725	0.000E+00	0.0000	6.338E-08	0.0123

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 3.000E+02 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.106E-15	0.0000	0.000E+00	0.0000	2.511E-13	0.0000
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.809E-12	0.0000	0.000E+00	0.0000	2.470E-08	0.0048
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	6.102E-11	0.0000
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.250E-27	0.0000	0.000E+00	0.0000	4.170E-06	0.8105
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.906E-07	0.1731
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.015E-18	0.0000	0.000E+00	0.0000	5.686E-09	0.0011
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.053E-14	0.0000	0.000E+00	0.0000	8.254E-09	0.0016
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.983E-23	0.0000	0.000E+00	0.0000	4.592E-08	0.0089
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.841E-12	0.0000	0.000E+00	0.0000	5.145E-06	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

Amount of Intake Quantities QINT(i,p,t) for Individual Radionuclides (i) and Pathways (p)
As pCi/yr at t= 1.000E+03 years

Radio-Nuclide	Water Independent Pathways (Inhalation w/o radon) Inhalation	Plant	Meat	Milk	Soil	Water Dependent Pathways Water	Fish	Plant	Meat	Milk	Total Ingestion*
Ac-227	1.020E-05	0.000E+00	2.198E-04	0.000E+00	1.431E-03	0.000E+00	0.000E+00	0.000E+00	3.232E-03	0.000E+00	4.883E-03
Pa-231	1.178E-05	0.000E+00	4.669E-02	0.000E+00	1.652E-03	0.000E+00	0.000E+00	0.000E+00	2.773E-01	0.000E+00	3.256E-01
Pb-210	1.618E-03	0.000E+00	1.030E+00	0.000E+00	2.269E-01	0.000E+00	0.000E+00	0.000E+00	3.172E-01	0.000E+00	1.574E+00
Po-210	1.604E-03	0.000E+00	5.064E+00	0.000E+00	2.250E-01	0.000E+00	0.000E+00	0.000E+00	1.447E+01	0.000E+00	1.975E+01
Ra-226	1.665E-03	0.000E+00	2.073E+00	0.000E+00	2.335E-01	0.000E+00	0.000E+00	0.000E+00	5.647E-01	0.000E+00	2.871E+00
Th-230	8.065E-03	0.000E+00	5.294E-01	0.000E+00	1.131E+00	0.000E+00	0.000E+00	0.000E+00	8.528E-07	0.000E+00	1.660E+00
U-234	2.945E-04	0.000E+00	6.802E-02	0.000E+00	4.131E-02	0.000E+00	0.000E+00	0.000E+00	4.713E-01	0.000E+00	5.806E-01
U-235	1.178E-05	0.000E+00	2.721E-03	0.000E+00	1.652E-03	0.000E+00	0.000E+00	0.000E+00	1.885E-02	0.000E+00	2.322E-02
U-238	2.945E-04	0.000E+00	6.802E-02	0.000E+00	4.131E-02	0.000E+00	0.000E+00	0.000E+00	4.713E-01	0.000E+00	5.806E-01

* Sum of all ingestion pathways, i.e. water independent plant, meat, milk, soil
  and water-dependent water, fish, plant, meat, milk pathways

Amount of Intake Quantities QINT9(irn,i,t) and QINT9W(irn,i,t) for Inhalation of
Radon and its Decay Products as pCi/yr at t= 1.000E+03 years

Radon Pathway	Radionuclides Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent   Water-dep. == Water-dependent

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-Nuclide	Ground risk	Ground fract.	Inhalation risk	Inhalation fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	Soil risk	Soil fract.
Ac-227	1.901E-09	0.0007	5.220E-11	0.0000	0.000E+00	0.0000	3.448E-12	0.0000	0.000E+00	0.0000	2.244E-11	0.0000
Pa-231	1.712E-10	0.0001	2.154E-11	0.0000	0.000E+00	0.0000	2.528E-10	0.0001	0.000E+00	0.0000	8.946E-12	0.0000
Pb-210	8.121E-10	0.0003	6.542E-10	0.0002	0.000E+00	0.0000	3.032E-08	0.0106	0.000E+00	0.0000	6.682E-09	0.0023
Po-210	8.545E-12	0.0000	5.762E-10	0.0002	0.000E+00	0.0000	2.826E-07	0.0985	0.000E+00	0.0000	1.255E-08	0.0044
Ra-226	1.644E-06	0.5728	1.164E-09	0.0004	0.000E+00	0.0000	2.646E-08	0.0092	0.000E+00	0.0000	2.980E-09	0.0010
Th-230	8.122E-10	0.0003	6.868E-09	0.0024	0.000E+00	0.0000	1.576E-09	0.0005	0.000E+00	0.0000	3.367E-09	0.0012
U-234	8.524E-12	0.0000	1.966E-10	0.0001	0.000E+00	0.0000	1.558E-10	0.0001	0.000E+00	0.0000	9.459E-11	0.0000
U-235	7.762E-10	0.0003	7.070E-12	0.0000	0.000E+00	0.0000	6.368E-12	0.0000	0.000E+00	0.0000	3.867E-12	0.0000
U-238	4.013E-09	0.0014	1.673E-10	0.0001	0.000E+00	0.0000	1.966E-10	0.0001	0.000E+00	0.0000	1.194E-10	0.0000
Total	1.653E-06	0.5758	9.708E-09	0.0034	0.000E+00	0.0000	3.416E-07	0.1190	0.000E+00	0.0000	2.583E-08	0.0090

Excess Cancer Risks CNRS(i,p,t) for Individual Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+03 years

Water Dependent Pathways

Radio-Nuclide	Water risk	Water fract.	Fish risk	Fish fract.	Plant risk	Plant fract.	Meat risk	Meat fract.	Milk risk	Milk fract.	All Pathways** risk	All Pathways** fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.289E-11	0.0000	0.000E+00	0.0000	2.032E-09	0.0007
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.571E-09	0.0005	0.000E+00	0.0000	2.025E-09	0.0007
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.509E-09	0.0033	0.000E+00	0.0000	4.798E-08	0.0167
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.195E-07	0.2855	0.000E+00	0.0000	1.115E-06	0.3886
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.328E-09	0.0026	0.000E+00	0.0000	1.682E-06	0.5860
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.581E-15	0.0000	0.000E+00	0.0000	1.262E-08	0.0044
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.129E-09	0.0004	0.000E+00	0.0000	1.585E-09	0.0006
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	4.617E-11	0.0000	0.000E+00	0.0000	8.396E-10	0.0003
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.426E-09	0.0005	0.000E+00	0.0000	5.922E-09	0.0021
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.405E-07	0.2929	0.000E+00	0.0000	2.870E-06	1.0000

** Sum of water independent ground, inhalation, plant, meat, milk, soil
and water dependent water, fish, plant, meat, milk pathways

Excess Cancer Risks CNRS9(irn,i,t) and CNRS9W(irn,i,t) for Inhalation of
Radon and its Decay Products at t= 1.000E+03 years

Radon Pathway	Rn-222	Po-218	Pb-214	Bi-214	Rn-220	Po-216	Pb-212	Bi-212
	Radionuclides							
Water-ind.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Water-dep.	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00
Total	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00	0.000E+00

Water-ind. == Water-independent Water-dep. == Water-dependent

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+03 years

Water Independent Pathways (Inhalation excludes radon)

Radio-	Ground		Inhalation		Radon		Plant		Meat		Milk		Soil	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	1.563E-25	0.0000	4.292E-27	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.689E-28	0.0000	0.000E+00	0.0000	1.846E-27	0.0000
Pa-231	2.029E-09	0.0007	7.221E-11	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.508E-10	0.0001	0.000E+00	0.0000	3.074E-11	0.0000
Pb-210	1.484E-23	0.0000	2.243E-23	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	5.748E-21	0.0000	0.000E+00	0.0000	3.518E-22	0.0000
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	4.731E-07	0.1648	7.134E-10	0.0002	0.000E+00	0.0000	0.000E+00	0.0000	1.039E-07	0.0362	0.000E+00	0.0000	6.775E-09	0.0024
Th-230	1.170E-06	0.4075	8.527E-09	0.0030	0.000E+00	0.0000	0.000E+00	0.0000	2.365E-07	0.0824	0.000E+00	0.0000	1.876E-08	0.0065
U-234	2.809E-09	0.0010	2.184E-10	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	7.158E-10	0.0002	0.000E+00	0.0000	1.398E-10	0.0000
U-235	8.190E-10	0.0003	8.603E-12	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.180E-11	0.0000	0.000E+00	0.0000	4.520E-12	0.0000
U-238	4.015E-09	0.0014	1.678E-10	0.0001	0.000E+00	0.0000	0.000E+00	0.0000	1.974E-10	0.0001	0.000E+00	0.0000	1.197E-10	0.0000
Total	1.653E-06	0.5758	9.708E-09	0.0034	0.000E+00	0.0000	0.000E+00	0.0000	3.416E-07	0.1190	0.000E+00	0.0000	2.583E-08	0.0090

Total Excess Cancer Risk CNRS(i,p,t)*** for Initially Existent Radionuclides (i) and Pathways (p)
and Fraction of Total Risk at t= 1.000E+03 years

Water Dependent Pathways

Radio-	Water		Fish		Radon		Plant		Meat		Milk		All pathways	
Nuclide	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.	risk	fract.
Ac-227	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	3.792E-27	0.0000	0.000E+00	0.0000	1.664E-25	0.0000
Pa-231	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.590E-09	0.0006	0.000E+00	0.0000	3.972E-09	0.0014
Pb-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.196E-20	0.0000	0.000E+00	0.0000	1.809E-20	0.0000
Po-210	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000
Ra-226	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	7.420E-07	0.2585	0.000E+00	0.0000	1.327E-06	0.4622
Th-230	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	9.299E-08	0.0324	0.000E+00	0.0000	1.526E-06	0.5318
U-234	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	2.383E-09	0.0008	0.000E+00	0.0000	6.265E-09	0.0022
U-235	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.055E-11	0.0000	0.000E+00	0.0000	9.245E-10	0.0003
U-238	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	1.430E-09	0.0005	0.000E+00	0.0000	5.931E-09	0.0021
Total	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	0.000E+00	0.0000	8.405E-07	0.2929	0.000E+00	0.0000	2.870E-06	1.0000

***CNRSI(i,p,t) includes contribution from decay daughter radionuclides

APPENDIX J

COST ESTIMATE DETAILS

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Appendix J, Table J-1
Summary of Alternative Costs
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

ALTERNATIVE	DESCRIPTION	ROUNDED COST (NEAREST $10,000)				DURATION (MONTHS)		
		CAPITAL COST (2020)	ANNUAL COST		NET PRESENT VALUE	PLANNING	CONSTRUCTION	TOTAL
			First 12 Years	To Year 99				
1	No Further Action	$ -	$ 819,000	$ 203,000	$ 9,383,000	0.00	0.00	0.00
2	Excavation and Off-Site Disposal at a Licensed, Low-Level Radioactive Waste Facility.	$ 898,714,371	$ 819,000	$ 203,000	$ 908,098,000	8.00	27.00	35.00
3	Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Above-Ground, On-Site Repository	$ 196,114,486	$ 819,000	$ 203,000	$ 205,502,000	12.00	33.00	45.00
4	Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Incised (Below-Ground), Tronox NAUM ALSD Regional Repository	$ 179,401,126	$ 819,000	$ 203,000	$ 188,785,000	8.00	27.00	35.00

Estimate Notes:

No Further Action annual costs include maintenance of erosion and stormwater controls and fencing.

Detailed personnel and equipment rates, quantities, and cost adjustment factors are provided in Tables J-6 thru J-8.

Equipment rates are based on rental rates obtained from Gordian (RS Means Heavy Construction Cost Data, 34th Annual Edition, 2020. Includes operator labor rates provided by EPA.

Production rates are obtained from Gordian (RS Means) Heavy Construction Cost Data, 34th Annual Edition, 2020.

The average density of all wastes were assumed to be 1.3 tons per cubic yard. Loose cubic yards assumed a 20% swell factor.

Craft labor costs assume a 10-hour work day and 5 day work week.

Labor was adjusted with a factor based on the Gallup, New Mexico city cost index for Site and Infrastructure, Demolition (RSMeans, page 635).

Materials were adjusted with a factor based on the Gallup, New Mexico city cost index for Site and Infrastructure, Demolition (RSMeans, page 635).

Equipment factor is based on the Gallup, New Mexico city cost index for Contractor Equipment (RSMeans, page 635).

Mobilization costs include transportation of equipment and personnel (e.g. heavy equipment, office trailers, and additional supplies/equipment) and limited a 5% of total construction.

Mileage is estimated to be 106 miles one way from Albuquerque, NM to the field site (86 miles to Grants plus 20 miles to site).

Per diem rates are based on the maximum Federal 2020 CONUS Per Diem Rates.

Costs for low level radiological waste disposal were obtained from quotes from vendors in December 2019.

Present Value Subtotal for PRSC costs assume a discount rate of 7.0%.

Present value of post removal site control (PRSC) costs assume quarterly SWPPP insepctions and an annual general inspection and report for the first 12 years. Costs also assume minor fencing, revegetation, and water system repairs during each inspection.

Net present value was calcuated as follows:

*NPV = Capital Cost + Annual Cost (Year 0 to 12) * P/A + Annual Cost (Years 12-99). Adjustments for future value at year 12 not included.*

Net Present Value (NPV)

Real Discount Rate, i =	7.0%
Life cycle 1 (years), n	12
Uniform Series Present Worth Factor (P/A) =	7.94
Life cycle 2 (years) to year 99, n	87
Uniform Series Present Worth Factor (P/A) =	14.25

Appendix J, Table J-2
Preliminary Construction Cost Estimate - Alternative 1
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

ALTERNATIVE 1 - No Further Action

Item	Description	Quantity	Unit	Unit Cost	Extension	Item Total	Duration (work days)
TOTAL CAPITAL COSTS:						***$0***	0
PRSC COSTS (O & M):							
1	Annual Cost for Year 1 to 12						
	Quarterly Inspections (4 person crew, 14 days, 10 hrs/day)	640	HR	$85	$54,400		
	Mileage Albuquerque, NM to Site (round trip)	424	MI	$0.58	$246		
	Mileage Grants, NM to Site (round trip)	1,280	MI	$0.58	$742		
	Inspection Crew Per Diem	64	DAY	$151	$9,664		
	Assumed Annual Maintenance Costs (revegetation, watering, fence repairs)	1,299	AC	$100	$129,860		
	Preparation of Semi-annual Reports (Professional Engineer)	80	HR	$120	$9,600		
TOTAL ANNUAL COST (YEAR 1 TO 12)				***Subtotal (Event)***	***$204,512***	***$818,049***	
2	Annual Cost for Year 13 to 99						
	Annual Inspections (4 person crew, 14 days, 10 hrs/day)	618	HR	$85	$52,562		
	Mileage Albuquerque, NM to Site (round trip)	424	MI	$0.58	$246		
	Mileage Grants, NM to Site (round trip)	1,280	MI	$0.58	$742		
	Inspection Crew Per Diem	64	DAY	$151	$9,664		
	Assumed Annual Maintenance Costs (revegetation, watering, fence repairs)	1,299	AC	$100	$129,860		
	Preparation of Semi-annual Reports (Professional Engineer)	80	HR	$120	$9,600		
TOTAL ANNUAL COST (YEAR 13 TO 99)				***Subtotal (Event)***	***$202,675***	***$202,675***	

Abbreviations:
AC = Acre HR=Hour MI = Mile O&M=Operations and Maintenance PRSC=Post-Removal Site Control

Appendix J, Table J-3
Preliminary Construction Cost Estimate - Alternative 2
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

ALTERNATIVE 2 - Excavation and Off-Site Disposal of Contaminated Soils at a Licensed, Low-Level Radioactive Waste Facility

Effort Legend
START CONTRACTOR / EPA
CONSTRUCTION CONTRACTOR

Item	Description	Quantity	Unit	Unit Cost	Extension	Item Total	Duration (work days)
CAPITAL COSTS:							
1	**Engineering Design**						168
	Project Manager	134	HR	$ 175.00	$23,520		
	Project Engineer	538	HR	$ 160.00	$86,016		
	Design Engineer	1,075	HR	$ 100.00	$107,520		
	CAD/GIS Operator	1,075	HR	$ 85.00	$91,392		
	Admin	134	HR	$ 78.00	$10,483		
	Expenses	1	LS	$ 5,000.00	$5,000		
	Subtotal Engineering Costs					***$323,931***	
2	**Planning Documents**						168
	Project Manager	134	HR	$175	$23,520		
	Project Engineer	1,075	HR	$160	$172,032		
	CAD/GIS Operator	323	HR	$85	$27,418		
	Admin	67	HR	$78	$5,242		
	Expenses	1	LS	$1,000	$1,000		
	Subtotal Planning Documents					***$229,211***	
3	**Resource Surveys**						168
	Cultural Resources Mitigation	1	EA	$200,000	$200,000		
	Geotechnical Testing and Report	2	EA	$25,000	$50,000		
	Pre-Project Aerial LIDAR Survey	1,299	AC	$ 103.50	$134,405		
	Post-Project Aerial LIDAR Survey	1,299	AC	$ 103.50	$134,405		
	Subtotal Resource Surveys					***$518,810***	
4	**Confirmation Sampling**						
	Develop Sampling and Analysis Plan (SAP)						168
	Geologist	240	HR	$105	$25,200		
	Project Manager	48	HR	$175	$8,400		
	Admin	40	HR	$78	$3,120		
	Sampling						171
	Sampling Team (five 2-person crews)	17,100	HR	$85	$1,453,500		
	Mileage (RT Grants to Site)	42,750	MI	$0.58	$24,795		
	Per Diem (10 people)	1,710	DAY	$151	$258,210		
	Miscellaneous Field Supplies and Expenses	171	DAY	$100	$17,100		
	Lab Analysis	34,125	EA	$75	$2,559,375		
	Reporting						189
	Geologist	120	HR	$105	$12,600		
	Project Manager	16	HR	$175	$2,800		
	Project Engineer	40	HR	$160	$6,400		
	CAD/GIS Operator	110	HR	$85	$9,350		
	Admin	24	HR	$78	$1,872		
	Copying	1	LS	$713	$713		
	Subtotal Confirmation Sampling					***$4,383,435***	
5	**Mobilization/Demobilization**						21
		1	LS	$15,912,548	$15,912,548		
	Subtotal Mob/Demob					***$15,912,548***	
6	**Improve/Blade Access Roads (2.6 miles)**						4.0
	Gravel Road Surfacing Materials - 8" Depth (RSM 01 55 23 0100)	30,873	SY	$13.12	$404,906		
	RSM 31 22 16.10 0010 - Crew B-32C: (1 crew)						
	Dozer, D-9 (1) & Operator	4	DAY	$3,539.41	$14,158		
	Grader (1) & Operator	4	DAY	$1,642.77	$6,571		
	Roller, Smooth Drum & Operator	4	DAY	$1,382.41	$5,530		
	Foreman (Outside)	40	HR	$86.00	$3,440		
	Laborer (2)	80	HR	$63.25	$5,060		
	Subtotal Improve Access Road					***$439,664***	

ALTERNATIVE 2 - Excavation and Off-Site Disposal of Contaminated Soils at a Licensed, Low-Level Radioactive Waste Facility							
					Effort Legend: START CONTRACTOR / EPA; CONSTRUCTION CONTRACTOR		
Item	**Description**	**Quantity**	**Unit**	**Unit Cost**	**Extension**	**Item Total**	**Duration (work days)**
7	**Clearing and Grubbing**						260
	RSM 31 11 10.10 0100 - Crew B-7 (5 crews)						
	Brush Chipper, 12" (1)	1,300	DAY	$987.11	$1,283,244		
	Crawler Loader and Operator (1)	1,300	DAY	$2,097.07	$2,726,187		
	Chain Saw, Gas (2)	2,600	DAY	$90.75	$235,950		
	Laborer (4)	52,000	HR	$63.25	$3,289,000		
	RSM 31 13 13.10 0300 - Crew B-11A: (5 crews)						
	Dozer, D-9 & Operator (1)	650	DAY	$3,539.41	$2,300,617		
	Laborer (1)	6,500	HR	$100.63	$654,095		
	Subtotal Clearing and Grubbing					***$10,489,093***	
8	**Fence Construction / Repair**						102
	RSM 32 31 13.20 0800 - Crew B-80C						
	Fence Materials (6 ga galvanized steel wire, 6' high)	127,248	LF	$30.15	$3,836,540		
	Flatbed Truck (1)	510	DAY	$932.77	$475,711		
	Manual Fence Post Auger (1)	510	DAY	$882.36	$450,004		
	Laborer (2)	1,020	HR	$63.25	$64,515		
	Subtotal Fence Construction/Repair					***$4,826,771***	
9	**Erosion and Sediment Control**						80
	RSM 32 25 14.16- Crew B-62 (2 crews)						
	Silt Fence (material)	1,038,880	LF	$1.93	$2,004,623		
	Hay Bales (material)	1,038,880	LF	$7.25	$7,531,880		
	Loader, Skid Steer, 30 H.P and Operator. (1)	800	DAY	$1,003.21	$802,564		
	Flatbed Truck and operator (1)	800	DAY	$932.77	$746,213		
	Laborer (2)	1,600	HR	$63.25	$101,200		
	Subtotal Erosion and Sediment Control					***$11,186,481***	
10	**On-Site Waste Excavation and Stockpiling**						358
	RSM 31 23 16.5 01000 - Crew B-33F (10 crews)						
	Scraper (1) & Operator	3,580	DAY	$3,133.00	$11,216,140		
	Dozer, D9 (1) & Operator	3,580	DAY	$3,539.41	$12,671,092		
	Loader (1) & Operator	3,580	DAY	$2,651.94	$9,493,961		
	Laborer (2)	71,600	HR	$63.25	$4,528,700		
	Subtotal On-Site Waste Excavation and Stockpiling		*CYD*	*$15*		***$37,909,893***	
11	**Transport and Disposal (Clean Harbors: Deer Trail, CO)**						442
	Loading: RSM 31 2323.15 6045 - Crew B-10T (5 crews)						
	Loader & Operator (1)	2,210	DAY	$2,651.94	$5,860,797		
	Laborer (2)	44,200	HR	$63.25	$2,795,650		
	Hauling: RSM 31 23 23.20 9714 (335 trucks/day)`						
	Dump truck (20 cyd highway)	148,070	DAY	$1,447.30	$214,301,711		
	Truck Mobilization Fee	335	EA	$1,289.15	$431,865		
	Truck Tarp	335	EA	$120.75	$40,451		
	Facility Disposal Fee	**3,849,631**	**TON**	**$75.00**	**$288,722,304**		
	Subtotal Off-Site Transport and Disposal	*2,961,254*	*CYD*	*$173*		***$512,152,779***	

ALTERNATIVE 2 - Excavation and Off-Site Disposal of Contaminated Soils at a Licensed, Low-Level Radioactive Waste Facility							Effort Legend: START CONTRACTOR / EPA; CONSTRUCTION CONTRACTOR
Item	**Description**	**Quantity**	**Unit**	**Unit Cost**	**Extension**	**Item Total**	**Duration (work days)**
12	**Site Restoration (staging areas, general disturbance areas)**						142.0
	RSM 31 13 13.10 0500 - Crew B-11A (1 crews)						
	Dozer, D-6 (200 HP) & Operator (1)	130	DAY	$2,061.53	$267,999		
	Laborer (1)	1,300	HR	$63.25	$82,225		
	RSM 31 22 16.10 0010 - Crew B-32C: (5 crew)						
	Grader (1) & Operator	790	DAY	$1,642.77	$1,297,786		
	Foreman (Outside)	7,900	HR	$86.00	$679,400		
	Laborer (2)	15,800	HR	$63.25	$999,350		
	RSM 32 92 19.14 4600 - Crew B-81						
	Flat Bed Truck & Operator (1)	710	DAY	$932.77	$662,264		
	Power Mulcher (1)	710	DAY	$1,135.34	$806,095		
	Laborer (1)	7,100	HR	$63.25	$449,075		
	Seed Mix	1,138	AC	$1,357.11	$1,543,715		
	Fertilizer	1,138	AC	$54.96	$62,521		
	Mulch	1,138	AC	$3,239.56	$3,684,996		
	Subtotal Site Restoration	*1,138*	*AC*	*$9,262*		***$10,535,426***	
13	**Contractor Site Overhead**	*568.0*	*DAYS OR*	*27*	*MONTHS*		-
	Project Manager (10% of time)	568	HR	$175	$99,400		
	Site Superintendent	28,400	HR	$101	$2,857,892		
	H&S Officer	11,360	HR	$85	$965,600		
	QA/QC Officer	28,400	HR	$85	$2,414,000		
	Site Foreman	28,400	HR	$86	$2,442,400		
	Field Clerk	11,360	HR	$19	$213,000		
	Site Vehicles - 4WD Trucks (10)	271	MO	$1,500.00	$406,500		
	Site Personal Vehicles (2)	271	MO	$500.00	$135,500		
	Mileage Grants, NM to Site (20 mi/each way)	90,880	MI	$0.58	$52,710		
	Construction Crew Per Diem (19 people)	10,792	DAY	$151	$1,629,592		
	Fuel for Site Vehicles (10)	271	MO	$1,600.00	$433,600		
	Port-o-let Rental (4)	109	MO	$208.00	$22,672		
	Job Trailers (2)	55	MO	$269.00	$14,795		
	Storage Boxes (2)	55	MO	$94.50	$5,198		
	Field Office Lights/HVAC (2)	55	MO	$179.00	$9,845		
	Telephone/internet (1)	28	MO	$96.00	$2,688		
	Field Office Equipment	28	MO	$230.00	$6,440		
	Field Office Supplies	28	MO	$96.00	$2,688		
	Trash (2 dumpsters)	271	MO	$910.00	$246,610		
	Air Monitoring Equipment	136	MO	$4,400.00	$598,400		
	Truck Scales	28	MO	$300.00	$8,400		
	Construction Water, including treatment (excavation)	4,935,424	GAL	$0.05	$246,771		
	Construction Water, including treatment (hauling)	88,837,632	GAL	$0.05	$4,441,882		
	6000 Gallon Water Truck and Operator (2)	1,136	DAY	$1,743.64	$1,980,774		
	Portable Water Tower Trailer, 10,000 gallons (2)	1,136	DAY	$172.36	$195,802		
	Subtotal Contractor Site Overhead	5.82%		$ 719,746.62	per mo	***$19,433,159***	
SUBTOTAL CAPITAL COSTS:							
	Planning, Engineering and Closeout		*0.88%*	of Construction		$5,455,387	
	Total Construction					$622,885,813	
14	Construction Observation/Owner's Representative		6.0%	x	$622,885,813	$37,373,149	
	Subtotal					***$665,714,349***	
15	Allowance for Level of Accuracy		25%	x	$665,714,349	$166,428,587	
	Subtotal					$832,142,936	
16	Indirect Costs - 8%		8%	x	$832,142,936	$66,571,435	
TOTAL CAPITAL COSTS:						***$898,714,371***	

ALTERNATIVE 2 - Excavation and Off-Site Disposal of Contaminated Soils at a Licensed, Low-Level Radioactive Waste Facility							Effort Legend
							START CONTRACTOR / EPA
							CONSTRUCTION CONTRACTOR
Item	**Description**	**Quantity**	**Unit**	**Unit Cost**	**Extension**	**Item Total**	**Duration (work days)**
PRSC COSTS (O & M):							
17	Annual Cost for Year 1 to 12						16.0
	Quarterly Inspections (4 person crew, 14 days, 10 hrs/day)	640	HR	$85	$54,400		
	Mileage Albuquerque, NM to Site (round trip)	424	MI	$0.58	$246		
	Mileage Grants, NM to Site (round trip)	1,280	MI	$0.58	$742		
	Inspection Crew Per Diem	64	DAY	$151	$9,664		
	Assumed Annual Maintenance Costs (revegetation, watering, fence repairs)	1,299	AC	$100	$129,860		
	Preparation of Semi-annual Reports (Professional Engineer)	80	HR	$120	$9,600		
TOTAL ANNUAL COST (YEAR 1 TO 12)				***Subtotal (Event)***	***$204,512***	***$818,049***	
18	Annual Cost for Year 13 to 99						
	Annual Inspections (4 person crew, 14 days, 10 hrs/day)	618	HR	$85	$52,562		
	Mileage Albuquerque, NM to Site (round trip)	424	MI	$0.58	$246		
	Mileage Grants, NM to Site (round trip)	1,280	MI	$0.58	$742		
	Inspection Crew Per Diem	64	DAY	$151	$9,664		
	Assumed Annual Maintenance Costs (revegetation, watering, fence repairs)	1,299	AC	$100	$129,860		
	Preparation of Semi-annual Reports (Professional Engineer)	80	HR	$120	$9,600		
TOTAL ANNUAL COST (YEAR 13 TO 99)				***Subtotal (Event)***	***$202,675***	***$202,675***	

Abbreviations:

AC = Acre	CYD = Cubic Yards per Day	EA = Each	GAL = Gallon
HR = Hour	LF = Linear Feet	LS=Lump Sum	MI=Miles
MO = Month	SY=Square Yards		

Appendix J, Table J-4
Preliminary Construction Cost Estimate - Alternative 3
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

ALTERNATIVE 3 - Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Above-Ground, On-Site Repository

Effort Legend
START CONTRACTOR / EPA
CONSTRUCTION CONTRACTOR

Item	Description	Quantity	Unit	Unit Cost	Extension	Item Total	Duration (work days)
CAPITAL COSTS:							
1	**Engineering Design**						252
	Project Manager	202	HR	$ 175.00	$35,280		
	Project Engineer	1,210	HR	$ 160.00	$193,536		
	Design Engineer	3,226	HR	$ 100.00	$322,560		
	CAD/GIS Operator	1,613	HR	$ 85.00	$137,088		
	Admin	202	HR	$ 78.00	$15,725		
	Expenses	1	LS	$ 5,000.00	$5,000		
	Subtotal Engineering Costs					***$709,189***	
2	**Planning Documents**						168
	Project Manager	134	HR	$175	$23,520		
	Project Engineer	1,075	HR	$160	$172,032		
	CAD/GIS Operator	323	HR	$85	$27,418		
	Admin	67	HR	$78	$5,242		
	Expenses	1	LS	$1,000	$1,000		
	Subtotal Planning Documents					***$229,211***	
3	**Resource Surveys**						168
	Cultural Resources Mitigation	1	EA	$200,000	$200,000		
	Geotechnical Testing and Report	2	EA	$25,000	$50,000		
	Pre-Project Aerial LIDAR Survey	1,299	AC	$ 103.50	$134,405		
	Post-Project Aerial LIDAR Survey	1,299	AC	$ 103.50	$134,405		
	Subtotal Resource Surveys					***$518,810***	
4	**Confirmation Sampling**						168
	Develop Sampling and Analysis Plan (SAP)						
	Geologist	240	HR	$105	$25,200		
	Project Manager	48	HR	$175	$8,400		
	Admin	40	HR	$78	$3,120		
	Sampling						171.0
	Sampling Team (five 2-person crews)	17,100	HR	$85	$1,453,500		
	Mileage (RT Grants to Site)	42,750	MI	$0.58	$24,795		
	Per Diem (10 people)	1,710	DAY	$151	$258,210		
	Miscellaneous Field Supplies and Expenses	171	DAY	$100	$17,100		
	Lab Analysis	34,125	EA	$75	$2,559,375		
	Reporting						189
	Geologist	120	HR	$105	$12,600		
	Project Manager	16	HR	$175	$2,800		
	Project Engineer	40	HR	$160	$6,400		
	CAD/GIS Operator	110	HR	$85	$9,350		
	Admin	24	HR	$78	$1,872		
	Copying	1	LS	$713	$713		
	Subtotal Confirmation Sampling					***$4,383,435***	
5	**Mobilization/Demobilization**						21
		1	LS	$6,263,672	$6,263,672		
	Subtotal Mob/Demob			.		***$6,263,672***	
6	**Improve/Blade Access Roads (2.6 miles)**						4.0
	Gravel Road Surfacing Materials - 8" Depth (RSM 01 55 23 0100)	30,873	SY	$13.12	$404,906		
	RSM 31 22 16.10 0010 - Crew B-32C: (1 crew)						
	Dozer, D-9 (1) & Operator	4	DAY	$3,539.41	$14,158		
	Grader (1) & Operator	4	DAY	$1,642.77	$6,571		
	Roller, Smooth Drum & Operator	4	DAY	$1,382.41	$5,530		
	Foreman (Outside)	40	HR	$86.00	$3,440		
	Laborer (2)	80	HR	$63.25	$5,060		
	Subtotal Improve Access Road					***$439,664***	

Appendix J, Table J-4 (Continued)
Preliminary Construction Cost Estimate - Alternative 3
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

ALTERNATIVE 3 - Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Above-Ground, On-Site Repository

Effort Legend
START CONTRACTOR / EPA
CONSTRUCTION CONTRACTOR

Item	Description	Quantity	Unit	Unit Cost	Extension	Item Total	Duration (work days)
7	**Clearing and Grubbing**						260
	RSM 31 11 10.10 0100 - Crew B-7 (5 crews)						
	Brush Chipper, 12" (1)	1,300	DAY	$987.11	$1,283,244		
	Crawler Loader and Operator (1)	1,300	DAY	$2,097.07	$2,726,187		
	Chain Saw, Gas (2)	2,600	DAY	$90.75	$235,950		
	Laborer (4)	52,000	HR	$63.25	$3,289,000		
	RSM 31 13 13.10 0300 - Crew B-11A: (5 crews)						
	Dozer, D-9 & Operator (1)	650	DAY	$3,539.41	$2,300,617		
	Laborer (1)	6,500	HR	$100.63	$654,095		
	Subtotal Clearing and Grubbing					***$10,489,093***	
8	**Fence Construction / Repair**						102
	RSM 32 31 13.20 0800 - Crew B-80C						
	Fence Materials (6 ga galvanized steel wire, 6' high)	127,248	LF	$30.15	$3,836,540		
	Flatbed Truck (1)	510	DAY	$932.77	$475,711		
	Manual Fence Post Auger (1)	510	DAY	$882.36	$450,004		
	Laborer (2)	1,020	HR	$63.25	$64,515		
	Subtotal Fence Construction/Repair					***$4,826,771***	
9	**Erosion and Sediment Control**						80
	RSM 32 25 14.16- Crew B-62 (10 crews)						
	Silt Fence (material)	1,038,880	LF	$1.93	$2,004,623		
	Hay Bales (material)	1,038,880	LF	$7.25	$7,531,880		
	Loader, Skid Steer, 30 H.P and Operator. (1)	800	DAY	$1,003.21	$802,564		
	Flatbed Truck and operator (1)	800	DAY	$932.77	$746,213		
	Laborer (2)	1,600	HR	$63.25	$101,200		
	Subtotal Erosion and Sediment Control					***$11,186,481***	
10	**On-Site Waste Excavation and Hauling**						329
	RSM 31 23 16.50 0200 - Crew B-33F (10 crews)						
	Scraper & Operator	3,300	DAY	$ 3,133.00	$10,338,900.00		
	Dozer, D9 (1) & Operator	3,300	DAY	$ 3,539.41	$11,680,056.67		
	Loader (1) & Operator	3,300	DAY	$ 2,651.94	$8,751,416.67		
	Laborer (2)	66,000	HR	$ 63.25	$4,174,500.00		
	RSM 31 23 23.15 6045 - Crew B-10T (6 crews)						
	Front End Loader, 3 CY bucket	708	DAY	$ 2,651.94	$1,877,577		
	Laborer	7,080	HR	$ 63.25	$447,810		
	RSM 31 23 23.20 6190 - Crew 34G (15 crews)						
	Haul Truck, 34 CY, Off-Road, 15 MPH, Cycle 4 miles	1,860	DAY	$ 2,213.87	$4,117,792.00		
	Laborer	18,600	HR	$ 63.25	$1,176,450.00		
	Subtotal On-Site Waste Excavation and Hauling	2,625,646	CYD	$16		***$42,564,502***	
11	**Final Cover Borrow Soil Excavation, Hauling, and Placement**						110
	RSM 31 23 16.46 5540 - Crew B-10X						
	Dozer, D-9 (460 HP) & Operator (1)	220	DAY	$3,539.41	$778,670		
	Laborer (1)	2,200	HR	$63.25	$139,150		
	RSM 31 23 23.15 6045 - Crew B-10T						
	Front End Loader, 3 CY bucket (1)	222	DAY	$2,651.94	$588,732		
	Laborer (1)	2,220	HR	$63.25	$140,415		
	RSM 31 23 23.20 6190 - Crew 34G (5 crew)						
	Haul Truck, 34 CY, Off-Road, 15 MPH, Cycle 2 miles (1)	580	DAY	$2,213.87	$1,284,043		
	Laborer (1)	5,800	HR	$63.25	$366,850		
	Subtotal Final Cover Borrow Soil Excavation, Hauling, and Placement	246245	CYD	$13		***$3,297,860***	

Appendix J, Table J-4 (Continued)
Preliminary Construction Cost Estimate - Alternative 3
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

ALTERNATIVE 3 - Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Above-Ground, On-Site Repository

Effort Legend
START CONTRACTOR / EPA
CONSTRUCTION CONTRACTOR

Item	Description	Quantity	Unit	Unit Cost	Extension	Item Total	Duration (work days)
12	**Construction of Waste Cell**						494
	RSM 31 23 17 0190 - Crew B-10M						
	Dozer, D-6 (300 HP) & Operator (1)	4,940	DAY	$2,061.53	$10,183,975		
	Laborer (1)	49,400	HR	$63.25	$3,124,550		
	RSM 31 23 23.23 5080 - Crew 10Y						
	Smooth Drum Roller, Riding	706	DAY	$1,382.41	$975,982		
	Laborer (1)	7,060	HR	$63.25	$446,545		
	Compaction Testing (1 per 1000 cyd)	2,468	EA	$253.00	$624,331		
	Grader (1) & Operator	706	DAY	$1,642.77	$1,159,793		
	Subtotal Construction of Waste Cell	*2,467,712*	*CYD*	*$ 6.69*		***$16,515,176***	
13	**Construction of Soil Cap**						50
	RSM 31 23 17 0190 - Crew B-10M x3						
	Dozer, D-6 (300 HP) & Operator (1)	345	DAY	$2,061.53	$711,229		
	Laborer (1)	3,430	HR	$63.25	$216,948		
	RSM 31 23 23.23 5080 - Crew 10Y						
	Smooth Drum Roller, Riding	72	DAY	$1,382.41	$99,534		
	Grader (1) & Operator	720	DAY	$1,642.77	$1,182,792		
	Laborer (1)	720	HR	$63.25	$45,540		
	Compaction Testing (1 per 1000 cyd)	246	EA	$253.00	$62,300		
	Subtotal Construction of Clean Soil Cover	*246,245*	*CYD*	*$ 9.41*		***$2,318,342***	
14	**Site Restoration (staging areas, general disturbance areas)**						142.0
	RSM 31 13 13.10 0500 - Crew B-11A (1 crews)						
	Dozer, D-6 (200 HP) & Operator (1)	130	DAY	$2,061.53	$267,999		
	Laborer (1)	1,300	HR	$63.25	$82,225		
	RSM 31 22 16.10 0010 - Crew B-32C: (5 crew)						
	Grader (1) & Operator	790	DAY	$1,642.77	$1,297,786		
	Foreman (Outside)	7,900	HR	$86.00	$679,400		
	Laborer (2)	15,800	HR	$63.25	$999,350		
	RSM 32 92 19.14 4600 - Crew B-81						
	Flat Bed Truck & Operator (1)	710	DAY	$932.77	$662,264		
	Power Mulcher (1)	710	DAY	$1,135.34	$806,095		
	Laborer (1)	7,100	HR	$63.25	$449,075		
	Seed Mix	1,138	AC	$1,357.11	$1,543,715		
	Fertilizer	1,138	AC	$54.96	$62,521		
	Mulch	1,138	AC	$3,239.56	$3,684,996		
	Subtotal Site Restoration	*1,138*	*AC*	*$9,262*		***$10,535,426***	

ALTERNATIVE 3 - Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Above-Ground, On-Site Repository

Effort Legend: START CONTRACTOR / EPA; CONSTRUCTION CONTRACTOR

Item	Description	Quantity	Unit	Unit Cost	Extension	Item Total	Duration (work days)
15	**Contractor Site Overhead**	*686.0*	*DAYS OR*	*33*	*MONTHS*		
	Project Manager (10% of time)	686	HR	$175	$120,050		
	Site Superintendent	34,300	HR	$101	$3,451,609		
	H&S Officer	13,720	HR	$85	$1,166,200		
	QA/QC Officer	34,300	HR	$85	$2,915,500		
	Site Foreman	34,300	HR	$86	$2,949,800		
	Field Clerk	13,720	HR	$19	$257,250		
	Site Vehicles - 4WD Trucks (10)	327	MO	$1,500.00	$490,500		
	Site Personal Vehicles (2)	327	MO	$500.00	$163,500		
	Mileage Grants, NM to Site (20 mi/each way)	109,760	MI	$0.58	$63,661		
	Construction Crew Per Diem (19 people)	13,034	DAY	$151	$1,968,134		
	Fuel for Site Vehicles (10)	327	MO	$1,600.00	$523,200		
	Port-o-let Rental (4)	131	MO	$208.00	$27,248		
	Job Trailers (2)	66	MO	$269.00	$17,754		
	Storage Boxes (2)	66	MO	$94.50	$6,237		
	Field Office Lights/HVAC (2)	66	MO	$179.00	$11,814		
	Telephone/internet (1)	33	MO	$96.00	$3,168		
	Field Office Equipment	33	MO	$230.00	$7,590		
	Field Office Supplies	33	MO	$96.00	$3,168		
	Trash (2 dumpsters)	327	MO	$910.00	$297,570		
	Air Monitoring Equipment	164	MO	$4,400.00	$721,600		
	Truck Scales	33	MO	$300.00	$9,900		
	Construction Water, including treatment (excavation)	4,935,424	GAL	$0.05	$246,771		
	Construction Water, including treatment (hauling waste soil plus cap mat'l)	100,983,096	GAL	$0.05	$5,049,155		
	6000 Gallon Water Truck and Operator (2)	1,372	DAY	$1,743.64	$2,392,273		
	Portable Water Tower Trailer, 10,000 gallons (2)	1,372	DAY	$172.36	$236,479		
	Subtotal Contractor Site Overhead	17.56%		*$ 700,003.96*	per mo	***$23,100,131***	
SUBTOTAL CAPITAL COSTS:							
	Planning, Engineering and Closeout		*4.44%*	of Construction		$5,840,645	
	Total Construction					$131,537,118	
16	Construction Observation/Owner's Representative		6.0%	x	$131,537,118	$7,892,227	
	Subtotal					***$145,269,989***	
17	Allowance for Level of Accuracy		25%	x	$145,269,989	$36,317,497	
	Subtotal					$181,587,487	
18	Indirect Costs - 8% (Items 1 - 17, and 19)		8%	x	$181,587,487	$14,526,999	
TOTAL CAPITAL COSTS:						***$196,114,486***	
PRSC COSTS (O & M):							
19	Annual Cost for Year 1 to 12						16.0
	Quarterly Inspections (4 person crew, 14 days, 10 hrs/day)	640	HR	$85	$54,400		
	Mileage Albuquerque, NM to Site (round trip)	424	MI	$0.58	$246		
	Mileage Grants, NM to Site (round trip)	1,280	MI	$0.58	$742		
	Inspection Crew Per Diem	64	DAY	$151	$9,664		
	Assumed Annual Maintenance Costs (revegetation, watering, fence repairs)	1,299	AC	$100	$129,860		
	Assumed Annual Cover Maintenance Costs (erosion repair & reseeding)	1	AC	$114	$104		
	Preparation of Semi-annual Reports (Professional Engineer)	80	HR	$120	$9,600		
TOTAL ANNUAL COST (YEAR 1 TO 12)				***Subtotal (Event)***	***$204,616***	***$818,465***	

ALTERNATIVE 3 - Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Above-Ground, On-Site Repository							**Effort Legend**
							START CONTRACTOR / EPA
							CONSTRUCTION CONTRACTOR
Item	**Description**	**Quantity**	**Unit**	**Unit Cost**	**Extension**	**Item Total**	**Duration (work days)**
20	**Annual Cost for Year 13 to 99**						
	Annual Inspections (4 person crew, 14 days, 10 hrs/day)	618	HR	$85	$52,562		
	Mileage Albuquerque, NM to Site (round trip)	424	MI	$1	$246		
	Mileage Grants, NM to Site (round trip)	1,280	MI	$0.58	$742		
	Inspection Crew Per Diem	64	DAY	$151	$9,664		
	Assumed Annual Cover Maintenance Costs (erosion repair & reseeding)	1	AC	$57	$52		
	Assumed Annual Maintenance Costs (revegetation, watering, fence repairs)	1,299	AC	$100	$129,860		
	Preparation of Semi-annual Reports (Professional Engineer)	80	HR	$120	$9,600		
TOTAL ANNUAL COST (YEAR 13 TO 99)				***Subtotal (Event)***	***$202,727***	***$202,727***	

Abbreviations:

AC = Acre
CYD = Cubic Yards per Day
EA = Each
GAL = Gallon
HR = Hour
LF = Linear Feet
LS=Lump Sum
MI=Miles
MO = Month
SY=Square Yards

Appendix J, Table J-5
Preliminary Construction Cost Estimate - Alternative 4
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

ALTERNATIVE 4 - Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Incised (Below-Ground), Tronox NAUM ALSD Regional Repository

Effort Legend
START CONTRACTOR / EPA
CONSTRUCTION CONTRACTOR

Item	Description	Quantity	Unit	Unit Cost	Extension	Item Total	Duration (work days)
CAPITAL COSTS:							
1	**Engineering Design**						168
	Project Manager	134	HR	$ 175.00	$23,520		
	Project Engineer	538	HR	$ 160.00	$86,016		
	Design Engineer	1,075	HR	$ 100.00	$107,520		
	CAD/GIS Operator	1,075	HR	$ 85.00	$91,392		
	Admin	134	HR	$ 78.00	$10,483		
	Expenses	1	LS	$ 5,000.00	$5,000		
	Subtotal Engineering Costs					***$323,931***	
2	**Planning Documents**						168
	Project Manager	134	HR	$175	$23,520		
	Project Engineer	1,075	HR	$160	$172,032		
	CAD/GIS Operator	323	HR	$85	$27,418		
	Admin	67	HR	$78	$5,242		
	Expenses	1	LS	$1,000	$1,000		
	Subtotal Planning Documents					***$229,211***	
3	**Resource Surveys**						168
	Cultural Resources Mitigation	1	EA	$200,000	$200,000		
	Geotechnical Testing and Report	2	EA	$25,000	$50,000		
	Pre-Project Aerial LIDAR Survey	1,299	AC	$ 103.50	$134,405		
	Post-Project Aerial LIDAR Survey	1,299	AC	$ 103.50	$134,405		
	Subtotal Resource Surveys					***$518,810***	
4	**Confirmation Sampling**						168
	Develop Sampling and Analysis Plan (SAP)						
	Geologist	240	HR	$105	$25,200		
	Project Manager	48	HR	$175	$8,400		
	Admin	40	HR	$78	$3,120		
	Sampling						171.0
	Sampling Team (five 2-person crews)	17,100	HR	$85	$1,453,500		
	Mileage (RT Grants to Site)	42,750	MI	$0.58	$24,795		
	Per Diem (10 people)	1,710	DAY	$151	$258,210		
	Miscellaneous Field Supplies and Expenses	171	DAY	$100	$17,100		
	Lab Analysis	34,125	EA	$75	$2,559,375		
	Reporting						189
	Geologist	120	HR	$105	$12,600		
	Project Manager	16	HR	$175	$2,800		
	Project Engineer	40	HR	$160	$6,400		
	CAD/GIS Operator	110	HR	$85	$9,350		
	Admin	24	HR	$78	$1,872		
	Copying	1	LS	$713	$713		
	Subtotal Confirmation Sampling					***$4,383,435***	
5	**Mobilization/Demobilization**						21
		1	LS	$5,724,813	$5,724,813		
	Subtotal Mob/Demob					***$5,724,813***	
6	**Improve/Blade Access Roads (2.6 miles)**						4.0
	Gravel Road Surfacing Materials - 8" Depth (RSM 01 55 23 0100)	30,873	SY	$13.12	$404,906		
	RSM 31 22 16.10 0010 - Crew B-32C: (1 crew)						
	Dozer, D-9 (1) & Operator	4	DAY	$3,539.41	$14,158		
	Grader (1) & Operator	4	DAY	$1,642.77	$6,571		
	Roller, Smooth Drum & Operator	4	DAY	$1,382.41	$5,530		
	Foreman (Outside)	40	HR	$86.00	$3,440		
	Laborer (2)	80	HR	$63.25	$5,060		
	Subtotal Improve Access Road					***$439,664***	
7	**Clearing and Grubbing**						260
	RSM 31 11 10.10 0100 - Crew B-7 (5 crews)						
	Brush Chipper, 12" (1)	1,300	DAY	$987.11	$1,283,244		
	Crawler Loader and Operator (1)	1,300	DAY	$2,097.07	$2,726,187		
	Chain Saw, Gas (2)	2,600	DAY	$90.75	$235,950		
	Laborer (4)	52,000	HR	$63.25	$3,289,000		
	RSM 31 13 13.10 0300 - Crew B-11A: (5 crews)						
	Dozer, D-9 & Operator (1)	650	DAY	$3,539.41	$2,300,617		
	Laborer (1)	6,500	HR	$100.63	$654,095		
	Subtotal Clearing and Grubbing					***$10,489,093***	

ALTERNATIVE 4 - Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Incised (Below-Ground), Tronox NAUM ALSD Regional Repository

Effort Legend
START CONTRACTOR / EPA
CONSTRUCTION CONTRACTOR

Item	Description	Quantity	Unit	Unit Cost	Extension	Item Total	Duration (work days)
8	**Fence Construction / Repair**						102
	RSM 32 31 13.20 0800 - Crew B-80C						
	Fence Materials (6 ga galvanized steel wire, 6' high)	127,248	LF	$30.15	$3,836,540		
	Flatbed Truck (1)	510	DAY	$932.77	$475,711		
	Manual Fence Post Auger (1)	510	DAY	$882.36	$450,004		
	Laborer (2)	1,020	HR	$63.25	$64,515		
	Subtotal Fence Construction/Repair					***$4,826,771***	
9	**Erosion and Sediment Control**						80
	RSM 32 25 14.16- Crew B-62 (2 crews)						
	Silt Fence (material)	1,038,880	LF	$1.93	$2,004,623		
	Hay Bales (material)	1,038,880	LF	$7.25	$7,531,880		
	Loader, Skid Steer, 30 H.P and Operator. (1)	800	DAY	$1,003.21	$802,564		
	Flatbed Truck and operator (1)	800	DAY	$932.77	$746,213		
	Laborer (2)	1,600	HR	$63.25	$101,200		
	Subtotal Erosion and Sediment Control					***$11,186,481***	
10	**On-Site Waste Excavation and Stockpiling**						358
	RSM 31 23 16.5 0100 - Crew B-33F (10 crews)						
	Scraper & Operator (1500 ft haul)	3580	DAY	$ 3,133.00	###########		
	Dozer, D9 (1) & Operator	3580	DAY	$ 3,539.41	###########		
	Loader (1) & Operator	3580	DAY	$ 2,651.94	$9,493,961.11		
	Laborer (2)	71600	HR	$ 63.25	$4,528,700.00		
	Subtotal On-Site Waste Excavation and Stockpiling	*2467712*	*CYD*	*$ 15.36*		**$37,909,893**	
11	**Transport and Disposal (Tronox ALSD Regional Repository)**						442
	Loading: RSM 31 2323.15 6045 - Crew B-10T (5 crews)						
	Loader & Operator (1)	2,210	DAY	$2,651.94	$5,860,797		
	Laborer (2)	44,200	HR	$ 63.25	$2,795,650		
	Hauling: RSM 31 23 23.20 4062						
	Haul Truck, 20 CY, Off-Road, 35 MPH, Cycle 6 miles	7,794	DAY	$1,447.30	$11,280,256		
	Truck Mobilization Fee	18	EA	$1,289.15	$23,205		
	Truck Tarp	18	EA	$120.75	$2,174		
	Subtotal Transport and Disposal (Tronox ALSD Regional Repository)	*1,162,696*	*CYD*	*$ 17.17*		***$19,962,082***	
12	**Site Restoration (staging areas, general disturbance areas)**						142
	RSM 31 13 13.10 0500 - Crew B-11A (1 crews)						
	Dozer, D-6 (200 HP) & Operator (1)	130	DAY	$2,061.53	$267,999		
	Laborer (1)	1,300	HR	$63.25	$82,225		
	RSM 31 22 16.10 0010 - Crew B-32C: (5 crew)						
	Grader (1) & Operator	790	DAY	$1,642.77	$1,297,786		
	Foreman (Outside)	7,900	HR	$86.00	$679,400		
	Laborer (2)	15,800	HR	$63.25	$999,350		
	RSM 32 92 19.14 4600 - Crew B-81						
	Flat Bed Truck & Operator (1)	710	DAY	$932.77	$662,264		
	Power Mulcher (1)	710	DAY	$1,135.34	$806,095		
	Laborer (1)	7,100	HR	$63.25	$449,075		
	Seed Mix	1,138	AC	$1,357.11	$1,543,715		
	Fertilizer	1,138	AC	$54.96	$62,521		
	Mulch	1,138	AC	$3,239.56	$3,684,996		
	Subtotal Site Restoration	*1,138*	*AC*	*$9,262*		***$10,535,426***	

Appendix J, Table J-5 (Continued)
Preliminary Construction Cost Estimate - Alternative 4
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

ALTERNATIVE 4 - Excavation, Consolidation, and Long-Term Management of Radiologically Contaminated Soils at an Incised (Below-Ground), Tronox NAUM ALSD Regional Repository

Effort Legend: START CONTRACTOR / EPA; CONSTRUCTION CONTRACTOR

Item	Description	Quantity	Unit	Unit Cost	Extension	Item Total	Duration (work days)
13	**Contractor Site Overhead**	*557.0*	*DAYS OR*	*27*	*MONTHS*		months
	Project Manager (10% of time)	557	HR	$175	$97,475		
	Site Superintendent	27,850	HR	$101	$2,802,546		
	H&S Officer	11,140	HR	$85	$946,900		
	QA/QC Officer	27,850	HR	$85	$2,367,250		
	Site Foreman	27,850	HR	$86	$2,395,100		
	Field Clerk	11,140	HR	$19	$208,875		
	Site Vehicles - 4WD Trucks (10)	266	MO	$1,500.00	$399,000		
	Site Personal Vehicles (2)	266	MO	$500.00	$133,000		
	Mileage Grants, NM to Site (20 mi/each way)	89,120	MI	$0.58	$51,690		
	Construction Crew Per Diem (19 people)	10,583	DAY	$151	$1,598,033		
	Fuel for Site Vehicles (10)	266	MO	$1,600.00	$425,600		
	Port-o-let Rental (4)	107	MO	$208.00	$22,256		
	Job Trailers (2)	54	MO	$269.00	$14,526		
	Storage Boxes (2)	54	MO	$94.50	$5,103		
	Field Office Lights/HVAC (2)	54	MO	$179.00	$9,666		
	Telephone/internet (1)	27	MO	$96.00	$2,592		
	Field Office Equipment	27	MO	$230.00	$6,210		
	Field Office Supplies	27	MO	$96.00	$2,592		
	Trash (2 dumpsters)	266	MO	$910.00	$242,060		
	Air Monitoring Equipment	133	MO	$4,400.00	$585,200		
	Truck Scales	27	MO	$300.00	$8,100		
	Construction Water, including treatment (excavation)	4,935,424	GAL	$0.05	$246,771		
	Construction Water, including treatment (hauling)	88,837,632	GAL	$0.05	$4,441,882		
	6000 Gallon Water Truck and Operator (2)	1,114	DAY	$1,743.64	$1,942,414		
	Portable Water Tower Trailer, 10,000 gallons (2)	1,114	DAY	$172.36	$192,010		
	Subtotal Contractor Site Overhead		16%	$ 709,142.59	per mo	***$19,146,850***	
SUBTOTAL CAPITAL COSTS:							
	Planning, Engineering and Closeout		*4.54%*	of Construction		$5,455,387	
	Total Construction					$120,221,072	
14	Construction Observation/Owner's Representative		6.0%	x	$120,221,072	$7,213,264	
	Subtotal					***$132,889,723***	
15	Allowance for Level of Accuracy		25%	x	$132,889,723	$33,222,431	
	Subtotal					$166,112,154	
16	Indirect Costs - 8%		8%	x	$166,112,154	$13,288,972	
TOTAL CAPITAL COSTS:						***$179,401,126***	
PRSC COSTS (O & M):							
17	Annual Cost for Year 1 to 12						16.0
	Quarterly Inspections (4 person crew, 14 days, 10 hrs/day)	640	HR	$85	$54,400		
	Mileage Albuquerque, NM to Site (round trip)	424	MI	$0.58	$246		
	Mileage Grants, NM to Site (round trip)	1,280	MI	$0.58	$742		
	Inspection Crew Per Diem	64	DAY	$151	$9,664		
	Assumed Annual Maintenance Costs (revegetation, watering, fence repairs)	1,299	AC	$100	$129,860		
	Preparation of Semi-annual Reports (Professional Engineer)	80	HR	$120	$9,600		
TOTAL ANNUAL COST (YEAR 1 TO 12)				***Subtotal (Event)***	***$204,512***	***$818,049***	
18	Annual Cost for Year 13 to 99						
	Annual Inspections (4 person crew, 14 days, 10 hrs/day)	618	HR	$85	$52,562		
	Mileage Albuquerque, NM to Site (round trip)	424	MI	$0.58	$246		
	Mileage Grants, NM to Site (round trip)	1,280	MI	$0.58	$742		
	Inspection Crew Per Diem	64	DAY	$151	$9,664		
	Assumed Annual Maintenance Costs (revegetation, watering, fence repairs)	1,299	AC	$100	$129,860		
	Preparation of Semi-annual Reports (Professional Engineer)	80	HR	$120	$9,600		
TOTAL ANNUAL COST (YEAR 13 TO 99)				***Subtotal (Event)***	***$202,675***	***$202,675***	

Abbreviations:
AC = Acre; CYD = Cubic Yards per Day; EA = Each; GAL = Gallon
HR = Hour; LF = Linear Feet; LS=Lump Sum; MI=Miles
MO = Month; SY=Square Yards

Appendix J, Table J-6
Equipment and Personnel Rates
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Equipment and Personnel Rates

Reference: RS Means Heavy Construction Cost Data 2020

Equipment and Operator Unit Costs

Equipment/Personnel	RS Means	Equipment Hourly Operating Cost	Equipment Rental per Month	Equipment Cost per Day	EPA Provided Operator/ Driver Hourly Rate	Equipment + Operator	Total per Day, including O&P
Manual Fence Post Auger	RSM 01 54 33.20 0095	$ 0.45	$ 755.00	$ 33.86	$ 84.85	$ 882.36	**$ 882.36**
Backhoe Loader (40 hp)	RSM 01 54 33.20 0400	$ 11.86	$ 2,200.00	$ 204.16	$ 84.85	$ 1,052.66	**$ 1,052.66**
Excavator (7 CY)	RSM 01 54 33.20 0340	$ 174.67	$ 30,600.00	$ 2,936.70	$ 84.85	$ 3,785.20	**$ 3,785.20**
Brush Chipper, 12" (130 hp)	RSM 01 54 33.20 0550	$ 23.60	$ 3,050.00	$ 354.61	$ 63.25	$ 987.11	**$ 987.11**
Grader (30,000 lbs)	RSM 01 54 33.20 1910	$ 32.76	$ 12,000.00	$ 794.27	$ 84.85	$ 1,642.77	**$ 1,642.77**
Power Mulcher	RSM 01 54 33.20 2860	$ 17.99	$ 2,750.00	$ 286.84	$ 84.85	$ 1,135.34	**$ 1,135.34**
Sheepsfoot Roller, Towed (50 hp)	RSM 01 54 33.20 3150	$ 25.56	$ 3,475.00	$ 390.74	$ -	$ 390.74	**$ 390.74**
Smooth Drum Vibratory Roller, (125 hp)	RSM 01 54 33.20 3400	$ 27.53	$ 6,650.00	$ 533.91	$ 84.85	$ 1,382.41	**$ 1,382.41**
Scraper (21 cy)	RSM 01 54 33.20 3550	$ 140.95	$ 22,500.00	$ 2,284.50	$ 84.85	$ 3,133.00	**$ 3,133.00**
Dozer, D-6 (200 hp)	RSM 01 54 33.20 4260	$ 62.97	$ 15,000.00	$ 1,213.03	$ 84.85	$ 2,061.53	**$ 2,061.53**
Dozer, D-9 (500 hp)	RSM 01 54 33.20 4370	$ 132.98	$ 35,000.00	$ 2,690.91	$ 84.85	$ 3,539.41	**$ 3,539.41**
Crawler Loader (3 CY)	RSM 01 54 33.20 4560	$ 71.19	$ 13,800.00	$ 1,248.57	$ 84.85	$ 2,097.07	**$ 2,097.07**
Front End Loader (8 CY)	RSM 01 54 33.20 4810	$ 90.90	$ 23,000.00	$ 1,803.44	$ 84.85	$ 2,651.94	**$ 2,651.94**
1 Loader, Skid Steer (30 hp)	RSM 01 54 33.20 4880	$ 9.54	$ 1,525.00	$ 154.71	$ 84.85	$ 1,003.21	**$ 1,003.21**
Dump Trail Only (20 CY)	RSM 01 54 33.20 5400	$ 6.18	$ 1,525.00	$ 121.11	$ -	$ 121.11	**$ 121.11**
Dump Truck, 34 CY, Off-Road (50 ton)	RSM 01 54 33.20 5610	$ 83.87	$ 16,500.00	$ 1,480.37	$ 73.35	$ 2,213.87	**$ 2,213.87**
Dump Truck, 20 CY, Highway rated	RSM 01 54 33.20 5310			$ 713.80	$ 73.35	$ 1,447.30	**$ 1,447.30**
Tractor, with Attachment	RSM 01 54 33.40 6465	$ 17.37	$ 3,525.00	$ 310.78	$ 84.85	$ 1,159.28	**$ 1,159.28**
6,000 Gal Water Truck	RSM 01 54 33.40 6950	$ 71.75	$ 7,525.00	$ 1,010.14	$ 73.35	$ 1,743.64	**$ 1,743.64**
Flatbed Truck (20,000 lb)	RSM 01 54 33.40 7290	$ 15.26	$ 1,200.00	$ 199.27	$ 73.35	$ 932.77	**$ 932.77**
Truck Tractor, 6 x 4 (450 hp)	RSM 01 54 33.40 7600	$ 44.23	$ 3,725.00	$ 587.16	$ 73.35	$ 1,320.66	**$ 1,320.66**
Portable Water Tower Trailer, 10,000 gallons	RSM 01 54 33.40.6925	$ 9.75	$ 1,925.00	$ 172.36	$ -	$ 172.36	**$ 172.36**
Pump, Concrete, Truck Mounted, 4" Line, 80' Boom	RSM 01 54 33.10.2120	$ 29.79	$ 2,575.00	$ 398.04	$ 73.35	$ 1,131.54	**$ 1,131.54**
Chain Saws, Gas				$ 90.75	$ -	$ 90.75	**$ 90.75**
Hydraulic Crane, 25 ton	RSM 01 54 19.50 0500	$ 36.36		$ 485.00	$ 84.85	$ 1,333.50	**$ 1,333.50**
Hydraulic Crane, 55 ton	RSM 01 54 33 2600	$ 53.78		$ 915.00	$ 84.85	$ 1,763.50	**$ 1,763.50**
Hydraulic Crane, 80 ton	RSM 01 54 19.50 0201	$ 75.71		$ 1,475.00	$ 84.85	$ 2,323.50	**$ 2,323.50**

Construction and Engineering Personnel Rates

Personnel	Source	Hourly Rate	Daily Rate
Truck Driver (Heavy)	RS Means Labor Data	$ 73.35	$ 733.50
Laborer	RS Means Labor Data	$ 63.25	$ 632.50
Foreman (Outside)	RS Means Labor Data	$ 86.00	$ 860.00
Equipment Operator (Medium)	RS Means Labor Data	$ 84.85	$ 848.50
Site Superintendent (maximum)	RSM 01 31 13.20	$ 100.63	$ 1,006.30
Admin (Clerk)	RSM 01 31 13.20	$ 18.75	$ 187.50
Sampling Team/Scientist		$ 85.00	$ 850.00
CAD/GIS Operator		$ 85.00	$ 850.00
Design Engineer		$ 100.00	$ 1,000.00
Geologist		$ 105.00	$ 1,050.00
Professional Engineer		$ 120.00	$ 1,200.00
Project Engineer		$ 160.00	$ 1,600.00
Project Manager		$ 175.00	$ 1,750.00
Admin Assistant		$ 78.00	$ 780.00

Per Diem and Mileage Rates

Allowance	Source	Lodging	M&IE	Total
Per Diem Rate (per Day)	www.gsa.gov	$ 96.00	$ 55.00	$ 151.00
Mileage Rate (per Mile)	www.gsa.gov	--	--	$ 0.58

Appendix J, Table J-7
Material and Work Quantities
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Material and Work Quantities

Removal Volume Estimates*	Depth (ft)	Surface Area (ft^2)	Surface Area (Acres)	Volume (ft^3)	Volume (CY)
Waste Material Volume*					
1 ft. Tronox and non-Tronox Excavation Area		*46,500,300*	1,067.50	46,498,850.30	1,722,180
2 ft. Tronox and non-Tronox Excavation Area		*10,066,716*	231.10	20,129,361.10	745,532
Totals of Excavation		**56,567,016**	**1,298.60**	**66,628,211.40**	**2,467,712**
Transported Volume, CY	Swell Factor =	20%	or x	1.20	2,961,254
Transported Weight, TONS	Conversion from tons to yd3			1.30	3,849,631
Truck loads	34 cubic yard vehicle less 10% for payload qty.				95,805
CYD to Tons coversion:	1 yd3 x 27 ft3/yd3 x 95 lbs/ft3 2000 / lbs/ton = 1.30 ton/yd3		(roundup)		
Alternative 3 - Repository Cap Volume					
Waste Material Volume (ft3)					66,628,211
Waste Material Volume (yd3)					2,467,712
Estimated Cap Footprint, Acres					62
Estimated Cap Footprint, Square Feet					39,802
Evapotranspiration/Erosion Control Layer Volume (C3D Volume)					337,374
Cap Volume (C3D Volume)					**246,245**

QUANTITIES CALCULATIONS

TOTAL VOLUME OF INFILL (CUYD): 2,471,014
TARGET VOLUME OF INFILL (CUYD): 2,467,712
VOLUME OF FILL FOR EVAPOTRANSPIRATION AND
EROSION CONTRL COVER (CUYD): 246,245
TOTAL AREA (ACRES): 62
BOUNDARY FENCE (LF): 6,592

Fencing Perimeter -Alternative 2, 3, & 4	Linear Feet
	127,248

Revegetation Areas

Revegetation Area - Alternative 2, 3, & 4	(MSF)	(ft^2)	(Acres)*
Removal Area	56,568	56,567,016	1,299
Repository Area (within Removal Area)	40	39,802	1

Appendix J, Table J-7 (Continued)
Material and Work Quantities
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Material and Work Quantities

Study Area Unit Costs

Work Item	Quantity	Unit	Unit Price	Extended Cost	Reference	Assumptions
Cultural Resources Mitigation	1	Each	$ 200,000.00	$ 200,000.00	Vendor's Quote	Cultural study has been performed but number of sites have not be selected
Geotechnical Testing and Report	2	Each	$ 25,000.00	$ 50,000.00	RSM 02 32 13.10	Assumed two studies for project
Aerial Survey (LIDAR)	1,299	AC	$ 103.50	$ 134,405.10	RSM 02 21 13.16 2000	Assumed price x2 due to small area

Material Unit Prices

Work Item	Quantity	Unit	Unit Price (x Factor)	Extended Cost	Reference	Assumptions
Road Gravel (Materials)	1	SY	$ 13.12	$ 13.12	RSM 01 55 23.50 0100	0.9 miles of road, 20 feet wide
Fence Repair (Materials)	1	LF	$ 30.15	$ 30.15	RSM 32 31 13.20 0200	
Silt Fence (Materials)	1	LF	$ 1.93	$ 1.93	RSM 31 25 14.16 1000	Assumed 800 feet required per acre
Sediment Log, filter Sock, 12"	1	LF	$ 7.25	$ 0.01	RSM 32 91 13.16 0350	
Seeds (Materials) - All Alternatives	1	AC	$ 1,357.11	$ 1,357.11	RSM 32 92 19.14 5300	
Soil Amendments (Humate) (Materials)	1	AC	$ 123,672.29	$ 123,672.29	RSM 32 91 13.23 4050	Assumed $250/ton delivered, at 700 lb/acre
Fertilizer (Materials) - All Alternatives	1	AC	$ 54.96	$ 54.96	RSM 32 91 13.23 4150	
Multch (Materials) - All Alternatives	1	AC	$ 3,239.56	$ 3,239.56	RSM 32 91 13.16 0700	
Waste Soil Transportation	1	TON	$ 105.00	$ 105.00	Facility Quote	Assumed 1.3 tons per CY, and 20% swell
Waste Soil Processing Fee	1	TON	$ 105.00	$ 105.00	Facility Quote	Assumed 1.3 tons per CY, and 20% swell
Truck Mobilization Fee	1	Each	$ 1,289.15	$ 1,289.15	Facility Quote	Assumed 300 trucks, 2-day rotation
Truck Tarp	1	Each	$ 120.75	$ 120.75	Facility Quote	Assumed 300 trucks, 2-day rotation
Job Trailers	1	MO	$ 269.00	$ 269.00	RSM 01 52 13.20 0350	
Storage Boxes	1	MO	$ 94.50	$ 94.50	RSM 01 52 13.20 1250	
Field Office Lights/HVAC	1	MO	$ 179.00	$ 179.00	RSM 01 52 13.40 0160	Assumed a 138 kV Transmission
Telephone/internet	1	MO	$ 96.00	$ 96.00	RSM 01 52 13.40 0140	
Portable Toilet	1	MO	$ 208.00	$ 208.00	RSM 01 54 33.40 6410	
Field Office Equipment	1	MO	$ 230.00	$ 230.00	RSM 01 52 13.40 0100	
Field Office Supplies	1	MO	$ 96.00	$ 96.00	RSM 01 52 13.40 0120	
Trash (2 dumpsters, 6CY capacity)	1	WEEK	$ 455.00	$ 910.00	RSM 02 41 19.19 0600	
Air Monitoring Equipment	1	MO	$ 4,400.00	$ 4,400.00	Vendor Quote	
Site Vehicles- 4WD Trucks	1	MO	$ 1,500.00	$ 1,500.00	RSM 01 54 33.40 7200	
Site Vehicles	1	MO	$ 500.00	$ 500.00	Engineering Estimate	
Fuel for Vehicles	1	MO	$ 1,600.00	$ 1,600.00	Engineering Estimate	$2.40/gal, 15 mi/gal, 10,000 miles/month
Truck Scales	1	MO	$ 300.00	$ 300.00	Engineering Estimate	
Construction Water, including Hauling	1	GAL	$ 0.05	$ 0.05	Engineering Estimate	Assumed 2 gal/CY for excavation, 30 gal/CY for hauling dust control
Construction Water, including Hauling	1	GAL	$ 0.05	$ 0.05	Engineering Estimate	Assumed 2 gal/CY for excavation, 30 gal/CY for hauling dust control
Portable Water Tower Trailer, 10,000 gallons	1	EA	$ 25,300.00	$ 25,300.00	RSM 33 16 36.16 0100	
Compaction Test (Field)	1	EA	$ 253.00	$ 253.00	RS Means 01 45 23.50 4	Assumed 1 test per 2,000 CY
Radiological Confirmation Sample (Lab)	1	EA	$ 75.00	$ 75.00	Engineering Estimate	Assumed 30 samples per acre, $60/lab sample, $15/sample for shipping

Reference: RS Means Heavy Construction Cost Data 2020

Abbreviations:

4WD = four-wheel drive AC = acre CUYD/ CY/ CYD = cubic yard ft^2 = square feet ft^3/ ft3 = cubic feet GAL = gallon LF = linear feet MO = month
MSF = thousand square feet SY = square yards yd3 = cubic yard

Appendix J, Table J-8
Location Adjustment Factors
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

Location Adjustment Factors for Gallup, New Mexico

Reference: RS Means Heavy Construction Cost Data 2020

The majority of the work will be Excavation (as defined by RS Means) by Equipment Operators, Laborers, and Foremen

Labor[1]

Category	Gallup, NM Installation Factor
Excavation	0.975

Materials[2]

	Gallup, NM Materials Factor
	1.005

Equipment[3]

	Gallup, NM Equipment Factor
	1.075

Time[4]

Historical Cost Indexes		
January 2020	January 2016	Time Factor
239.1	207.3	1.15

[1] Labor factor is based on the Gallup, New Mexico city cost index for Site and Infrastructure, Demolition (RSMeans, page 635).
Workers Comp % is based on New Mexico rates for Excavation (RSMeans, page 669).

[2] Materials factor is based on the Gallup, New Mexico city cost index for Site and Infrastructure, Demolition (RSMeans, page 586).

[3] Equipment factor is based on the Gallup, New Mexico city cost index for Contractor Equipment (RSMeans, page 635).

[4] Time factor is based on adjusting 2016 cost data to January 2020, using RS Means Historical Cost Indexes (RS Means, page 612).

APPENDIX K

LONG-TERM STORAGE FACILITY (REPOSITORY) RADON FLUX CALCULATIONS

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Alternative 3 (Above-Ground, On-Site Repository) and Alternative 4 (Incised [Below-Ground], Tronox NAUM ALSD Regional Repository)

	Type of Material	[1]Thickness of Layer (cm) (x)	[2]Porosity of Material (Unitless) (n)	[3]Density of Material (g/cm^3) (ρ)	[4]Radon Emanation Coefficient (Unitless) (E)	[4]Radon Decay Constant (1/s) (λ)	[3]Long-term Average Moisture Content (Dry weight percentage) (w)	[4]Specific Gravity of Soils (Unitless) (G)
Contaminated Soils	Native soil	222	0.305660377	1.84	0.35	2.10E-06	10	2.65
Cover layer	Native soil	0	0.305660377	1.84	0.35	2.10E-06	10	2.65
	[3]Specific Activity of Ra-226 (pCi/g) (R)	[2]Moisture saturation fractions (Unitless) (m)	[2]Radon Diffusion Coefficients (cm^2/s) (D)	[2]Inverse relaxation length (1/cm) (b)	[2]Interface constants (cm^2/s) (a)	[4]Equilibrium distrubution Coffecient of Radon in Water and Air (pCi/cm^3) (k)	[2]Radon Flux from the bare contaminated soil (pCi/m^2-s) (J_t)	[2]Radon Flux from the Cover (pCi/m^2-s) (J_c)
Contaminated Soils	12.51	0.6020	5.75E-03	0.0191	0.0002	0.2600	9	
Cover Layer	1.1	0.6020	5.75E-03	0.0191	0.0002	0.2600		**8.9**
							State of New Mexico Guidance Radon Flux Limit:	20

[1]Thickness of cover layer was determined by trial and error in order to determine the maximum thickness with a Radon Flux result less than or equal to the state of New Mexico guidance limit of 20 pCi/m2-s. A cover thickness of 0 centimeters produces a radon flux of 8.9 pCi/m^2-s. The contaminated soil thickness of 222 centimeters = 7.3 feet. The long-term storage facility (repository) designs for Alternatives 3 and 4 feature a contaminated-soils thickness greater than 222 centimeters; the radon flux calculated result remains the same (8.9 pCi/m^2-s) beyond a thickness of 222 centimeters.

[2]Value calculated per NRC Regulatory Guide 3.64 formulas noted below. The NRC Regulatory Guide 3.64 formulas were designed with uranium mill tailings in mind; therefore, the subscripts 't' and 'c' in the formulas below refer to 'tailings' and 'cover', respectively. In this case, the formulas and terms with the 't' subscript are used for 'Contaminated Soils' and the formulas and terms with the 'c' subscript are used for 'Cover layer'.
[3]The Contaminated Soils Specific Activity of Ra-226 value equals the mean analytical result for all surface and subsurface soil samples (see Tables 1-2 and 1-3 and Figures 1-13 through 1-19. The Cover Layer Specific Activity of Ra-226 value equals the mean surface soil sample analytical result of the Central GSA Background Reference Area.
[4]Value obtained from NRC Regulatory Guide 3.64.

NRC Regulatory Guide 3.64 Radon Flux Formulas:

$J_t = 10^4 * R * \rho * E * \sqrt{\lambda * D}$ * hyperbolic tangent of $(x * \sqrt{\lambda / D})$

$$J_c = \frac{2 * J_t * e^{-b_c * x_c}}{1 + \sqrt{a_t / a_c}}$$

$$D = 0.07 * e^{-4 * (m - (m * n^2) + (m^5))}$$

$m = \frac{10^{-2} * \rho * w}{n * \rho_w}$; ρ_w is the mass density of water = 1 g/cm3

$n = 1 - \frac{\rho}{G * \rho_w}$; ρ_w is the mass density of water = 1 g/cm^3

$b = \sqrt{\lambda / D}$

$a = n^2 * D * (1-((1-k) * m))^2$

APPENDIX L

LONG-TERM STORAGE FACILITY (REPOSITORY) PRELIMINARY DESIGN DRAWINGS

QUANTITIES CALCULATIONS

TOTAL VOLUME OF INFILL (CUYD):	2,471,014
TARGET VOLUME OF INFILL (CUYD):	2,467,712
FILL VOLUME FOR EVAPO-TRANSPIRATION/ EROSION LAYER (CUYD):	246,245
TOTAL AREA (ACRES):	62
BOUNDARY FENCE (LF):	6,592

NO.	DATE	APPR.	REVISION	NO.	DATE	APPR.	REVISION

ENVIRONMENTAL PROTECTION AGENCY
TRONOX NAUM, CENTRAL GSA MINES SITE

GRANTS NEW MEXICO

WESTON SOLUTIONS

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CHECKED	RGE	DATE SEPT 20	CLIENT APPROVALS	DATE
DES. ENG.	RE/AWB	SEPT 20		
PROJ. ENG.	DSC	SEPT 20		
PROJ. MGR.	RGE	SEPT 20		
APPROVED				
APPROVED				

CENTRAL GSA
PRELIMINARY ON-SITE REPOSITORY
PLAN VIEW

DRAWN	DATE	DWG. NO.	REV. NO.
AMB/RW	SEPT 20	FIG 1	A
SCALE	W.O. NO. 20600.012.001.1035	SHT. ---- OF 2	

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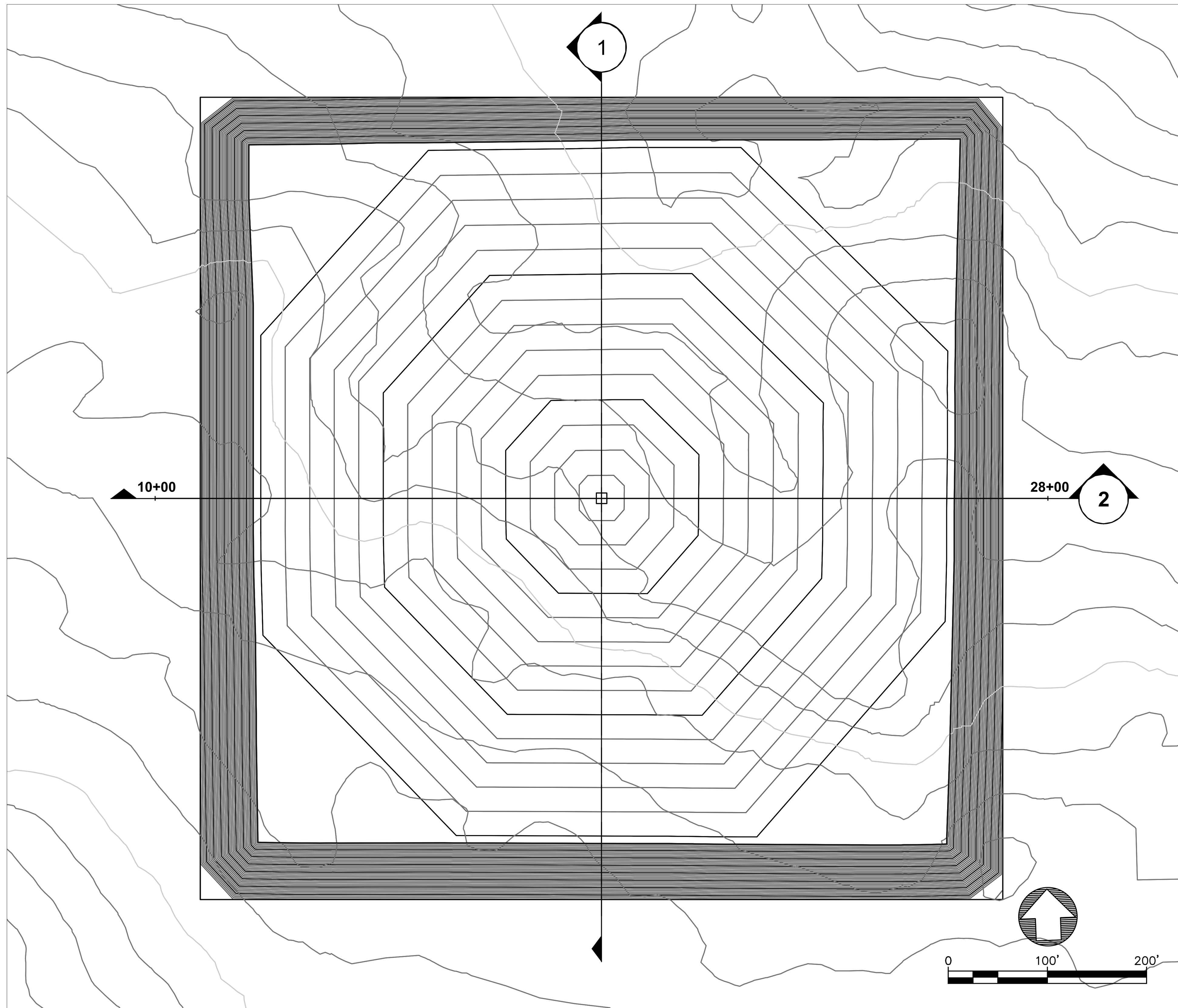
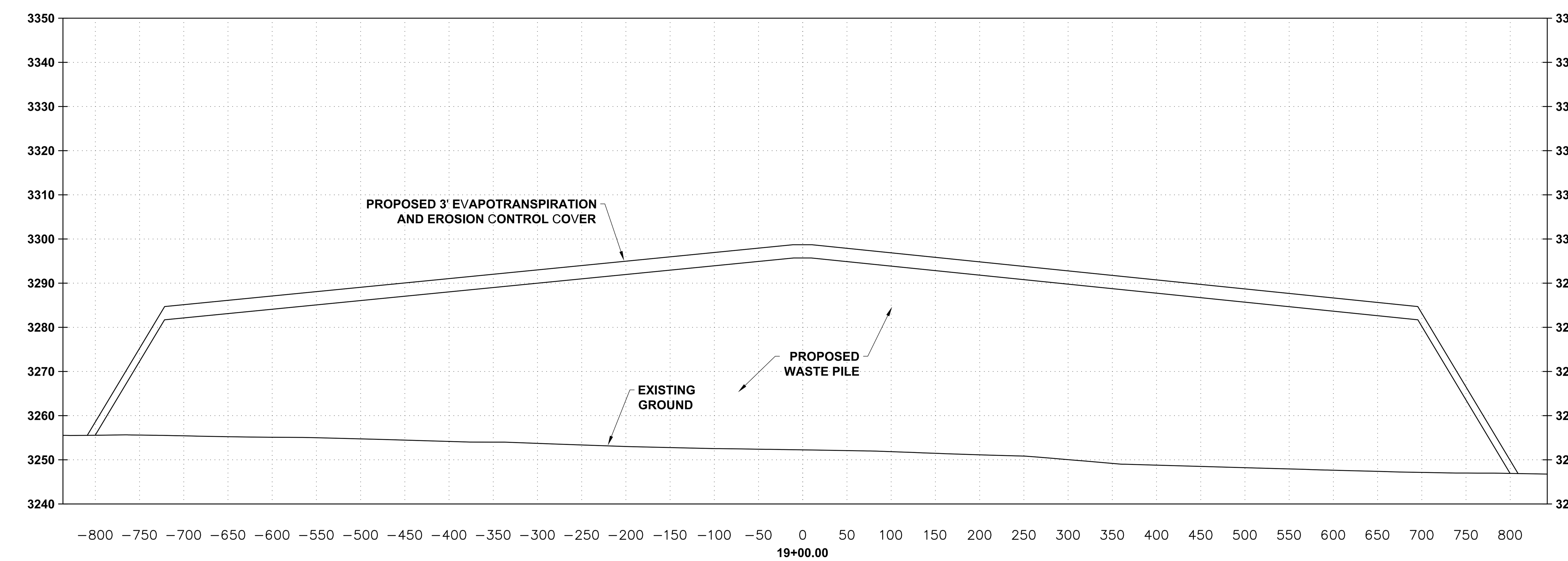
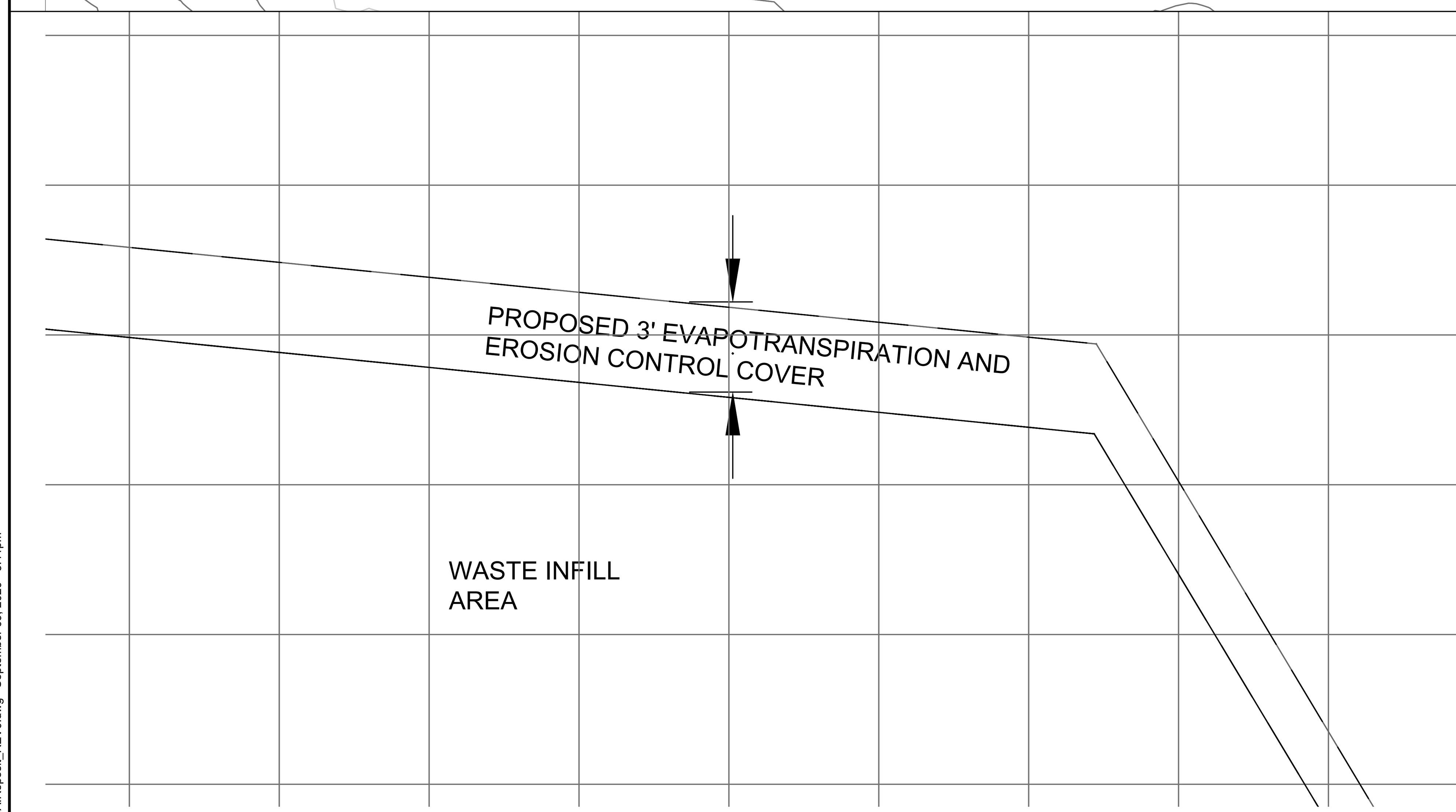




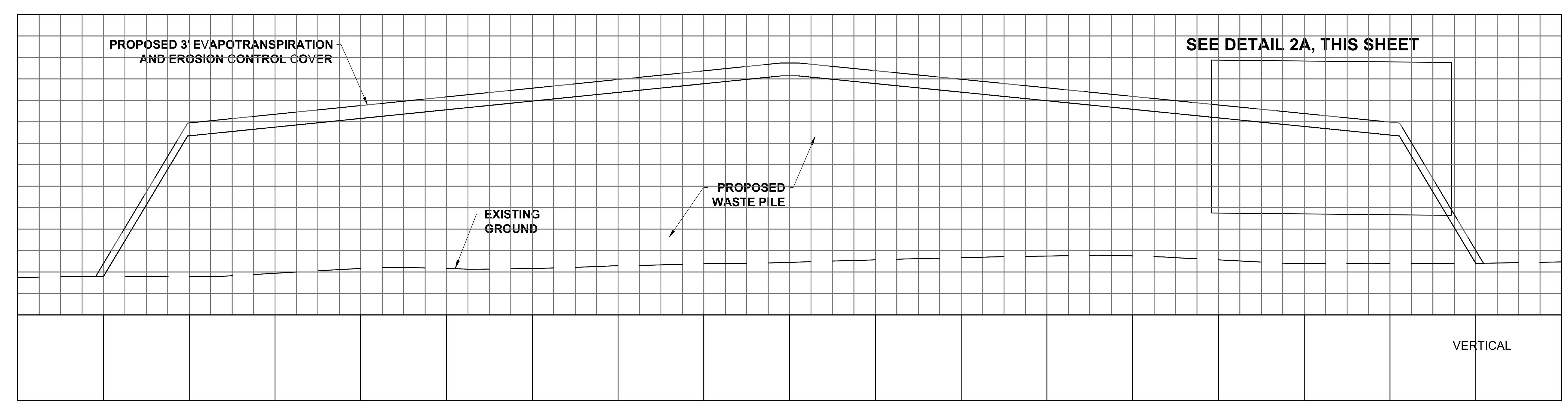
1 WASTE PILE AND CAP
SECTION VIEW

0 100' 200'
HORIZONTAL

0 20' 40'
VERTICAL



2A WASTE PILE AND CAP DETAIL
NOT TO SCALE



2 WASTE PILE AND CAP
PROFILE VIEW

0 100' 200'
HORIZONTAL

0 20' 40'
VERTICAL

NO.	DATE	APPR.	REVISION	NO.	DATE	APPR.	REVISION

ENVIRONMENTAL PROTECTION AGENCY
TRONOX NAUM, CENTRAL GSA MINES SITE

GRANTS — NEW MEXICO

WESTON SOLUTIONS

		DATE	CLIENT APPROVALS	DATE
CHECKED	RGE	SEPT 20		
DES. ENG.	RE/AMB	SEPT 20		
PROJ. ENG.	DSC	SEPT 20		
PROJ. MGR.	--	SEPT 20		
APPROVED				
APPROVED				

ALTERNATIVE 3: ABOVE-GROUND ON-SITE REPOSITORY PLAN, PROFILE AND SECTION VIEWS

DRAWN	DATE	DWG. NO.	REV. NO.
AMB/RW	SEPTEMBER '20	FIG. 2	A
SCALE	W.O. NO. 20600.012.001.1035	SHT ---- OF 2	

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APPENDIX M

GREEN ALTERNATIVES ASSESSMENT

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1. Green Alternatives Assessment

Based on EPA guidance, there are five core (key) elements in "greener cleanup activities" that should be considered throughout the remedy selection process (EPA, 2016). These key elements include: minimizing total energy use and increasing the percentage of renewable energy; minimizing air pollutants and greenhouse gas emissions; minimizing water use and negative impacts on water resources; protecting ecosystem services; and improving materials management and waste reduction efforts by reducing, reusing, or recycling whenever feasible (EPA, 2012). This analysis compares the effects each removal action alternative, described in Section 3 of the main Engineering Evaluation/ Cost Analysis (EE/CA) report, has on the five key "green" elements. Each of the five elements was scored qualitatively for each removal alternative using a numerical ranking system 1 through 4, with 1 being the best and 4 being the worst (i.e., low scores are greener cleanup alternatives). Each alternative's Greener Cleanup Assessment Score was derived from the sum of the five scores for that alternative. The results of this assessment are summarized in Table M-1. Alternative 3, Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Above-Ground, On-Site Repository, scored the best (low score of 8) of the 4 removal alternatives.

2. Minimizes Total Energy Use and Increases Percentage of Renewable Energy Use

Out of the four removal action alternatives, Alternative 1, the No Further Action Alternative is the only alternative that requires no energy. For the 3 other alternatives, energy usage can be broken into two main categories: electrical usage and direct fossil fuel combustion.

All of the alternatives have relatively low electrical requirements. The main electricity demands are expected to be for power to pump water from the on-site supply well, to operate the water treatment system, to be constructed as part of the removal action, and to heat and cool to the office trailers brought in to support personnel. Alternative 2 would have higher electrical demand than Alternatives 3 or 4 since the off-site low-level radioactive disposal facility would require additional office support and water. Alternative 4 would have a slightly higher electrical demand than Alternative 3 since the regional Ambrosia Lake Sub-District (ALSD) repository would require more infrastructure (secondary supply well, water treatment system, office trailers) than an on-site repository located on the Central GSA Mines Site. Since active removal work is expected to be conducted during daylight hours, lighting requirements are expected to be minimal for all alternatives. The primary expected lighting needs would be during the darkest winter months, should work occur during those periods, to illuminate the on-site office trailer(s) and equipment yards.

The greatest fossil fuel consumption will be for heavy equipment and trucks used during excavation and transportation. Heavy construction equipment would be used to clear and grub, excavate, transfer, load, and grade the access roads, site, and impacted materials. Large dump trucks would be used to transport clean backfill to the site and to transport and dispose of waste material. Alternative 2 has the largest fossil fuel demand due to having the greatest number of loads transported off-site and farthest distance to the off-site disposal facility. Alternative 4 has a larger fossil fuel demand than Alternative 3 due to having a farther distance to the regional ALSD repository. The transportation requirement of each alternative is summarized in Table 4-2 of the main EE/CA report.

The use of biodiesel in place of diesel for heavy equipment use or transportation is recommended. Given that the ability to use biodiesel does not vary between alternatives and it is unknown if biodiesel fuels will be ultimately used, this analysis assumes heavy equipment will be operated using traditional petroleum-based fuel sources.

The alternatives rank as follows in order of least to most fossil fuel consumption: Alternative 1 (No Further Action), Alternative 3 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Above-Ground, On-Site Repository), Alternative 4 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Incised (Below-Ground), ALSD Regional Repository, and Alternative 2 (Excavation and Off-Site Disposal of Contaminated Soils at Licensed Low-Level Radioactive Waste Facility)..

3. Minimizes Air Pollutants and Greenhouse Gas Emissions

Relevant air pollutants include greenhouse gases, nitrogen oxides (NOx), sulfur oxides (SOx), particulate matter less than 10 microns in size (PM10), and hazardous air pollutants (HAPs). Fossil fuel combustion is expected to be the only source of HAPs and the major source of greenhouse gases, NOx, SOx, and PM10.

PM10 is generated during excavating and grading activities, including excavating material, hauling or otherwise handling excavated material, placing and compacting earthen materials, and driving on unpaved roads. Dust generation can be reduced through dust suppression methods, such as applying water, covering material in open trucks, using soil tackifiers, covering stockpiles, limiting on-site vehicle speed, and revegetating excavated areas as quickly as possible. Due to the factors discussed previously, air pollution emissions will be highest for alternatives that transport waste off-site.

As with energy demand, the greatest air pollution generation will be from the operation of heavy equipment during excavation activities and from trucks used to transport materials and waste. Estimated greenhouse gas emissions due to off-site trucking are summarized in Table 4-2 (main EE/CA report). Thus, the ranking for air pollution and greenhouse gas emissions is the same as for minimizing energy consumption. As with energy demand, Alternative 2 is expected to create air pollution that is an order of magnitude greater than the other alternatives due to the significant number of loads transported off-site and the distance to the off-site disposal facility.

Given all the factors outlined above, the alternatives rank as follows from least to most air pollution generated: Alternative 1 (No Further Action), Alternative 3 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Above-Ground, On-Site Repository), Alternative 4 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Incised (Below-Ground), ALSD Regional Repository, and Alternative 2 (Excavation and Off-Site Disposal of Contaminated Soils at Licensed Low-Level Radioactive Waste Facility).

4. Minimizes Water Use and Negative Impacts to Water Resources

Surface waters in the area are ephemeral and are generally only present for a day or two after rains occur during summer monsoon periods. Because of this, a local water source is unavailable; water demand will have to be met by trucking water in from outside or by installing a well. Water use should also be considered as part of the energy demand transportation requirements and thus should be minimized because of the impact on water resources and because of the associated increase in electrical and fossil fuel demands. The main use of water, regardless of which alternative is selected, will be for dust suppression and soil moisture conditioning to achieve the required relative density for compacted soil. Water will also be used for equipment decontamination. Thus, the alternatives with the highest excavation, consolidation, and transportation requirements will also have the highest water use.

Water use will not be the only impact on water resources. The creation of impervious caps reduces the infiltration of stormwater, resulting in higher peak flows in the receiving stream. The creation of engineered soil caps will temporarily increase runoff until vegetation is well established and final stabilization is achieved, which could take as long as 10 years. The higher peak flows will result in an increased risk of flooding and higher rates of erosion, which would impact water quality. This effect will increase in direct proportion to the footprint of any impervious cap. If the waste is disposed of at a licensed facility, the size of the cap in relation to the volume of waste may be reduced due to consolidation with waste from other sites. However, these facilities are also the most likely to use impervious caps. The risk of increasing peak flows can be mitigated by diverting the runoff for another use, such as irrigation, or diverting it to an area it can infiltrate into the ground, such as bioswales and stormwater detention basins. In addition to reducing infiltration, a cap can potentially change drainage patterns. However, this effect can be reduced by mimicking the slope of existing terrain.

Sediment runoff, particularly during excavation activities, can also degrade water quality during the project. Sediment runoff will increase nutrient loading and suspended solids in the receiving water. Since the sediment runoff would largely be from contaminated soil, another potential impact is the migration of radiation into nearby water resources. The greater the excavation footprint and duration of excavation, the greater expected impact. Sediment runoff can be minimized by avoiding excavation activities during the monsoon season, minimizing the amount of soil disturbed at a given time, and using sediment controls (e.g., reseeding bare soil as quickly as possible; installing silt fence, straw wattles and fiber rolls; and constructing stormwater detention basins). Migration of waste off-site through stormwater is a general concern for water bodies. With the exception of Alternative 1, No Further Action, all of the alternatives provide long-term mitigation of waste migration off-site. Alternative 4 has a larger water use and impact on water resources than Alternative 3 because the regional ALSD repository contributes to a larger overall footprint. Alternative 2 has a higher water usage than Alternatives 3 or 4 since the off-site low-level radioactive disposal facility requires additional resources.

Given all the factors outlined above, the alternatives rank as follows for their water use and impact on water resources from best to worst: Alternative 3 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Above-Ground, On-Site Repository), Alternative 4 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Incised (Below-Ground), ALSD Regional Repository, Alternative 2 (Excavation and Off-Site Disposal of Contaminated Soils at Licensed Low-Level Radioactive Waste Facility), and Alternative 1 (No Further Action).

5. Improves Materials Management and Waste Reduction Efforts

Materials management and waste reduction efforts consider the total amount of materials used on-site and the percentage of those materials that are produced from recycled material, reused material, or waste material. Excluding fuels, which are evaluated separately, imported materials include the earth and rock materials in caps, geotextile fabrics, temporary fencing, silt fencing, culverts, large rock for riprap, and other water management and sediment and erosion control devices. The alternatives will all generate cleared vegetation in proportion to the amount of land disturbed. These factors are expected to apply regardless of which alternative is selected (i.e., whether on- or off-site, all are expected to require varying amounts of the above materials).

Alternative 4 has a larger footprint than Alternative 3 and therefore will require the use of more materials. Alternative 2 requires more resources and materials than Alternatives 3 or 4.

Given these factors, the alternatives rank as follows for their impact on materials management and waste reduction from best to worst: Alternative 1 (No Further Action), Alternative 3 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Above-Ground, On-Site Repository), Alternative 4 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Incised (Below-Ground), ALSD Regional Repository, and Alternative 2 (Excavation and Off-Site Disposal of Contaminated Soils at Licensed Low-Level Radioactive Waste Facility).

6. Protects Ecosystem Services

The negative effect on water resources described above is one of the ecosystem services impacts. Degrading water quality and quantity will affect the flora and fauna that depend on these sources. Increased nutrient loading could cause algae blooms in downstream water bodies, and increased suspended solids could inhibit stream life by blocking sunlight that allows photosynthesis. The more effective alternatives will be more protective of ecosystem services.

Given that none of the alternatives disturb previously undisturbed areas, or areas with hazardous waste, long-term habitat degradation on land is unlikely in all alternatives. However, removal activities themselves will cause a temporary disruption to wildlife. Noise, ground disturbing work, and any artificial light can all impact sensitive species. To minimize these impacts, it is recommended to avoid conducting operations during nesting or breeding seasons whenever possible.

Given all the factors outlined previously, the alternatives rank as follows for their impact on ecosystem services from best to worst: Alternative 3 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Above-Ground, On-Site Repository), Alternative 4 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Incised (Below-Ground), ALSD Regional Repository, Alternative 2

(Excavation and Off-Site Disposal of Contaminated Soils at Licensed Low-Level Radioactive Waste Facility), and Alternative 1 (No Further Action).

7. Summary

A summary of the rankings for each of the core elements can be found in Table M-1. This table also presents an overall greenness score for each alternative. The overall greenness score was calculated by summing the ranks that each alternative received for each of the five core areas. A lower score represents a greener cleanup alternative. The overall ranking of alternatives for greenness, from best to worse, are as follows:

Alternative 3 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Above-Ground, On-Site Repository), (Score: 8)

Alternative 1 (No Further Action), (Score: 11)

Alternative 4 (Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Incised (Below-Ground), ALSD Regional Repository,

(Score: 13), and

Alternative 2 (Excavation and Off-Site Disposal of Contaminated Soils at Licensed Low-Level Radioactive Waste Facility) (Score: 18).

8. References

EPA. 2012. *Methodology for Understanding and Reducing a Project's Environmental Footprint*. February.

EPA. 2016. *Memorandum: Consideration of Greener Cleanup Activities in the Superfund Cleanup Process*. August 2.

9. List of Tables

Appendix M, Table M-1
Green Alternatives Assessment Summary
Tronox Navajo Area Uranium Mines, Central GSA Mines Site
McKinley County, New Mexico

	Minimizes Total Energy Use and Maximizes Use of Renewable Energy	Minimizes Air Pollutants and Greenhouse Gas Emissions	Minimizes Water Use and Impacts to Water Resources	Improves Materials Management and Waste Reduction Efforts	Protects Ecosystem Services	TOTAL
Alternative 1, No Further Action	1	1	4	1	4	**11**
Alternative 2, Excavation and Off-Site Disposal of Contaminated Soils at Licensed, Low-Level Radioactive Waste Facility	4	4	3	4	3	**18**
Alternative 3, Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Above-Ground, On-Site Repository	2	2	1	2	1	**8**
Alternative 4, Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Incised (Below-Ground) ALSD Regional Repository	3	3	2	3	2	**13**

Note: The ranking scores of 1 through 4 represent Best to Worst relative to the 4 removal action alternatives. Thus, a lower score score represents a better green outcome. Alternative 3, Excavation, Consolidation, and Long-Term Management of the Radiologically Contaminated Soils at an Above-Ground, On-Site Repository, with a Total green assessment score of 8, ranks as the greenest removal action alternative of the 4 alternatives.