Prepared for:

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FINAL

REMOVAL SITE EVALUATION WORK PLAN
NORTHEAST CHURCH ROCK MINE SITE

August 30, 2006

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August 30, 2006

Approved by:

US EPA Region IX Remedial Project Manager – Andrew Bain	Date
US EPA Region IX Quality Assurance Manager – Eugenia McNaughton	Date
UNC Project Manager – Roy Blickwedel	Date
MWH Project Manager – Toby Leeson	Date

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ACRONYMS

bgs	below ground surface
Bi-214	bismuth-214
Bq/kg	bequerel per kilogram
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COC	constituents of concern
C-O-C	chain-of-custody
COPC	constituents of potential concern
CSM	conceptual site model
cpm	counts per minute
CWA	Clean Water Act
DCGL	Derived Concentration Guideline Level
DGPS	differential global positional system
DQA	Data Quality Assurance
DQO	Data Quality Objective
EDD	electronic data deliverable
EPA	United States Environmental Protection Agency
EPC	exposure-point concentration
HAS	historical site assessment
HHRA	human health risk assessment
HI	hazard index or hazard indices
HQ	hazard quotient
IDW	investigation derived waste
MARSSIM	Multi-Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
MDL	method detection limit
MMD	New Mexico Mining and Mineral Division
NaI	sodium iodide
NCP	National Contingency Plan
NECR	Northeast Church Rock
NEMSA	non-economic material storage area
NFA	no further action
NMEID	New Mexico Environmental Improvement Division
NMED	New Mexico Environment Division
NMMA	New Mexico Mining Act
NNEPA	Navajo Nation Environmental Protection Agency
NOI	Notice of Intent
NPDES	National Pollutant Discharge Elimination System
NRC	Nuclear Regulatory Commission
pCi/g	picoCurie per gram
PPE	personal protective equipment
PRG	preliminary remediation goal
QA/QC	quality assurance/quality control
QAPP	Quality Assurance Project Plan
Ra-226	radium-226
RPM	Remedial Project Manager
RSE	removal site evaluation
SARA	Superfund Amendments and Reauthorization Act
SPLP	synthetic precipitation leaching procedure
SVOC	semi-volatile organic compound

TCLP	toxicity characteristic leaching procedure
UCL	upper confidence limit
UMTRCA	Uranium Mill Tailings Radiation Control Act
UNC	United Nuclear Corporation
USCS	Unified Soils Classification System
VOC	volatile organic compound
VSP	Visual Sampling Plan
Work Plan	Removal Site Evaluation Work Plan
WRS	Wilcoxon Rank Sum

1.0 INTRODUCTION

This Removal Site Evaluation Work Plan (Work Plan) describes the objectives, scope of work and methods for conducting a Removal Site Evaluation (RSE) consisting of investigation of surface and subsurface soils and sediments at the Northeast Church Rock (NECR) Mine (the Site), and adjacent properties. The Site is located approximately 16 miles northeast of Gallup, McKinley County, New Mexico, as shown on Figure 1-1, *Site Location*. This Work Plan has been prepared for United Nuclear Corporation (UNC) and is consistent with the National Contingency Plan (NCP) and uses applicable aspects of the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM, EPA, 2000a), as well as other applicable Environmental Protection Agency (EPA) guidance documents referenced throughout this Work Plan. This section summarizes the problem statement, objectives, site history, land use and the regulatory history of the Site. References in this Work Plan to site history, past operations, and the title status are asserted by UNC to be correct, and are subject to verification by EPA and the Navajo Nation.

1.1 PROBLEM STATEMENT AND OBJECTIVES

The NECR Mine is an inactive uranium mine site. The bulk of the mining lease is located on Navajo surface trust lands that are administered by the Navajo Regional Office Bureau of Indian Affairs. UNC owns the remaining portion of the Site through a patented mining claim. The Mine is subject to the New Mexico Mining Act (NMMA), as well as other statutory and regulatory requirements detailed below. UNC had submitted a closeout plan to the New Mexico Mining and Mineral Division (MMD) on January 30, 2004, received comments from MMD on June 23, 2004, incorporated those comments and responded on July 30, 2004. On November 10, 2004 the MMD supplemented their closeout plan comments with a request for UNC to submit a Materials Characterization Work Plan. UNC submitted the plan in December 2004. On February 15, 2005, MMD conditionally-approved the plan along with some comments, which UNC responded to on March 11, 2005.

On March 22, 2005, the Navajo Nation Environmental Protection Agency (NNEPA) requested that EPA Region 9 take the lead to ensure proper cleanup of the NECR Mine in coordination with the NNEPA, the State of New Mexico and the Bureau of Indian Affairs. On November 7, 2005, EPA Region 9 agreed to act as the lead regulatory agency for the Site. On December 16, 2005, MMD informed UNC that it would defer further permitting action at the mine pending successful completion of the EPA process.

Based on Navajo interest, in 2003 the EPA Las Vegas Radiation Laboratory and NNEPA walked the Site and conducted limited data collection programs including the performance of a gamma radiation survey adjacent to NECR-1. In a March 8, 2006 correspondence, to UNC, NNEPA and others, EPA reported its initial observations concerning the Site. EPA noted the presence of:

> "*uranium mine waste ore piles with uranium mill tailings in several ponds and sand fill areas. Additionally, alleged disposal and burial of unknown wastes have been reported at the Site. Access to the Site is uncontrolled and hazardous substances have likely been released to the environment. It is apparent that persons and livestock have been on site. In addition, Navajo residences downgradient of the Site may also be impacted by potential hazardous substance releases that are transported off-site by wind and through historic dewatering and run-offs during snow, rain and flood events.*"

EPA has requested that UNC, the former operator of the mine, undertake an environmental evaluation of the Site for purposes of determining whether a CERCLA removal action is warranted. UNC representatives met with federal, state and tribal agencies on February 28, 2006, March 27-28,

2006, and May 23, 2006. This Work Plan is based upon EPA's written guidance as well as oral guidance during these meetings and other teleconference discussions.

The main objective of this Work Plan is to conduct an RSE that is consistent with the NCP, 40 CFR 300.410 – 415. The NCP lists several factors to be considered in determining the appropriateness of a removal action in 300.415 (b)(2). The decision as to which specific factors and removal actions are relevant to the Site will be made by the EPA in consultation with NNEPA and UNC. Those factors that may be relevant to the Site include:

- Actual or potential exposure to nearby human populations, animals, or the food chain from hazardous substances;
- Actual or potential contamination of drinking water supplies or sensitive ecosystems;
- High levels of hazardous substances in soils largely at or near the surface, that may migrate; and
- Weather conditions that may cause hazardous substances to migrate.

The scope of work presented herein is intended to provide the types of data required to evaluate the relevant conditions and complete a human health risk assessment (HHRA). Moreover, it will provide the support for a decision regarding a removal action, or alternatively, to support the no-action alternative.

The NCP lists the general types of removal actions in 300.415 (e) that may be appropriate. The RSE is intended to assess the nature and extent of releases in sufficient detail to assess the appropriateness of the following actions that may be relevant to the Site:

- Site control options such as fencing or warning signs to limit access to the Site by humans or animals;
- Drainage controls such as run-on and run-off diversion measures, to mitigate migration of water into the release area, or the migration of hazardous substances away from the release area;
- Stabilization measures such as berms, dikes or impoundments to maintain the integrity of sediment and erosion control measures;
- Capping of contaminated soils to prevent exposure to and migration of hazardous substances into soil, groundwater, surface water, or air;
- Excavation, consolidation or removal of highly contaminated soils from drainages or other areas; and
- Temporary relocation or evacuation.

In order to comply with the NCP, the objectives of the RSE will be to:

- Conduct an RSE in conformance with the NCP;

- Characterize the nature and extent of releases of radionuclides in soil and sediment;
- Characterize the nature and concentrations of releases of metals in soil and sediment;
- Collect data to determine the appropriate response;
- Identify exposure pathways;
- Evaluate baseline human health risks;
- Define survey areas and boundaries;
- Define the potential range of removal actions that are consistent with intended land uses; and
- Evaluate soil for the reestablishment of a self sustaining ecosystem.

1.2 SITE HISTORY AND LAND USE

1.2.1 Ownership and Surrounding Land Use

Figure 1-2, *Local Land Use*, illustrates the property interests that encompass the Site and the surrounding lands that are of potential interest to the RSE. Surface ownership for Section 35 of T17N, R16W and Section 3 of T16N, R16W, which includes the majority of the NECR mine permit area, is held in trust by the Bureau of Indian Affairs for the Navajo Nation. The mineral rights are owned by Newmont USA, Ltd, successor to Santa Fe Pacific Gold Corporation. A small portion of the permit area is located on lands owned by UNC in the eastern part of Section 34, T17N, R16W. The remainder of Section 34 to the west of the NECR mine permit area is controlled by the Bureau of Land Management and is used for grazing, and potentially for mining. The NECR mine permit area encompasses approximately 125 acres.

UNC owns Section 36, T17N, R16W to the east, and Section 2, T16N, R16W to the southeast of the Site. These parcels are part of the Church Rock mill and tailings storage facility that is maintained under a Source Material License in compliance with Nuclear Regulatory Commission (NRC) requirements. Upon termination of the license, and to comply with Title II of the Uranium Mill Tailings Radiation Control Act (UMTRCA), these lands will be deeded to the Department of Energy, and will be held in perpetuity in the Legacy Monitoring Program. The Church Rock tailings storage facility is an EPA Region 6 National Priority List Site that is operated and maintained primarily through a NRC Source Materials License.

All lands to the north of the Site are part of the Navajo Indian Reservation. From the late 1960's into the early 1990's, the part of the reservation immediately adjacent to the Site was mined by Kerr-McGee Corporation through a lease with the Navajo Nation. The Kerr McGee's subsurface mining operations extended to near the underground workings of the Northeast Church Rock Mine. Based upon aerial photos, by 1997 the Kerr-McGee mine had been closed. Between 1997 and 2004, it appears that between six and nine home sites had been developed on the land located south of the Kerr-McGee mine. Aerial photographs reveal some prior disturbances surrounding the home sites that appear to be related to the mining activity on the reservation; however, there was no previous, significant development prior to the building of the home sites. The area is also used for grazing. Because natural water supplies are high in dissolved minerals content, potable and livestock water is supplied to the reservation via Navajo utilities. Two wells in the area, NR-1 and Friendship Well, are

located northwest of the home sites. Both wells appear to have been unused for several years and the NR-1 well is locked by UNC.

1.2.2 Mining Practices

The majority of the mine property (i.e., that part which lies on lands held in trust by the Bureau of Indian Affairs for the Navajo Nation) was operated by UNC under the terms of a mineral lease with the predecessors of what is now Newmont USA, Ltd. Active mine operations at the Site took place between 1968 and 1982 at which time the mine was placed on stand-by status. Mining was conducted by underground methods. The infrastructure included two main shafts (NECR-1 and NECR-2), several vent holes, support buildings, roads, and water treatment facilities, as shown on Figure 1-3, *Site Layout*. Reviews of historical aerial photographs, and Site reconnaissance have indicated that portions of the Site are located within an arroyo, including the northwestern edge of the NECR-1 area.

The NECR-1 area consists of a level pad constructed by cut and fill methods. The southeast portion of the pad is built on top of native soils and the northwest part is built up with 20 to 30 feet of mine overburden and non-economic materials along the northern perimeter adjacent to the Navajo Reservation boundary.

Beginning in 1979 and ending when the mine went on standby status, pursuant to a permit from the New Mexico Environmental Improvement Division (NMEID), UNC used coarse tailings sands from the mill to provide roof support for critical mined-out portions of the NECR mine. The tailings sands were temporarily staged at the three locations shown in Figure 1-3, and then were pumped underground into specified areas using a sand slurry. Backfill preparation within the underground mine consisted of building bulkheads equipped with drains around the area to be backfilled. The entrained slurry water drained into the mine drainage system, where it mixed with mine water that was collected and pumped to the surface.

Dewatering operations continued into 1983. The water was treated in three constructed ponds to reduce suspended solids and radionuclide concentrations before being discharged into an unnamed arroyo. Upon passage of the Clean Water Act (CWA), discharges were released pursuant to a National Pollutant Discharge Elimination System (NPDES) permit. Treatment processes were added or changed over the years, principally to meet revisions to discharge requirements as dictated by the CWA; however, mine water was never directly discharged to the unnamed arroyo without some type of treatment. Even before the discharges were permitted, ponds were used to settle suspended solids. Pond No. 1 functioned as a surge tank to allow for homogenization and sand settling. A flocculant was also added in Pond No. 1 to remove suspended solids. The clarified water then flowed into Pond No. 2. Between Pond No. 2 and Pond No. 3a, sulfuric acid and barium chloride were added, resulting in the removal of radium through precipitation as radium sulfate in Pond No. 3/3a. Water from Pond No. 3 was fed to an ion exchange (IX) plant for the recovery of uranium and then discharged into the unnamed arroyo. The IX Plant was added to the Site's NRC license in 1977 and operated until dewatering operations ceased, at which point UNC closed the IX Plant, mine water treatment ponds, and tailings sand backfill areas in accordance with its NRC Source Materials License.

Closure of the NECR Mine was performed between 1986 and the end of 1994 pursuant to NRC requirements and the mining lease. In addition to removing the IX Plant and sludge-contaminated soils from the treatment ponds, closure actions included: removal of equipment and some buildings; backfilling and sealing the two shafts and associated vent holes with reinforced concrete caps; regrading, covering and revegetating the non-economic materials storage area (NEMSA). The only remaining structural features include the main office, power poles, building foundations and other concrete platforms. The concrete pads were left standing at the request of the

Pinedale Navajo Chapter house. A disposal area is located on that part of Section 34 owned by UNC (the Boneyard). The Boneyard was used to store old equipment, tires, wood pallets, and other miscellaneous materials. The material was either removed from the Site or buried at the area. The area was covered with one foot of soil and reseeded as part of the closure activities completed by the end of 1994.

1.2.3 Regulatory History

The NECR Mine has been regulated under various permits during active and post-closure operations, as listed below.

- A NPDES permit for the treatment and discharge of mine water.
- An amendment to the radioactive materials license from the State of New Mexico for the operation of the IX Plant.
- A discharge permit and radioactive materials license from the State of New Mexico for backfilling coarse tailings sand into the mine.
- A source materials license with NRC following the June 1986 return of the State's licensing authority to the NRC for the closure of the sand backfill staging areas and the IX plant and water treatment ponds.
- A mining permit issued by the State of New Mexico in 2004 to conduct additional mine closeout activities under the NMMA.
- A storm water discharge permit with EPA in 2005.

The NPDES permit covered the discharge of treated mine water into the unnamed arroyo, which flowed into the next downstream, unnamed arroyo (a tributary to the Pipeline Arroyo). The water was monitored for flow rate, pH, suspended solids, radionuclides and trace metals; and was reported to the State of New Mexico and EPA in quarterly reports. The permit was inactive after mine dewatering ceased in 1983, and the permit was allowed to lapse at the end of 1993, at the same time that the mineral lease expired. According to the New Mexico Environmental Improvement Division's Surface Water Quality Bureau, compliance evaluation inspections were conducted in 1995, 1999 and 2002. The inspection reports asserted permit violations that were disputed by UNC with the result that no further regulatory actions were taken.

On June 23, 1977, UNC's State-issued radioactive materials license (UN-UNC-ML) was amended to allow for the operation of the IX Plant, and on January 29, 1979, the license was again amended to govern radiological aspects for the backfilling of coarse tailings sands into the mine workings for structural control. (During this period, New Mexico had agreement state status and was authorized to administer the license.) The NMEID issued discharge permit DP-63 to govern water quality aspects of the tailings sand backfill. As a basis for the permit, Battelle (1982) investigated potential impacts from the sand backfill areas on groundwater quality, and concluded that degradation would not occur. The permit required groundwater monitoring to verify the conclusions reached by Battelle.

In June 1986, the State of New Mexico returned its licensing authority for uranium recovery facilities to the NRC. UNC therefore closed the IX Plant, mine water treatment ponds, and tailings sand backfill areas in accordance with its NRC Source Materials License. This included the removal of radiologically contaminated soils and process equipment, which were disposed of at the mill site in

conjunction with mill decommissioning and reclamation activities. NRC certified the completion of the NECR cleanup activities in October 1989.

UNC halted on-site activities at NECR in December 1993. In September 2002, the New Mexico Appellate Court held that NECR was subject to the NMMA. UNC submitted a mine permit application in July 2003 and a Closeout Plan in January 2004 (MWH, 2004) to the MMD. UNC worked with MMD to complete work plans for site characterization and mine closure through March 2005. The State of New Mexico issued a letter in June 2004 for UNC to prepare a groundwater abatement plan. At roughly the same time that UNC received conditional approval to execute the Materials Characterization Work Plan (MWH, 2004), the NNEPA requested that EPA assume jurisdiction for mine cleanup. On November 7, 2005, EPA agreed to the NNEPA's request, and in a December 16, 2005 letter from MMD to UNC, MMD deferred further permit action for NECR to EPA on the presumption that an EPA-led cleanup would result in compliance with the NMMA. MMD reserved its right to make a determination of NMMA compliance following EPA's release of the mine site.

On May 13, 2005, UNC submitted a complete Notice of Intent (NOI) form seeking coverage under EPA's Multi-Sector General Permit for storm water discharges. There have been no discharge events to trigger any monitoring events since the permit has been in place, nor has there been continuous flow into the arroyos adjacent to the site. UNC has implemented and maintains the best management practices that are contained in the Stormwater Pollution Prevention Plan (MWH, 2005).

1.2.4 Previous Work

Previous work that has been condcuted at the Site is documented in serveral historical documents. These documents include those listed below.

- Closeout Plan (MWH, 2004a)
- Material Characterization Work Plan (MWH, 2004b)
- Groundwater Quality in the Westwater Canyon Member at the Northeast Church Rock Mine (MWH, 2004c)
- Northeast Church Rock Mine Site Assessment (MWH, 2003)
- Tailings Sand Backfill Cleanup Verification Report (UNC, 1989a)
- Kermac Operations and Closure Report (date unknown)

Additionally, data concerning the results of the EPA field radiological scan that was conducted in 2005 (see Section 1.1) was conveyed to the project team by personal communication (EPA, personal communication, 2006).

1.3 PHYSICAL SETTING

1.3.1 Physiography

The site is located in the southeastern part of the Colorado Plateau Physiographic Province. The plateau is characterized by large regions of folding with broad uplifts and intervening basins. The site

is located at the juncture of several of these major structures: the San Juan Basin, the Zuni Uplift, and the Defiance Uplift.

The NECR mine is located in an unnamed arroyo that drains to the northeast into another unnamed arroyo that drains to the east into Pipeline Canyon. Elevations at the Site range from 7,100 to 7,200 feet. Pipeline canyon is a northeast-southwest trending alluvial valley that drains intermittently to the southwest, eventually emptying into the Rio Puerco. Surface water flow from the Site discharges intermittently into the unnamed arroyo that empties into Pipeline Canyon via the other unnamed arroyo.

1.3.2 Climate

The average temperature in Gallup, 16 miles south of the Site, ranges between an average of 29 degrees Fahrenheit in January to an average of 68 degrees Fahrenheit in July. Gallup receives an average of 0.8 inches of precipitation in January and 2 inches in August, with a total annual average precipitation of 11 inches. Daily extremes reach as high as 100 degrees Fahrenheit in summer and as low as –34 degrees Fahrenheit in winter.

Potential evaporation in New Mexico is much greater than average precipitation. The annual net pan evaporation is approximately 54 inches. Wind speeds over the state are usually moderate, although relatively strong winds often accompany occasional frontal activity during late winter and spring months. Blowing dust and serious soil erosion is a problem during dry spells. Based on data (1992-2002) from the Gallup airport, winds predominate from the west to southwest 11 months out of the year. A predominant direction from the south is reported for the month of August (http://www.wrcc.dri.edu).

1.3.3 Geology and Groundwater Quality

The surface of the Site, beneath the soil or colluvium layers (see Section 1.3.4) consists of alluvium along the axes of the drainages and bedrock in other areas. The alluvium present generally consists of clay, silt, sand, and gravel deposited in interfingering layers. The alluvium is very thin or absent at the mine, and is unsaturated. Approximately one mile southeast of the Site, in the valley bottom along the axis of Pipeline Canyon, the alluvium attains sufficient thickness and continuity to be a mappable geologic unit. Similarly, the alluvium becomes partially saturated only along the axis of Pipeline Canyon, in large part if not entirely due to infiltration of mine water discharge from the two upstream mines. Water levels in the alluvium have been gradually lowering ever since mine water discharges ceased.

The Site is underlain by the upper Cretaceous Crevasse Canyon Formation. The cliffs that rim the Site are comprised of white, medium- to coarse-grained sandstone of the Dalton Sandstone Member of the Crevasse Canyon Formation, while much of the Site permit area is underlain by unsaturated mudstones, sandstones, and coal beds of the Crevasse Canyon Formation. Underlying the Crevasse Canyon Formation are the Gallup and Mancos Shale formations; also of Cretaceous age. Groundwater is first encountered in the Gallup Formation; during the drilling of the NECR-1 mine shaft an approximately 30 gpm yield was reported. The Mancos is a very effective confining layer being comprised of 500-800 feet of shale.

Underlying the Cretaceous sediments, are the Jurassic Morrison Formation and Dakota Formation. The primary uranium ore body mined at the Site is present within the Westwater Canyon Sandstone Member of the Morrison Formation. The NECR-1 and NECR-2 mine shafts at the Site extended to a depth of approximately 1,500 to 1,800 feet into the Westwater Canyon Sandstone Member. The

Dakota and Morrison formations may be hydraulically connected; together they constitute a very productive aquifer, and produced about 1,500 gpm during mine dewatering operations.

Groundwater quality data at the Site was presented in the document *Groundwater Quality in the Westwater Canyon Member at the Northeast Church Rock Mine* (MWH, 2004c). Maximum concentrations for background mine water quality exceeded NMED standards for iron, manganese, nitrate, and radium-226 (Ra-226). A sample collected from the NECR-1 well on May 17, 2004 exceeded New Mexico Environment Division (NMED) standards for pH, total dissolved solids and boron.

1.3.4 Soils

The native soils within the Site boundary consist of well-drained silty sands and inorganic silts and clays, characteristic of a semi-arid pinyon-juniper region. Soils in the areas surrounding the nine home sites are expected to be similar. Coarser, poorly sorted alluvial deposits containing gravel and cobbles are found along the unnamed arroyo. The NECR-1 pad was constructed of non-economic mine materials consisting of sandstone and clay shale fragments, while the NECR-2 pad was constructed primarily of native soils. The NEMSA and the Boneyard were seeded in 1994, after being covered with one foot of native topsoil. Currently, areas of the site have supported a variety of native vegetation but revegetation of some areas has had little success due to livestock grazing.

The water treatment ponds (Pond No. 1, Pond No. 2, and Pond No. 3/3a) were originally filled with water and sediments settled in them from storm water runoff that drained the tailings sand backfill areas, as well as water from mine operations (see Section 1.2.2). The sediments were periodically removed and placed on the Sediment Pad for temporary storage prior to being transported off-site for processing at the mill. Residual tailings were removed from the ponds and the Sediment Pad as part of the 1986 cleanup pursuant to Condition 33 of NRC Permit License No. SUA-1475 (UNC, 1989a). Currently, the ponds and the Sediment Pad primarily consist of native materials.

As stated above, the sand backfill areas originally were used to store tailings from the mill. As discussed in Section 1.0, the tailings were removed and used to backfill the mine workings. The sand backfill areas were then included in the 1986 cleanup pursuant to Condition 33 of NRC Permit License No. SUA-1475 (UNC, 1989a). As such, the sand backfill areas now consist of native materials.

2.0 PROJECT MANAGEMENT

2.1 PROJECT ORGANIZATION AND KEY PERSONNEL

The responsibilities and contact information for key project personnel are listed below in Table 2.1, *Project Personnel Contact Information.*

TABLE 2.1
PROJECT PERSONNEL CONTACT INFORMATION

Name	Organization Affiliates	Title	Contact Information
Mr. Roy Blickwedel	UNC	UNC Representative	Office Phone: (610) 992-7935 Email: Roy.Blickwedel@corporate.ge.com
Mr. Larry Bush	UNC	Site Manager and UNC VP	Office Phone: (505) 722-6651 Email: larry.bush@ae.ge.com
Mr. Toby Leeson	MWH	MWH Project Manager	Office Phone: (970) 879-6260 Email: toby.leeson@mwhglobal.com
Ms. Leah Wolf Martin	MWH	MWH Assistant Project Manager	Office Phone: (970) 879-6260 Email: leah.wolf.martin@mwhglobal.com

The responsibilities for key project personnel are included in the following sections.

2.1.1 United Nuclear Corporation Representative

The UNC representative, Mr. Roy Blickwedel, will be responsible for overall program execution and quality, and will have overall responsibility for the execution of the Work Plan activities. The UNC representative will be ultimately responsible for the quality of the data collected and interpretations based upon these data that will be presented in the investigation report. The UNC representative will also take the lead on all agency communications.

2.1.2 Site Manager

The Site Manager, Mr. Larry Bush, who is also Vice President of UNC, will be responsible for managing all activities of the Work Plan that are associated with coordination of the field work. He will also coordinate access to the Site.

2.1.3 MWH Project Manager

The MWH Project Manager, Mr. Toby Leeson, and Assistant Project Manager, Ms. Leah Wolf Martin, will be responsible for coordinating the surveys, managing subcontractor personnel, and overall project management, quality control and document preparation and review. The MWH Project Manager is responsible for staffing and execution of field activities and the preparation of the investigation report.

2.1.4 Data Administrator and Quality Manager

The Data Administrator, Mr. Toby Leeson, will be responsible for coordinating and overseeing the compilation, updating, and maintenance of an electronic database of all analytical data, field measurements, and associated data validation information. The Quality Manager, Ms. Leah Martin, will be responsible for coordinating and overseeing the implementation of the quality assurance program and supervising any audits of the project for compliance with program procedures and specifications. The Quality Manager will also be responsible for overseeing the execution of

validation of the analytical data. The Quality Manager will be responsible for the quality of the data gathered, oversight, and assessments conducted in accordance with this Work Plan.

2.1.5 Analytical Laboratory Manager

The Analytical Laboratory Manager, Mr. Craig Moore, will be responsible for overseeing project analytical activities, and developing laboratory analytical reports in a timely manner. The Analytical Laboratory Manager will also be responsible for management of the analytical laboratory.

2.1.6 Radiological Specialist

The radiological technical specialist, Mr. Nat Patel of AVM Environmental, will responsible for planning and overseeing the radiological surveys as well as evaluation and interpretation of the results.

2.1.7 Field Sampling Team Members

Field sample collection will be led by a MWH Field Sampling Team Leader and will be performed by qualified field personnel. The Field Sampling Team Leader and the field personnel are responsible for implementing the field activities of the Work Plan, under the supervision and direction of the MWH Project Manager and/or the Assistant Project Manager.

2.1.8 Risk Assessor

The Risk Assessor, Dr. Bruce Narloch of MWH, will be responsible for conducting the HHRA, including development of the site-specific conceptual site model and exposure pathway diagram, and evaluation of risks to human health and the environment. The Risk Assessor will also be responsible for ensuring that appropriate samples are collected and analyzed for the evaluation of risk.

2.1.9 Regulatory Oversight

EPA Region 9 will oversee the work. The EPA Region 9 Remedial Project Manager (RPM) is Mr. Andy Bain and the On-Scene Coordinator is Mr. Harry Allen.

2.2 DELIVERABLES

The RSE will include several deliverables. Draft documents will be submitted to the EPA for review. Comments will be submitted in writing and once all comments have been received a comment response document will be provided to the EPA. A conference call or meeting may be required to discuss comments and comment responses. Final documents will be revised based upon comment resolution. The investigation report will include sampling methods, sample locations, and results of the field activities described in this Work Plan.

2.3 SCHEDULE

UNC currently estimates that the field work will require approximately one month of field labor but will include two mobilizations separated by approximately six to eight weeks. The first phase of field work will begin approximately four to six weeks after EPA's approval of the Work Plan, NNEPA arrangements for access on Navajo controlled lands, and UNC's authorization to proceed. The initial phase of the field work will include collection of background soil samples and collection of soil samples and static gamma measurements for the purpose of determining background and developing correlation data for the gamma radiation surveys. It is anticipated that it will take approximately six

weeks to receive the radionuclide data from the laboratory due to the in-growth time required for radionuclide analysis. Following validation of the laboratory data, a technical memorandum will be transmitted to the EPA that discusses the background and correlation results. The correlation will be used to evaluate the results of the field gamma surveys based on EPA approval of the correlation methods and results.

The second mobilization will entail a backhoe, an auger drill rig, a sampling team, and subcontractor personnel. Prior to initiating field work, health and safety training will be provided according to the Health and Safety Plan in Appendix D. A detailed schedule of planned activities will be prepared after EPA approves the Work Plan. This schedule will be provided to EPA for field oversight-planning purposes. Data analysis and presentation will be performed concurrent with and subsequent to field activities, and results will be presented in the investigation report. It is anticipated that data analysis and preparation of a draft investigation report will be submitted three months following the completion of field work.

3.0 PROJECT DATA QUALITY OBJECTIVES

The data generation and acquisition methods and procedures explained in this Work Plan were developed using the EPA's Data Quality Objective (DQO) process, as per *Guidance on Systematic Planning Using the Data Quality Objectives Process EPA QA/G-4* (EPA, 2006a). The DQO process comprises the following seven steps. A brief description of each step from the EPA guidance is discussed below.

1. **State the problem**. Concisely describe the problem to be studied. Review prior studies and existing information to gain a sufficient understanding to define the problem. Identify the planning team members, including the decision-makers. For each data gap category, the problem statement is presented. Planning team members and decision-makers are the same for each data collection activity.

2. **Identify the decision**. Identify what questions the study will attempt to resolve and what actions may result from each decision. Develop a decision statement.

3. **Identify the decision inputs**. Identify the information that needs to be obtained and the measurements that need to be taken to resolve the decision statement.

4. **Define the study boundaries**. Specify the time periods and spatial boundaries to which decisions will apply. Determine when and where data should be collected. Define the target population of interest.

5. **Develop the decision rules**. Define the statistical parameter of interest, specify the screening level and Derived Concentration Guideline Level (DCGL), and integrate the previous DQO outputs into a single statement that describes the logical basis for choosing among alternative actions. Define an "if... then..." statement.

6. **Specify tolerance limits on decision errors**. Define the decision-makers' tolerable decision error rates based on a consideration of the consequences of making an incorrect decision.

7. **Optimize the sampling design**. Evaluate information from the previous steps and generate alternative data collection designs. Choose the most resource-effective design that meets all DQOs.

Details associated with Steps 1 through 7 of the overall Work Plan DQOs are presented, sequentially in this section.

3.1 STATE THE PROBLEM (DQO STEP 1)

This section provides a description of the problems associated with the Site, and discusses the Site conceptual model, the survey areas, site exposure scenarios, and classification of the survey areas based on MARSSIM (EPA, 2000a). The planning team members, available resources for implementation of the surveys, and relevant deadlines are presented in Section 2.0.

3.1.1 Site Conceptual Model

The primary ore mineral was coffonite [U(SiO4)1-x(OH)4x], which was deposited in the Westwater Canyon Sandstone Member, part of the Morrison Formation. This unit is 1,500 to 1,800 feet below ground surface (bgs) and is stratigraphically below the Mancos Shale (see Section 1.3). Coffinite and other uranium-bearing minerals were deposited along an oxidation-reduction front in what is referred

to as a roll-front deposit. Ore was brought to the ground surface via mechanical lift and loaded onto trucks for transport to the Church Rock mill site. Small temporary stockpiles were placed at NECR-1 and NECR-2 before transport to the mill. Groundwater from the mine workings was pumped to the surface and treated, and discharged under an NPDES permit as described in Section 1.2.2. As described in more detail in Section 1.2.2, fill material used to construct the NECR-1 pad consisted of non-economic materials that were understood to have been placed to a maximum depth of approximately 30 feet bgs in the northwestern corner of NECR-1. Ore and low-grade ore stockpiles were temporarily stored on the NECR-1 and NECR-2 pads. Residual tailings material in the three sand backfill areas and in the sediments in the ponds and Sediment Pad were removed and taken off-site in 1986, pursuant to NRC License No. SUA-1475, Condition 33 (UNC, 1989b). The tailings material was identified based on the ratio of natural uranium to Ra-226, which was less than 0.75 for tailings. Low-grade ore and non-economic material had a ratio of greater than 0.75 and native ground had low concentrations of all radionuclides. The bulk of the tailings material from the sand backfill areas was placed in the mine stopes pursuant to State approval; remaining tailings were removed offsite as part of the 1986 NRC cleanup. Because the NRC cleanup removed only tailings, materials with residual levels of radionuclides may still reside in these areas, as suggested by the verification results shown in the *Tailings Sand Backfill Cleanup Verification Report* (UNC, 1989a).

Non-economic material was also placed in the NEMSA and refuse and other discarded equipment was placed in the Boneyard (see section 1.2.2). Both of these sites were reclaimed in 1994 by UNC. Reclamation reportedly included placement of one foot of topsoil over the disposed materials and then seeding.

In addition to the materials still present at the Site, impacts may have occurred off-site to the northeast as a result of suspended sediment transport during mine water discharge or storm water events, as well as the transport of contaminants by wind, or to a lesser extent human and animal activities. Due to these potential transport mechanisms, there is concern about whether impacts to nine home sites near the confluence of the unnamed arroyo and the next unnamed arroyo may have occurred. In order to evaluate potential impacts, a Work Plan that is consistent with the NCP is needed to provide the following:

- Characterize the nature and extent of releases of radionuclides in soil and sediment;
- Characterize the nature and concentrations of releases of metals in soil and sediment;
- Collect data to determine the appropriate response;
- Identify exposure pathways;
- Evaluate baseline human health risks;
- Define survey areas and boundaries;
- Define potential range of removal actions that are consistent with intended land uses; and
- Evaluate soil for the reestablishment of a self-sustaining ecosystem.

3.1.2 Survey Areas

Based on the information presented in Sections 1.0 and 3.1, as well as consultation with EPA and NNEPA, 13 individual survey areas have been identified for further evaluation and are included in this Work Plan. Pond 3 consists of two parts, 3 and 3a, which are considered one area under the RSE. Additionally, due to their adjacent locations and small sizes, Ponds 1 and 2 are considered one survey area in this Work Plan (see Section 5.0). As presented in this Section, each of these survey areas will undergo characterization surveys as set forth in MARSSIM. These 13 survey areas are listed in the following sections along with a description of the area classifications, based on MARSSIM (EPA, 2000a). The locations of these survey areas are shown on Figure 1-3.

3.1.2.1 Potential Class 1 Sites

The following sites are classified as Class 1, based on MARSSIM (EPA, 2000a):

- Sand Backfill Area No. 1
- Sand Backfill Area No. 2
- Sand Backfill Area No. 3
- Ponds No. 1 and No. 2
- Pond No. 3/3a
- Sediment Pad

These sites are considered Potential Class 1 sites because they were remediated by UNC (UNC, 1989a), as discussed above and in Section 1.2.2. These areas were cleaned of tailings materials based on determination of uranium to Ra-226 ratios. Furthermore, since the previous removal action (UNC, 1989a) targeted only tailings, investigation of these sites will be conducted as Characterization Surveys, as per MARSSIM (EPA, 2000a), to evaluate the nature and extent of impacts from radionuclides, and the concentrations of metals, in soil. Due to their small sizes, proximity to each other, and similar uses, Ponds No. 1 and No. 2 are considered one survey area for the purposes of the sampling design.

3.1.2.2 Potential Class 2 Sites

The following sites are classified as Potential Class 2 sites:

- NECR-1
- NECR-2
- NEMSA
- Unnamed arroyo

Each of these on-site areas is thought to contain non-economic materials and/or low-grade ore, but it is not expected that contaminant concentrations will exceed screening levels. Investigation of these sites will be conducted as Characterization Surveys, as per MARSSIM (EPA, 2000a). In addition, soil samples will be collected in the unnamed arroyo along systematic transects, as opposed to a grid, as explained in Sections 3.7 and 5.0.

3.1.2.3 Potential Class 3 Sites

The nine home sites located near the confluence of the unnamed arroyo and the next unnamed arroyo that it drains into are considered Potential Class 3 sites. Investigation will assess impacts to these sites

due to unexpected wind transport of soil particles during operations containing elevated levels of radionuclides or metals. If radionuclides or metals are present, they are expected to be present at concentrations below the screening levels. Investigation of these areas will be conducted in a judgmental manner, as preliminary surveys (see Section 3.7) in accordance with MARSSIM guidelines (EPA, 2000a). A judgmental investigation is one in which investigation areas and sampling locations are chosen based on professional judgment and evaluation of historical information.

3.1.2.4 Screening Site

One site, the Boneyard, will be investigated to screen for radionuclides, metals, and organic constituents to evaluate whether impacts to this site have occurred. Investigation of this site will be conducted as a screening assessment to evaluate whether impacts by preliminary COPCs have occurred.

Investigation will be performed in a judgmental manner for the Boneyard. Subsurface samples will be collected from test pits in the Boneyard. While excavating the test pits, visual observations will be made to evaluate the nature of any buried materials encountered. Further discussion of the sampling design for this site is included in Section 3.7 and 5.0.

3.1.2.5 Background Reference Area

A background reference area has been selected where sampling and analysis of surface soil samples will be conducted to establish background values for radionuclides and metals. The location of this area and the sampling design (see Section 3.7) were selected based on MARSSIM (EPA, 2000a). The area will be located to the northwest of the Boneyard. This location was selected based on the following:

- Similar geology to the Site (Crevasse Canyon Formation);
- Upwind of the predominant wind direction (west to southwest);
- Distance from the Site (approximately one-half mile from permit boundary); and
- No evidence of impacts due to exploration or mining.

Based on evaluation of aerial photographs and the 7.5-minute United States Geological Survey quadrangle, the selected background area has similar topography and drainage patterns as the Site. In addition, the background area is located west to northwest of the Site, which is along the strike of the regional geologic formations. The regional geologic formations dip to the north. Therefore, the surface and subsurface geology of the background area are representative of the Site. It has been determined using data from the State of New Mexico's land ownership on the New Mexico Resource Geographic Information System Program that the background area is located on land owned by BLM.

3.1.3 Definition of Exposure Scenarios

As described in more detail in Section 6.0, the study area contains historic sources of radionuclides including uranium and Ra-226, their daughter products and, potentially, metals in soils from historic mining activities at the Site. Sources of radionuclide contamination may be associated with former ore stockpiles at NECR-1 and NECR-2, non-economic material storage at the NEMSA, and the deposition of tailings at the sand backfill areas. There may also be residual radionuclides in the Sand Backfill Areas No. 1, No. 2 and No. 3, and the three ponds and Sediment Pad, although none are expected due to the NRC cleanup that was conducted in these areas (UNC, 1989a). Additionally, radionuclides and metals are present naturally in the rocks of this region. Mine water was discharged to the unnamed arroyo, and storm water runoff may also have flowed intermittently from the Site to the unnamed arroyo. Metal and other types of debris were disposed of in the Boneyard.

Contaminants may have been released from these source areas to soils and sediments through entrainment of dust in ambient air by wind; weathering of residual ore, non-economic material, tailings or metal debris; deposition of suspended sediment being carried in storm water runoff and mine water discharge or potential leaching into infiltrating precipitation. These release mechanisms have resulted in the migration of contaminants from on-site source areas to ambient air, surface water, sediment or groundwater of which air and water sampling are not included in this evaluation. However the potential for leaching is being studied via SPLP sampling.

As stated in Section 1.3.3, groundwater quality data from the Site were presented in the document *Groundwater Quality in the Westwater Canyon Member at the Northeast Church Rock Mine* (MWH, 2004c). Maximum concentrations for background mine water quality exceeded NMED standards for iron, manganese, nitrate, and Ra-226. A sample collected from the NECR-1 well on May 17, 2004 exceeded New Mexico Environment Division (NMED) standards for pH, total dissolved solids and boron.

The Site is currently inactive, and human receptors at the Site are limited to facility oversight, security personnel, and unauthorized visitors (there is evidence that unauthorized visitors have been on-site, based on the presence of cut fencing); wildlife also use the Site. With cooperation of the NNEPA, access to the Site for the foreseeable future will be secured and limited to allow only periodic inspections, and wildlife access. Grazing would be permissible approximately 13 years after the mine reclamation is completed. If consistent with any applicable mineral rights or grazing permits, and if such historical land uses are established, future use may include Navajo traditional and cultural land uses, including medicinal plants.

In addition, nine home sites are located northeast of the Site, and surrounding areas are also used for cattle grazing and hunting. It is conceivable that home sites could be constructed in the future on other Navajo Tribal Trust lands or on the reservation; however the lands closest to the Site (i.e., those owned by the Bureau of Land Management and UNC) cannot, consistent with existing mineral rights, be used for future residential development.

Based on future intended land uses for the Site, there may be a potential for human and ecological receptors to be exposed to radionuclides and metals through ambient air, surface water, sediment and biota (i.e., plants and animals). These potential exposure pathways are described in more detail in Section 6.1.

3.2 IDENTIFY THE DECISION (DQO STEP 2)

The principal study questions are listed below.

1) What are the levels and extent of previously observed (EPA field surveys) hazardous constituents related to residual low-grade ore, by-product material, or non-economic material present at the Site?

2) Have hazardous constituents (i.e., radionuclides or metals) been transported and deposited off-site above screening levels?

3) Would the levels of such hazardous constituents pose a current or future risk to human health and the environment?

Since the individually identified survey areas are classified differently (see Section 3.1) as per MARSSIM (EPA, 2000a), there are more specific study questions for each type of classification, as presented below.

- The seven Potential Class 1 sites (three sand backfill areas, three ponds and Sediment Pad) will be investigated as Characterization Surveys to evaluate the nature and extent of radionuclides and metals within each area. The principal study question for the Potential Class 1 sites is: are there levels of radionuclides and metals in these seven survey areas above the screening levels that warrant further characterization or evaluation for a removal action to prevent direct exposure or their transport via wind, water, or to a lesser extent human and animal activities?

- The three Potential Class 2 sites (NECR-1, NECR-2, and NEMSA) will also be investigated as Characterization Surveys. The principal study question for these three Potential Class 2 sites is: are there levels of radionuclides and metals in these three survey areas above the screening levels that warrant further characterization or evaluation for a removal action to prevent direct exposure or their transport via wind, water, or to a lesser extent human and animal activities?

- The principal study question for the unnamed arroyo (a Potential class 2 Site) is: have impacts to alluvial sediments from the transport of radionuclides or metals by wind, water, or to a lesser extent, human and animal activities occurred along the unnamed arroyo, and are there concentrations above the screening levels that warrant further characterization or evaluation of a removal action alternative?

- The one Potential Class 3 site (the nine home sites) will be investigated as a preliminary assessment. The principal study question for the Potential Class 3 site is: have impacts to surface soils from the transport of radionuclides or metals by wind, or to a lesser extent human and animal activities occurred at the nine home sites, and are their concentrations above screening levels that warrant additional investigation, such as indoor air monitoring or the need to discriminate their origin between the two separate mines in the area?

- The principal study question for the Boneyard is: are materials present in the surface or subsurface that contain liquids other than stormwater, or are there concentrations of radionuclides, metals, and other organic constituents above screening levels?

- Background samples representative of Site conditions will be considered during the development of final cleanup goals. The principal study question for the background reference areas is: what is the mean, standard deviation, and 95 percent upper confidence level of the background concentrations of radionuclides and metals at the Site?

3.3 IDENTIFY THE DECISION INPUTS (DQO STEP 3)

The primary data that will be needed are as follows:

- Vertical and lateral extent of concentrations of radionuclides in surface and subsurface soils
- The nature and concentration of metals in surface and subsurface soils
- The nature and concentration of organic constituents in subsurface soils at the Boneyard
- Spatial location (horizontal and vertical) of samples and measurements
- Count rate of collimated and non-collimated surface gamma radiation (field gamma survey)
- List of chemical analyses for off-site measurement at the laboratory
- DCGLs and the Minimum Detectable Concentrations (MDCs)

The specific preliminary constituents of potential concern (preliminary COPCs) are as follows:

- Ra-226 and daughters
- Arsenic (As)
- Molybdenum (Mo)
- Selenium (Se)
- Uranium (U)
- Vanadium (V)

This list of preliminary COPCs was chosen because these constituents are commonly associated with uranium roll-front deposits and are expected to be co-located and proportional where present due to mining activities. The preliminary COPCs will be evaluated using off-site laboratory analysis. Additionally, gamma radiation levels will be surveyed using a field gamma meter and used to evaluate the distribution of Ra-226, where present. Metals will be analyzed for screening purposes only and not for delineating the vertical and lateral extent of metals in soil. Progeny of Ra-226 will not be analyzed during the investigation but will be accounted for during the Site risk evaluation.

At the Boneyard, the full suite of volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) as well as analysis of the eight Resource Conservation and Recovery Act (RCRA) metals by Toxicity Characteristics Leaching Procedure (TCLP) will be included.

The decision questions will be answered by evaluation of data from previous studies (see Section 1.0) and the results of this RSE. In addition to the sampling and analysis mentioned above, it will be necessary to fully characterize the complete exposure pathways. This will be done by developing a Conceptual Site Model using the existing data, the data collected during this study, and conceptual modeling, as discussed in more detail in Section 6.0.

A discussion of screening levels that will be used for this investigation is included in Section 3.5. The analytical methods that will be used for the laboratory analysis of Ra-226, and the five metals are shown in Table 3.1, *List of Analytical Methods and Screening Levels*. The radiological field scans will be conducted using a gamma scintillation meter, as discussed in Section 3.7 and Section 5.3. Analytical methods for the analysis of leachate by Synthetic Precipitation Leaching Procedure (SPLP) and TCLP are also included. The SPLP results will be used to evaluate whether the concentrations of preliminary COPCs in leachate due to precipitation exceed screening levels and may suggest the need to evaluate removal action alternatives to protect groundwater resources.

3.4 DEFINE THE BOUNDARIES

The sample population of interest is concentrations of the preliminary COPCs (see Section 3.3) in surface soils (0 to 0.5 feet) and in subsurface soils to the maximum depth of non-native materials, which could be anywhere from less than a foot to over 30 feet bgs. Additionally, the gamma radiation level will be measured at the ground surface. Concentrations of the preliminary COPCs in a synthetic precipitation leachate will also be evaluated for protection of groundwater. The data collected during this study are considered to be valid for a period of five years, as natural processes could redistribute the preliminary COPCs beyond this timeframe.

The scale of the decision making [survey unit sizes] is based on the area classifications and sampling methodology used (i.e., percent coverage). Soil samples collected for laboratory analysis will be evaluated as a whole for each individual survey area. The final survey unit sizes may be revised if a Removal Action is required.

TABLE 3.1
LIST OF ANALYTICAL METHODS AND SCREENING LEVELS

Metals in Soil (mg/kg)

Analyte	Analytical Method	Reporting Limit	Industrial Standard	Residential Standard	Source
Arsenic	EPA 6020	0.4	1.6	0.039	EPA PRGs[1, 5]
Molybdenum	EPA 6020	0.5	5,100	390	EPA PRGs[1]
Selenium	EPA 6020	0.3	5,100	390	EPA PRGs[1]
Vanadium	EPA 6020	1.0	1,000	78	EPA PRGs[1]
Uranium	EPA 6020	0.15	200	16	EPA PRGs[1]

Metals and Radionuclides in Leachate by Synthetic Precipitation Leaching Procedure (mg/L)

Analyte	Analytical Method	Reporting Limit	Standard
Arsenic[3]	EPA 6020	0.001	See discussion in Section 7.4 for screening levels
Molybdenum[4]	EPA 6020	0.001	See discussion in Section 7.4 for screening levels
Selenium[3]	EPA 6020	0.001	See discussion in Section 7.4 for screening levels
Vanadium	EPA 6020	0.005	See discussion in Section 7.4 for screening levels
Uranium[3]	EPA 6020	0.003	See discussion in Section 7.4 for screening levels
Ra-226[3]	EPA 903.0	0.1	See discussion in Section 7.4 for screening levels

Metals in Leachate by Toxicity Characteristic Leaching Procedure (mg/L)

Analyte	Analytical Method	Reporting Limit	TCLP Standard
Arsenic	EPA 6020	0.001	5
Barium	EPA 6020	--	100
Cadmium	EPA 6020	0.001	1
Chromium	EPA 6020	0.001	5
Lead	EPA 6020	0.001	5
Mercury	EPA 7470A	0.02	0.2
Selenium	EPA 6020	0.001	1
Silver	EPA 6020	0.001	5

Organic Compounds (mg/kg)

Analyte	Analytical Method	Reporting Limit	Standards
VOCs	EPA 8260B	See Appendix A	EPA PRGs[1]
SVOCs	EPA 8270C	See Appendix A	EPA PRGs[1]

Radionuclides in Soil (pCi/g)

Analyte	Analytical Method	Reporting Limit	Residential Soil Standard	Agricultural Soil Standard	Outdoor Worker Soil Standard	Source
Ra-226	EPA 901.1	0.5	0.0124	0.000632	0.0258	EPA/PRG[2]

Notes:
[1]EPA Region 9 PRG Table, October 2004
[2]EPA Radionuclide Toxicity and PRGs for Superfund, August 2004.
[3] New Mexico Groundwater Human Health Standards per 20.6.2
[4]New Mexico Groundwater Irrigation Standards per 20.6.2
[5]Analytical methods are not currently available that can achieve a reporting limit low enough to meet the residential PRG of 0.039 mg/kg for arsenic.
NA = not available

3.4.1 Lateral Boundaries

The 11 on-site survey areas included in this Work Plan are based on areas of impact at the Site, which are small and well defined. The lateral extents of these 11 survey areas are based on knowledge of past activities, materials handled at the Site, site reconnaissance, and the previous removal actions (UNC, 1989a). The area boundaries will be delineated by observations of unimpacted ground, roads,

structures, fences or other features, as well as radiological survey results. As explained in Section 3.7, the field radiological surveys will extend beyond the current boundaries, to the extent necessary, until a non-elevated response (less than the screening level) is observed.

No soils data have been collected to-date from the unnamed arroyo, however if impacts have occurred due to transport by wind, water, or to a lesser extent human and animal activities, it is expected that they will be confined to the primary drainage channel. As such, the survey will be confined to limits of the primary drainage channel and extend from the NPDES discharge point to the confluence with the next unnamed arroyo (downstream). The arroyo will be surveyed using transects across the channel (see Sections 3.7 and 5.0).

The one-half acre area surrounding each home site will be sampled and surveyed. Sampling will not be conducted inside the buildings as part of this RSE.

Constraints to the sampling are as follows:

- Within NECR-1 there are several buildings and/or building foundations still present. Sampling of these structures or the soils beneath them will not be conducted. If a sample location is placed on one of these structures, the actual sample location will be moved in the field to the closest soil-covered surface location so that the total number of required samples is maintained.

- The nine home sites will include the main homes plus potentially other structures or belongings of the owners (e.g., autos, farming equipment, etc.). No permanent structures will be moved and sampling will not be conducted beneath them. No indoor sampling will be conducted either. If necessary to meet the DQOs, the cooperation of the owner will be sought to move other items to permit sampling.

- Sampling at the nine home sites will not commence until the EPA or NNEPA obtains applicable access authorizations and appropriate notice is given to homeowners.

- Sampling of the background reference area will not commence until access is obtained from the BLM.

- If surveying occurs during or soon after a rainy period, there may be storm water in the ponds. Storm water will be dissipated until dry conditions exist via evaporation/infiltration from the ponds prior to conducting the surveys, if possible.

If the results of the field radiological surveys indicate that impacts extend beyond the current boundaries, then the survey boundaries will be revised and sampling will be expanded accordingly.

3.4.2 Vertical Boundaries

Soil sampling will be confined to the upper 0 to 0.5 feet bgs (surface soil) at the home sites. In the arroyo, sediment will be collected from 0 to 1 foot bgs. At the Potential Class 1 and Class 2 survey areas, sampling will be conducted primarily at the surface (0 to 0.5 feet bgs), with limited subsurface sampling (see Section 3.7). Subsurface sampling will be conducted to the maximum depth of non-native materials. The pad for NECR-1 was constructed by cut and fill; the fill areas include non-native material that are anticipated to extend to a maximum depth of approximately 30 feet bgs, but could be deeper. The pad for NECR-2 was made entirely of native materials, so subsurface sampling will be fairly shallow (less than 5 feet). The maximum depth of non-native materials at the NEMSA,

the sediment pad and the Boneyard is unknown, but is not expected to extend beyond 10 feet bgs. The maximum depth of non-native materials at the ponds and sand backfill areas is not expected to extend beyond one foot.

3.5 DEVELOP THE DECISION RULES

The parameters of interest are the absolute concentrations and the mean concentrations of each preliminary COPC in each survey area. The null hypothesis will be that the concentrations or mean concentrations of the measured preliminary COPCs are greater than the screening levels as defined below. The alternative hypothesis will be that the concentrations or mean concentrations of the measured preliminary COPCs are less than the associated screening levels. The hypotheses will be tested using statistical methods consonant with the assumptions supported by the data. All statistical estimators (e.g., means, regression parameters and estimates of constants in mathematical functions) will have acceptable confidence limits, as specified in Section 3.6.

In order to develop the decision rules to evaluate the null and alternative hypotheses, screening levels must be used to evaluate the preliminary COPC concentrations. The EPA Superfund Preliminary Remediation Goals (PRGs) for radionuclides (EPA, 2004c) and the EPA Region 9 PRGs for metals and organic constituents (EPA, 2004a) are proposed for use as screening levels for this investigation, as summarized in Table 3.1. The PRGs in Table 3.1 are not cleanup goals, but are risk-based concentrations associated with 10^{-6} risk level or a hazard index of 1 for non-cancer endpoints, whichever is lower. Because risk-based PRGs do not necessarily represent realistic exposure and risk, these initial numbers may not be appropriate cleanup levels. Other factors related to technical limitations (e.g., detection or quantification limits) also need to be considered (Interstate Technology and Regulatory Council, 2002). PRGs constitute initial guidelines, not final cleanup goals [40 CFR 300.430 (e)(2)(I], and were used to guide the DQO process.

For Ra-226 plus daughters, the residential, agricultural, and outdoor worker PRGs for soil are 0.0124 pCi/g, 0.000632 pCi/g, and 0.0258 pCi/g, respectively. These values are not achievable by standard EPA-approved analytical methods. The standard reporting limit (RL) of commercial laboratories using EPA Method 901.1, Ra-226 by gamma spectrometry is 0.5 pCi/g.

Based on the technical limitations of Ra-226 analysis an alternate screening level and DCGL is required for Ra-226. The initial $DCGL_W$ needs to be determined based on the minimum detectable concentration (MDC) of the analyses. According to MARSSIM (EPA, 2000a) Section 4.7.1, it is generally considered good practice to select a measurement system with an MDC between 10-50% of the $DCGL_W$. Three alternate $DCGL_W$ values were initially considered based on different regulatory strategies are described as follows:

- Reconsidering a $DCGL_W$ of 1.24 or 2.58 pCi/g Ra-226, based on a reasonable and achievable MDC, results in a risk within the acceptable risk range of 10^{-4} to 10^{-6} for residential and outdoor worker scenarios.

- Use of the soil cleanup levels according to 40 CFR 192 under the UMTRCA results in a level of 5 pCi/g Ra-226 on the surface (upper 6 inches) and 15 pCi/g Ra-226 at depth (deeper than 6 inches).

- Calculation of the Ra-226 $DCGL_W$ in soil based on the EPA recommended annual dose of 15 mrem/year (3×10^{-4} risk) (Interstate Technology and Regulatory Council, 2002) results in a level of 5.9 pCi/g Ra-226.

The laboratory RLs are able to achieve each of the regulatory derived values listed above. A $DCGL_W$ of 1.24 pCi/g plus background for Ra-226 will be used in the DQO process. A $DCGL_{EMC}$ of 2.0 pCi/g plus background will be used in the DQO process. The laboratory MDC is less than the uncertainty or 50 percent of the $DCGL_W$. Background concentrations are reportedly around 1 to 2 pCi/g (UNC, 1989a), which results in a preliminary screening level for Ra-226 of 2 to 3 pCi/g. Background levels will need to be considered for Ra-226 and metals, such as arsenic, because the background level may be greater than the screening level in some instances. However, these values represent initial screening levels only; and the results of this study will be used to develop final site-specific cleanup goals.

The final cleanup goals will be determined based on the following:

- The calculated risks within an acceptable risk range considering exposures anticipated from the intended land use;
- EPA PRGs for metals and radionuclides; and
- Background concentrations.

The decision rules for each survey area are detailed in the remainder of this section.

As discussed in Section 3.2, the principal study question for the Potential Class 1 sites is: are there levels of radionuclides and metals in these seven survey areas above the screening levels that warrant further characterization or evaluation for a removal action to prevent direct exposure or their transport via wind, water, or to a lesser extent human and animal activities? Therefore the decision statements for the seven Potential Class 1 sites (three sand backfill areas, three ponds and Sediment Pad) are:

- If no, the applicable survey areas will be ready for closure actions.
- If yes, evaluation of removal action alternatives and/or additional investigation will be required.

As discussed in Section 3.2, the principal study question for the Potential Class 2 sites is: are there levels of radionuclides and metals in these three survey areas above the screening levels that warrant further characterization or evaluation for a removal action to prevent direct exposure or their transport via wind, water, or to a lesser extent human and animal activities? Therefore, the decision statements for the three Potential Class 2 sites (NECR-1, NECR-2 and NEMSA) are:

- If concentrations above screening levels are detected, evaluation of removal action alternatives and/or additional investigation will be required.
- If concentrations are below screening levels, the applicable survey areas will be recommended for release.

As discussed in Section 3.2, the principal study question for the unnamed arroyo, a Potential Class 2 area, is: have impacts to alluvial sediments from the transport of radionuclides or metals by wind, water, or to a lesser extent human and animal activities occurred along the unnamed arroyo, and are there concentrations above appropriate screening levels that warrant further characterization or evaluation of a removal action alternative? Therefore, the decision statements for the unnamed arroyo are:

- If concentrations above screening levels are detected, an additional investigation and evaluation of best management practices or potential removal action alternatives may be warranted.

- If concentrations are not above screening levels, there will be no further action.

As discussed in Section 3.2, the principal study question for the Potential Class 3 site is: have impacts to surface soils from the transport of radionuclides or metals by wind, or to a lesser extent human and animal activities occurred at the nine home sites, and are their concentrations above screening levels that warrant additional investigation, such as hotspot investigation and indoor air monitoring or the need to discriminate their origin between the two separate mines in the area? Therefore, the decision statements for the one Potential Class 3 site (the home sites) are:

- If the results of the survey indicate that soils surrounding any of the home sites are impacted (i.e., concentrations of radionuclides or metals above screening levels), additional soil sampling and/or indoor air surveys performed by the EPA inside the residences may be conducted (this potential additional work is not part of this scope of work).

- If concentrations are not above screening levels, there will be no further action under this Work Plan.

As discussed in Section 3.2, the principal study question for the Boneyard is: are materials present in the surface or subsurface that contain liquids, or are there concentrations of radionuclides, metals, or organic constituents above screening levels? Therefore, the decision statements for the Boneyard are:

- If concentrations of radionuclides, metals, or organic constituents are detected above screening levels, additional investigation and evaluation of potential removal action alternatives may be warranted.

- If concentrations are not above screening levels, there will be no further action.

The decisions to conduct additional investigations and conduct removal actions or no actions will be made by the EPA.

3.6 SPECIFY THE TOLERANCE ON DECISION ERRORS

All statistical significance tests will be conducted at the 95% confidence level (i.e., a false positive rate or Type I error of 5%) and a nominal Type II error of 10%. Stated otherwise, all significance tests will have a significance level, α, equal to 0.05 and a Type II error, β, equal to 0.10 for those studies not associated with biased or judgmental sampling. The Type II error rate, which characterizes the risk of performing unnecessary remediation, may be adjusted to reflect the relative costs of remediation versus additional sampling.

The statistical techniques used for the conductance of the significance tests will be chosen such that their underlying assumptions are supported by the data. Evaluation of the data and the selection of the appropriate statistical testing procedure will be made during the Data Quality Assessment (DQA) as discussed in Section 7.0.

3.7 OPTIMIZE SAMPLING DESIGN

The objective of this section is to develop the process for collection and measurement of the decision inputs. The sampling program was designed to support the individual DQOs identified with each type of data need. In addition, the sampling design was developed in order to meet the tolerance criteria outlined above in Section 3.6.

3.7.1 Potential Class 1 Sites

The survey areas listed below will be evaluated for metals and radiological characterization in surface and subsurface soils.

- Sand Backfill Area No. 1
- Sand Backfill Area No. 2
- Sand Backfill Area No. 3
- Ponds No. 1 and No. 2
- Pond No. 3/3a
- Sediment Pad

Surface soil sampling will be performed as part of a characterization survey at each Potential Class 1 Area. Pond No. 1 and Pond No. 2 will be grouped as a single survey area. The number of surface soil samples was determined using the Wilcoxon Rank Sum (WRS) test per MARSSIM guidance (EPA, 2000a). The WRS test is used for areas where COCs are present in background. The surface soil results will be compared to the background areas to determine if the results from the survey areas are statistically different from the background areas. The statistical parameters used to determine the number of data points needed to apply a nonparametric test such as WRS are defined in Table 3.2, *Statistical Parameters for Wilcoxon Rank Sum Test*.

TABLE 3.2
STATISTICAL PARAMETERS FOR WILCOXON RANK SUM TEST

Parameters	Value
Type I Error Rate (alpha - α)	0.05
Type II Error Rate (beta - β)	0.10
Pre-Planning screening level	1.24 pCi/g
Shift ($DCGL_w$ - LBGR)	0.90
Standard Deviation (sigma - σ)	0.55
Relative Shift (Δ/σ = between 1 and 3)	1.6
Number of Samples (N)	13

The statistical parameters shown in Table 3.2 were selected in order achieve a low error rate as well as a relative shift between one and three. The relative shift is based on the lower bound of the gray region and the standard deviation. In addition, the number of data points determined using the WRS test was increased by 20 percent to account for possible lost or unusable data. This statistical test resulted in a minimum of 13 samples being collected for each survey area and reference or background area.

Stationary soil radiation measurements will be collected on an 80-foot grid at each Potential Class 1 area. Surface soil samples will be collected at 20 percent of the stationary gamma measurements, or a maximum of 13 samples, whichever is greater. The surface soil samples will be analyzed for the preliminary COPCs, Ra-226 and the five metals.

Visual Sampling Plan (VSP) was used to determine the locations of the stationary gamma measurements and the surface soil samples. The static gamma measurements and surface sample locations were located by using a triangular grid cast on a random origin. Investigation of these areas by judgmental and systematic field radiological scanning will extend out beyond the current boundaries along transects, if necessary, to the point where an elevated response (greater than the screening level) is no longer observed. Detailed methods for the collection of gamma measurements and surface soil samples are located in Section 5.0 and standard operating procedures (SOPs) in Appendix C.

The subsurface soil evaluation will rely on sample collection and laboratory analysis of Ra-226 and metals. Five locations at each Potential Class 1 survey area will be selected for subsurface samples. These locations will be based on judgmental sampling and will be located coincident with surface soil sample locations. Soil grab samples will be collected every five feet from the ground surface to native soil including a sample of native soil. If the depth to native soil is less than five feet, one soil grab sample will be collected from the mid-depth of the non-native material in addition to a native soil sample.

Two soil samples collected in a judgmental manner will also be collected from each survey area for potential leaching of Ra-226 and metals using SPLP analysis. These samples will be collected at two of the surface or subsurface soil sample locations based on the total metal results. For each sample, the percent or factor difference between the metal concentration and screening level will be determined. This percent or factor difference will be summed for each metal associated with the soil sample. The two samples from each survey area with the highest percent or factor difference will be selected for SPLP analysis. In addition, soil samples for agronomic analysis will be collected from the survey areas. The samples will be collected and analyzed following the methods in Section 5.0

3.7.2 Potential Class 2 Sites

The survey areas listed below will be investigated to evaluate the nature and extent of preliminary COPCs in the surface and subsurface.

- NECR-1
- NECR-2
- NEMSA
- Unnamed arroyo

Static gamma measurements, gamma scans, and soil sampling will be performed as part of a characterization survey at each Potential Class 2 Areas. The methods and number of static gamma measurements and surface soil samples was determined as described for the Potential Class 1 survey areas. A total of 31 and 15 surface soil samples will be collected from NECR-1 and NECR-2, respectively, and only five surface soil samples will be collected from NEMSA due to the reclamation that occurred. The surface soil samples will be analyzed for preliminary COPCs. A total of 30 surface (zero to one foot bgs) soil samples will be collected along 10 transects across the unnamed arroyo.
The subsurface soil evaluation will rely on sample collection and laboratory analysis of Ra-226 and metals. Subsurface samples greater than 1-foot will not be collected for the unnamed arroyo. Five locations at each Potential Class 2 survey area will be selected for subsurface samples, except the unnamed arroyo. These locations will be based on judgmental sampling and will be located coincident with surface soil sample locations. Soil grab samples will be collected every five feet from the ground surface to native soil including a sample of native soil. If the depth to native soil is less than five feet, one soil grab sample will be collected from the mid-depth of the non-native material in addition to a native soil sample.

Two soil samples collected in a judgmental manner will also be collected from each survey area for potential leaching of Ra-226 and metals using SPLP analysis. These samples will be collected at two of the surface and/or subsurface soil sample locations based on the total metal results. For each sample, the percent or factor difference between the metal concentration and screening level will be determined. This percent or factor difference will be summed for each metal associated with the soil sample. The two samples from each survey area with the highest percent or factor difference will be selected for SPLP analysis. In addition, soil samples for agronomic analysis will be collected from the survey areas. The samples will be collected and analyzed following the methods in Section 5.0

The sediments in the unamed arroyo will be evaluated by collection of sediments in the top one foot of ground. Ten transects will be evenly spaced between the the former NPDES discharge point and the confluence with the next unnamed arroyo. Along each transect, three grab samples from 0 to 1 foot bgs will be collected for laboratory analysis of Ra-226 and metals. The three samples will be evenly spaced across the bottom of the arroyo. A scanning gamma radiation survey will also be performed longitudanally along the axis of the channel.

3.7.3 Potential Class 3 Sites

The home sites are north of NECR-1, west of Red Water Pond Road, and south of the unnamed arroyo that flows into the Pipeline arroyo. A half-acre area around each home site was selected for the intial lateral boundaries. Five surface soil samples (0 to 0.5 ft bgs) will be collected in a judgemental manner for laboratory analysis of Ra-226 and metals from outdoor surface soils only within each home site area. The surface sample locations will be leveled to grade after sampling with remaining soil. A field radiological scan will also be performed over each home site.

3.7.4 Site Screening Survey Areas

A site screening evaluation will be performed at the Boneyard. Judgmental surface and subsurface soil sampling will be used at the Boneyard to evaluate the potential for impacts by preliminary COPCs in addition to VOCs, SVOCs, and the TCLP analyses of the eight RCRA priority pollutant metals for the subsurface samples. The five locations will be selected in the field based on soil staining and visual evidence of impacts or buried material. Borings or standard test pits will be used depending on the depth to native soil. Soil grab samples will be collected at the current surface, the pre-cap surface, and every five feet from the ground surface to native soil. If the depth to native soil is less than five feet, one soil grab sample will be collected from the mid-depth of the non-native material in addition to a native soil sample. A scan will be performed over a maximum of 20 percent of the Boneyard.

3.7.5 Background Areas

The background levels within the area have not been adequately characterized to define an appropriate background value and associated variance for statistical purposes. Therefore, background measurements for use in two population statistical tests will be obtained during the RSE. One area to the northwest of the Boneyard, approximately five acres in size, will be used to determine the background concentrations of metals and Ra-226. A total of 25 samples based on the WRS test will be collected from the background area and sent for laboratory analysis of Ra-226 and metals. The sample locations were determined using VSP and are based on an equally spaced triangular grid, which was cast on a random origin.

4.0 QUALITY ASSURANCE PROGRAM

4.1 QUALITY ASSURANCE PROJECT PLAN

A Quality Assurance Project Plan (QAPP) was developed for the project and is presented in Appendix A. The QAPP was prepared to describe the project requirements for all field and Contract Laboratory activities and data assessment activities associated with this Work Plan. The QAPP presents in specific terms the policies, organization, functions, and quality assurance/quality control (QA/QC) requirements designed to meet the DQOs for the sampling activities described in this Work Plan. Additionally, the QAPP provides guidance that establishes the analytical protocols and documentation requirements to ensure the data are collected, reviewed, and analyzed in a consistent manner. The QAPP was prepared in accordance with the document *EPA Requirements for Quality Assurance Project Plans* (EPA, 2001); the EPA guidance document *Guidance for Quality Assurance Project Plans* (EPA, 2002a) was also used.

4.2 DATA MANAGEMENT

MWH will manage all data pertinent to this project by establishing data handling procedures and a centralized database management system. This section of the Work Plan provides details on the data management procedures that will be implemented during this project.

Data management will be achieved using a standard relational database format. Database fields will encompass standard sample and analytical information, including:

- Sample identifications
- Matrices
- Analytical methods
- Dates & times
- Chain-of-custody information
- Analytical results
- Detection limits and reporting limits
- Quality control results
- Coordinate information

Horizontal coordinate information will be referenced to the State Plane Coordinate System, New Mexico West, North American Datum of 1983. Vertical coordinates will be referenced to the North American Vertical Datum of 1988.

The database will serve as a central repository for data from many different project tasks. It is one foundation for making project decisions. Making sure the data are technically accurate, complete and correctly represented in the database is referred to as "data integrity." Project staff will assume that data within the database are correct and ready to use in analyses, reports, graphics, geographic information system (GIS), modeling and for other purposes. Therefore, the Database Manager will ensure that the following tasks have been applied to all data in the database:

- Data will be received from the laboratory using an electronic data deliverable (EDD) format compatible with the project database format;

- Data will be assembled and reviewed by the person compiling the data for completeness and technical accuracy (hydrogeologist, chemist, project manager and others);

- Data will have been validated using procedures presented in the QAPP; no draft or preliminary (i.e., unvalidated and unqualified) data will be put into the master database;

- Data will be transcribed accurately from any hard copies during data entry (100% error free transcription); and

- Data are converted and imported accurately from any electronic files (spreadsheets, ASCII files, and EDDs).

The Database Manager will also ensure that all data products (report summary tables, appendices, programs and files exported to other applications) represent the data in the database accurately.

4.3 ASSESSMENT AND OVERSIGHT

Program assessment and oversight will be performed by the Quality Manager and/or designee and will include assessments and response actions, reports to management, as well as nonconformance and corrective action training.

All personnel are responsible for ensuring that the program is implemented in accordance with this Work Plan and applicable professional standards. All personnel are also expected to stop and take appropriate action when it is determined that conditions adversely affecting the quality of the data have occurred (e.g., an instrument is not working properly). Work may be stopped to determine what further action is needed to meet the quality objectives of this study.

4.3.1 Assessments and Response Actions

Program assessment and oversight will include surveillance/audit of field sampling activities, the analytical program, and program records. Surveillance of sampling activities will focus on adherence to procedures outlined in this Work Plan and will include observation of sampling procedures and selected documentation (e.g., field logbooks).

Review of program records will include both sampling and laboratory records. Review of the laboratory data will serve as verification that the quality program as described in this Work Plan and the laboratory QAPP is being implemented, thus allowing for the collection of data that support the DQOs.

4.3.2 Nonconformance and Corrective Action

All of the individuals involved in this program will follow a formalized process for documenting non-conformances. The nonconformance process consists of the following:

- Identification of the nonconformance;

- Determination of the immediate actions to be taken as a result of the nonconformance;

- Root cause analysis and identification of real root cause(s);

- Proposed action to prevent recurrence of the nonconformance and implementation of the correction; and

- Follow-up and verification of the effectiveness of the corrective action.

Any deviations from the specifications described in this Work Plan, field sampling protocols, field measurement SOPs, or laboratory quality system will be documented and addressed. A signed corrective action or field change request (see Appendix B) form will be submitted to the EPA for their approval prior to proceeding with the affected task. A prompt response from the EPA will be required to prevent delays in the execution of field activities. The form(s) will be forwarded to the UNC Project Manager and MWH Project Manager and Quality Manager.

4.3.3 Data Validation and Usability

Data verification is used to ensure that the requirements stated in the planning documents are implemented as prescribed. Data validation is used to ensure that the results of the data collection activities support the objectives of the survey as documented in the QAPP, or permit a determination that these objectives should be modified. Data quality assessment is the scientific and statistical evaluation of data to determine if the data are of the right type, quality, and quantity to support their intended.

4.3.4 Verification and Valuation Methods

Labs are required to submit a data package for all data in accordance with the requirements defined in the QAPP. The review of all data from contract laboratories associated with field activities will be at Level III and 10 percent of the data will undergo Level IV data validation. Level III consists of a review of all summary forms, but does not include a review of the raw data. This review includes laboratory and field QC sample results to determine whether the analytical process is in control.

Each sample will be verified during validation to ensure that the procedures used to generate the data were implemented as specified. Data validation activities should determine how much a sample deviated beyond the acceptable limit so that the potential effects of the deviation can be evaluated during data quality assessment.

This plan specifies the QC checks that are to be performed during sample collection, handling, and analysis. These include calibration and analyses of check standards, blanks, spikes, and replicates, which provide indications of the quality of data being produced by specific steps of the measurement process. Data validation should document any corrective actions that were taken, which samples were affected, and the potential effect of the actions on the validity of the data. When issues are identified in the verification and validation process, the validator will make appropriate comments and/or assign data flags to alert the data user to potential limitations on the usability of the data.

Level IV consists of review and cross-check of all required data deliverables; review of all raw data; recalculation of all values, including standards concentration, reagent preparation, percent moisture values, analytical results, etc.; comparison of all recalculated values to the reported values; and flagging of all data that were not produced in accordance with the specifications set forth in this Work Plan and laboratory QAPP. All electronic copy entries will be verified against hard-copy results reported by the laboratory and sampling personnel. If the hard copy is generated by the same information management system used to store the electronic data, then this review is not required.

4.3.5 Reconciliation with User Requirements

Data collected during the field activities will be reconciled with the requirements of the data user. There are five steps in the DQA Process:

- Review the DQOs and survey designs;

- Conduct a preliminary data review;
- Select the statistical test;
- Verify the assumptions of the statistical test; and
- Draw conclusions from the data.

These five steps are presented in a linear sequence, but the DQA process is applied in an iterative fashion much like the DQO process. The strength of the DQA process is that it is designed to promote an understanding of how well the data will meet their intended use by progressing in a logical and efficient manner.

5.0 FIELD SAMPLING PLAN

5.1 SAMPLING RATIONALE AND OBJECTIVES

5.1.1 Surface Soil & Sediment Sampling

Surface soil sampling will be conducted at the 11 on-site survey areas, the unnamed arroyo, the nine home sites, and the background area, as discussed in Section 3.0. Surface soil samples will be collected manually as grab samples (see Section 5.3) from 0 to 0.5 feet bgs (0 to 1 foot bgs composite for the arroyo) and submitted to the laboratory and analyzed for preliminary COPCs, as presented in more detail in Section 5.2.

From the on-site survey areas, except the Boneyard and NEMSA, 20 percent of the static measurements or a minimum of 13 samples, whichever is greater, will be collected on a triangular grid cast on a random origin in accordance with MARSSIM (EPA, 2000a) guidance, as presented in Section 3.7; sample locations are shown in Figures 3-1 through 3-12. A total of 25 samples from the background area will also be collected on a triangular grid cast on a random origin. The background and survey area samples are designed to:

- Obtain a sample population that can be statistically compared to the background sample population (see MARSSIM (EPA, 2000a));
- Be individually compared to screening levels;
- Determine the upper 95 percent confidence level for background concentrations; and
- Provide complete coverage of each survey area.

These samples will also be used to screen for preliminary metal COPCs, to assist characterization of the nature and extent of impacts from Ra-226 at each survey area, and to meet the DQOs, as described in Section 3.0. In addition, the preliminary metal COPCs and Ra-226 samples will be collocated to evaluate whether a correlation between metals and radionuclides exists at the Site. The surface soil samples will also be collocated with static gamma measurements.

Because the Boneyard and NEMSA were reclaimed in 1994 and covered with a one-foot layer of topsoil, they are unlikely to have preliminary COPCs at the surface. Therefore, only five judgmental surface samples will be collected from each of these sites to evaluate if any impacts subsequent to reclamation have occurred. The sample locations will be chosen based on field observations or evidence that impacts may have occurred (e.g., stressed vegetation, eroded ground, areas with sediments deposited from storm water runoff from other areas). If no such evidence exists, the samples will be collected randomly. Surface samples from the Boneyard and NEMSA will be analyzed for preliminary COPCs and samples will be collected from the pre-cap surface as discussed in Section 5.3.2. Samples for agronomic analysis as discussed below will be co-located with the surface sampling for preliminary COPCs.

An additional set of surface soil samples (10 to 15 samples from several survey areas) will be collected from locations coincident with stationary gamma scan locations to develop a correlation between Ra-226 and the gamma radiation count rate. A separate correlation will be required for the arroyo due to the geometry of the arroyo and surface soil samples and stationary gamma locations will be collected. The correlation sample locations will be chosen in the field in a judgmental manner at locations with low activity, high activity and levels in between, based on the field radiological scans.

These samples will be analyzed for Ra-226 only. Additional methods for the collection of surface soil samples for the correlation study are presented in Section 5.3.

Samples collected from the unnamed arroyo will be collected from 10 transects oriented perpendicular to the arroyo, from the former NPDES discharge point to its confluence with the next unnamed arroyo. Three samples will be collected from each transect, one at each edge of the arroyo and one at the midpoint. The transects are shown schematically in Figure 3-10. Surface soil samples will be composited from 0 to 1 foot bgs and will be analyzed for preliminary COPCs and will be used to evaluate whether impacts have occurred along the arroyo. The surface soil sample locations were chosen to provide broad spatial coverage of the arroyo downstream of the Site. Field radiological scans will be conducted along the centerline in the unnamed arroyo from the NPDES discharge point to its confluence with the next unnamed arroyo.

Five samples will be collected for the analysis of preliminary COPCs from each of the nine home sites in a judgmental manner within a one-half acre buffer around each home site, as shown on Figure 3-11. The samples will be located on native ground and will be collected from the top 6 inches of soil. If grass is covering the soil, a small patch of grass will be cleared down to the soil surface, as that will likely be the zone that wind borne particles from the Site would deposit if they were to make it to that location. These samples will be collected at relatively evenly spaced intervals within the one-half acre buffer, to the extent possible given the physical constraints at each home site. The sample locations will be chosen to provide a representative set of samples from each home site to evaluate whether impacts from preliminary COPCs have occurred. The surface sample locations will be leveled to grade after sampling with remaining soil.

Approximately 5 to 10 surface soil samples throughout the survey areas may be collected from judgmental locations such as at locations that have the potential to accumulate contamination in low lying areas of the ponds. Sample splits will be collected from 10% of the locations in addition to the quality control samples discussed in Section 5.3.6. Split samples will be submitted to the EPA's laboratory for quality assurance purposes.

Surface soil samples will be collected from the on-site survey areas for analysis of agronomic properties. Five samples will be collected from each set of survey areas with similar characteristics, as follows:

- Five samples total from the Ponds No. 1 and No. 2 and No. 3/3a, and the Sediment Pad;
- Five samples from Sand Backfill No. 1, No. 2 and No. 3;
- Five samples from NECR-1 and NECR-2; and
- Five samples from the Boneyard and the NEMSA.

This equates to a total of 20 samples. The sample locations will be chosen in a judgmental manner from areas representative of the areas that may require reclamation, such as the application of top soil and/or reseeding. These data will be used to determine the suitability of the soils as growth media including availability of nutrients and any potential toxicity.

Another set of samples will be collected for the analysis of preliminary COPCs in leachate using the SPLP method. Two samples will be collected in a judgmental manner from each of the on-site survey areas that have not been reclaimed (i.e., not including the NEMSA or the Boneyard). The sample locations will be chosen at the surface or subsurface location in each of the survey areas that report the highest total metal results as described in Section 3.7. The samples will be used to evaluate the potential for leaching of the impacted materials and potential impacts to surface water and groundwater. A sample for TCLP analysis of the eight RCRA priority pollutant metals will also be

collected from each of the five biased locations in the Boneyard. These five samples will be chosen from either surface or subsurface locations based on the highest total metal results as described in Section 3.7.

It must be noted that the boundaries of the survey areas may be redrawn in the field based on the boundary delineation studies and GPS measurements. The proposed locations may be revised based on the field survey boundaries and access problems such as the presence of foundations or other structures.

5.1.2 Subsurface Soil Sampling

Judgmental subsurface samples will be collected from the potential Class 1 and Class 2 survey areas and the Boneyard. Soil samples collected from the unnamed arroyo will only consist of composite samples from 0 to 1 foot bgs as discussed in Section 5.1.1. Subsurface soil samples collected at the Boneyard and NEMSA will include one sample of the pre-cap soil at each subsurface location. A total of five locations will selected from each survey area and will be co-located with gridded surface soil sample locations.

Grab samples will be collected from representative non-native materials every five feet to native soil and one grab sample from the native soil. If the depth of non-native materials is less than five feet, one sample of non-native material will be collected at approximately a mid-depth of the materials as well as the native soil sample.

Soils will be visually classified in the field in accordance with the Unified Soil Classification System (USCS), and any soil horizons observed during the sample collection will be noted in the field logs. Test pits will be dug to collect the subsurface samples. Where subsurface material characterization requires a sample collection depth greater than the reach of a backhoe (~10 feet), hollow-stem auger borings will be drilled to collect material at depth. Drill holes are anticipated to be completed at NECR-1 due to depth of non-native materials of approximately 20 to 30 feet in the northwest corner of the area. The soil samples will be analyzed for preliminary COPCs at each of the survey areas. At the Boneyard, samples for VOCs, SVOCs, and TCLP analysis will be collected in addition to the preliminary COPCs. The numbers of subsurface soil samples are based on the following assumptions:

- Ponds No. 1 and No.2: five locations to a maximum depth of five feet (a total of 10 samples);
- Pond No 3/3a: five locations to a maximum depth of five feet (a total of 10 samples);
- Sand Backfill Area No. 1, No. 2, and No. 3: five locations in each area to a maximum depth of five feet (a total of 30 samples);
- Sediment Pad: five locations to a maximum depth of 10 feet (a total of 10 samples);
- Boneyard: five locations to a maximum depth of 10 feet including one sample of the pre-cap soil (a total of 15 samples);
- NEMSA: five locations to a maximum depth of 10 feet including one sample of the pre-cap soil (total of 15 samples);
- NECR-2: five locations to a maximum depth of five feet (total of 10 samples); and

- NECR-1: two locations to a maximum depth of 30 feet, plus three locations to a maximum depth of 15 feet (total of 21 samples).

5.1.3 Field Radiological Scans

The primary radionuclide of concern at the Site is Ra-226, due to its decay into alpha-emitting radon progeny, which diffuse into the atmosphere and impose internal radiation exposure through inhalation, and gamma-emitting decay products, which would pose a direct external radiation exposure. Thus determination of Ra-226 would provide the primary radiation hazard assessment associated with uranium ore and impacted soils. Nevertheless, determination of Ra-226 content would also provide estimation of other radionuclide concentrations of concern (U-natural and Th-230) in soil derived from uranium ore because all of the radionuclides should be in secular equilibrium in uranium ore. However, Ra-226 may not be able to accurately estimate other radionuclide concentrations in processed waste materials since Ra-226 is likely to be in partial secular equilibrium.

The field radiological stationary measurements and scans will consist of direct gamma radiation level measurements using a scintillation detector coupled with a single-channel rate meter and a DGPS. Use of DGPS will facilitate development of a site survey map with radiological isopleth contours in various ranges of uncorrected raw data and Ra-226 concentrations in soil. Soil sampling will be performed to correlate and calibrate the gamma radiation level measurements in counts per minute to soil Ra-226 concentrations. Correlations will be developed for both shielded and unshielded measurements. Shielded sodium iodide (NaI) scintillation detectors may be used in some areas to avoid any radiation shine interference. This static gamma radiation level measurement for Ra-226 is consistent with criteria for selection of direct measurement method specified in Section 4.7.3 of MARSSIM (EPA, 2000a). Correlation of direct gamma level measurements to laboratory concentrations has been approved by several agencies and successfully used at sites such as the Kirtland Air Force Base in New Mexico, the Riley Pass Uranium Mines in South Dakota, the Dawn Mining Company Uranium Millsite in Washington, the Grants Uranium Mill Site in California, the Section 8 Uranium Site in Utah, and the Bluewater Mill Site in New Mexico. The field methods for the field gamma survey and the correlation study as well as example MDC calculations are described in Section 5.3.3 as well as SOPs 1, 2, and 3.

The direct gamma radiation measurement technique is appropriate for a quantitative determination of gamma emitting radionuclides only in surface soils and is a qualitative technique for subsurface soils, depending on the depth of contamination. Surface gamma radiation surveys are not adequate for a vertical extent of contamination greater than 0.5 feet. Therefore, the concentration of Ra-226 in subsurface soils will be determined by collection of soil grab samples and analysis by an off-site laboratory, as described in Section 5.3.2.

5.2 ANALYTICAL PROGRAM

This section describes the analytical program that will be used for the analysis of surface and subsurface soil samples submitted to a chemical laboratory.

As discussed in Section 5.1, a total of approximately 360 samples will be collected for laboratory analysis. A summary of these samples in included in Table 5.1, *Summary of Soil Sampling Program.*

5.2.1 Analyses

Samples will be processed for three groups of analytes as summarized in the following tables:

- Table 5.2, *Radionuclide and Total Metals Analyses*;

- Table 5.3, *Synthetic Precipitation Leaching Procedure Analyses;*
- Table 5.4, *Toxicity Characteristic Leaching Procedures Analyses;*
- Table 5.5, *Volatile Organic Compounds and Semi-volatile Organic Compounds;* and
- Table 5.6, *Agronomic Analyses.*

TABLE 5.1
SUMMARY OF SOIL SAMPLING PROGRAM

Sample Set	Sampling Method	Quantity	Analytical Suite
Surface Soil Samples			
NECR-1 & NECR-2	Triangular grid on random origin	46	preliminary COPCs
Ponds No. 1 and No. 2 & Pond No, 3/3a	Triangular grid on random origin	32	preliminary COPCs
Sand Backfill Areas 1, 2 & 3	Triangular grid on random origin	41	preliminary COPCs
Sediment Pad	Triangular grid on random origin	13	preliminary COPCs
NEMSA	Judgmental	5	preliminary COPCs
Boneyard	Judgmental	5	preliminary COPCs
Background areas	Triangular grid on random origin	25	preliminary COPCs
Unnamed Arroyo	Transects/Judgmental	30	preliminary COPCs
Home sites	Judgmental	40	preliminary COPCs
Site-wide[1]	Judgmental	10	Preliminary COPCs
Correlation samples	Judgmental	30	Ra-226
Agronomic	Judgmental	20	Agronomic
SPLP	Judgmental	16	preliminary COPCs
Subsurface Soil Samples			
Ponds No. 1 and No. 2 & Pond No, 3/3a	Judgmental	20	preliminary COPCs
Sand Backfill Areas 1, 2 & 3	Judgmental	30	preliminary COPCs
Sediment Pad	Judgmental	10	preliminary COPCs
NECR-1	Judgmental	21	preliminary COPCs
NECR-2	Judgmental	10	preliminary COPCs
NEMSA	Judgmental	15	preliminary COPCs
Boneyard	Judgmental	15	preliminary COPCs, VOCs, SVOCs, and TCLP
Quality Control Samples			
Field Replicates[2]	Rate of 5%	20	preliminary COPCs
EPA Splits[2]	Rate of 10%	40	preliminary COPCs
Equipment rinsate samples	One per day	15	preliminary COPCs

Notes:
[1] These samples will be collected at locations most likely to accumulate impacted material.
[2] The quantity of replicates and splits is based on the percentage indicated times the total number of samples, not including the agronomic or SPLP samples.

5.2.1.1 Radionuclides and Total Metals

Total metals and Ra-226 analysis will be performed on soil samples to characterize the type and quantity of preliminary COPCs. A summary of the analytical program for the preliminary COPCs is included in Table 5.2. Ra-226 will be analyzed by EPA Method 901.1 and metals by SW-846 6020/200.8. This table is also a summary of pertinent field sampling information (i.e., sample containers, preservative and holding times).

TABLE 5.2
RADIONUCLIDE AND TOTAL METALS ANALYSES

Analyte	Analytical Method	Sample Container	Preservative	Holding Time
Ra-226	901.1	Gallon ziploc bag	None	180 days
Arsenic	EPA 6020/200.8	4-8-oz glass wide-mouth jar with Teflon-lined cap	None	180 days
Molybdenum	EPA 6020/200.8	Same container as Arsenic	None	180 days
Selenium	EPA 6020/200.8	Same container as Arsenic	None	180 days
Uranium	EPA 6020/200.8	Same container as Arsenic	None	180 days
Vanadium	EPA 6020/200.8	Same container as Arsenic	None	180 days

5.2.1.2 Synthetic Precipitation Leaching Procedure

Potential impacts to surface water and groundwater will be determined using EPA Method 1312, SPLP. The dynamic leaching test will be performed on samples to determine the leachate water quality of soil samples under current conditions. The standard SPLP test involves cycling one milliliter of pH 5.0 lixiviant per gram of soil in a prepared column. The SPLP leachate will be analyzed for the water quality parameters listed in Table 5.3.

SPLP testing will be performed on soils to evaluate the current and long-term potential of these materials to leach metals either through the oxidation of sulfide minerals, mobilization of residual low pH fluids, or dissolution of highly soluble sulfate salts. Because the surficial mine-related materials have undergone more than 20 years of natural weathering, these exposed materials may be tested under present conditions to evaluate the geochemical reactions that will affect long-term seepage and runoff water quality. Utilizing this approach, static geochemical testing will involve testing of a limited number of samples to evaluate leachate water quality. Also, the basic purpose is to be able to conservatively evaluate if infiltration can leach elements present at concentrations above some action level (e.g., the MCLs), and cause their transport into water resources.

TABLE 5.3
SYNTHETIC PRECIPITATION LEACHING PROCEDURE ANALYSES

Analyte	Analytical Method	Sample Container	Preservative	Holding Time
Arsenic	EPA 6020/200.8	4-8-oz glass wide-mouth jar with Teflon-lined cap	None	180 days
Molybdenum	EPA 6020/200.8	Same container as Arsenic	None	180 days
Selenium	EPA 6020/200.8	Same container as Arsenic	None	180 days
Vanadium	EPA 6020/200.8	Same container as Arsenic	None	180 days
Uranium	EPA 6020/200.8	Same container as Arsenic	None	180 days
Ra-226	EPA 903.0	Same container as Arsenic	None	180 days
Note: All parameters are for dissolved fraction unless otherwise noted				

5.2.1.3 Toxicity Characteristic Leaching Procedure

Samples will be collected for TCLP analysis (EPA Method 1311) from subsurface locations in the Boneyard at each of the five judgmental sampling locations. TCLP is designed to determine the mobility of both organic and inorganic analytes present in liquid, solid, and multiphasic wastes. The TCLP leachate will be analyzed for the eight RCRA priority pollutant metals listed in Table 5.4.

TABLE 5.4
TOXICITY CHARACTERISTICS LEACHING PROCEDURE ANALYSES

Analyte	Analytical Method	Sample Container	Preservative	Holding Time
Arsenic	EPA 6020/200.8	4-8-oz glass wide-mouth jar with Teflon-lined cap	None	180 days
Barium	EPA 6020/200.8	Same container as Arsenic	None	180 days
Cadmium	EPA 6020/200.8	Same container as Arsenic	None	180 days
Chromium	EPA 6020/200.8	Same container as Arsenic	None	180 days
Lead	EPA 6020/200.8	Same container as Arsenic	None	180 days
Mercury	EPA/7470A	Same container as Arsenic	4°C ± 2°C	28 days
Selenium	EPA 6020/200.8	Same container as Arsenic	None	180 days
Silver	EPA 6020/200.8	Same container as Arsenic	None	180 days

Note:
All parameters are for dissolved fraction unless otherwise noted

5.2.1.4 Volatile Organic Compounds and Semi Volatile Organic Compounds

Samples will be collected for VOCs and SVOCs from subsurface samples in the Boneyard at each of the five judgmental sampling locations. The full suite of VOCs and SVOCs will be analyzed by EPA Methods 8260B and 8270C, respectively. The VOC samples will be collected according to EPA Method 5035A using TerraCore samplers, as well as glass jars. A summary of the analytical methods and procedures is included in Table 5.5.

TABLE 5.5
VOLATILE ORGANIC COMPOUNDS AND SEMI VOLATILE ORGANIC COMPOUND ANALYSES

Analyte	Analytical Method	Sample Container	Preservative	Holding Time
VOCs	8260B	TerraCore Samplers and 4 oz glass wide-mouth jar with Teflon-lined cap	Sodium Bisulfate/Methanol 4°C ± 2°C	14 days
SVOCs	8270C	8-oz glass wide-mouth jar with Teflon-lined cap	4°C ± 2°C	14 days

5.2.1.5 Agronomic Analytical Procedures

Agronomic analyses will be used to evaluate potential revegetation alternatives for the Site for purposes of closeout of the Mining Act Permit. Results of these data will be used to determine suitability of the soils as growth media including availability of nutrients and any potential toxicity. Table 5.6 lists the analytes for which samples will be analyzed.

5.2.2 Analytical Laboratory

5.2.2.1 Primary Laboratory

UNC proposes to use Energy Labs for all laboratory analyses. All analyses, within the capabilities of the laboratory, will be performed at the Casper, Wyoming facility. Energy Labs is a NELAC certified analytical laboratory.

TABLE 5.6
AGRONOMIC ANALYSES

Analyte	Analytical Method	Sample Container	Preservative	Holding Time
pH	ASA No. 9, Method 10-3.2	Gallon ziploc bag	None	Not established
Electrical Conductivity	ASA No. 9, Method 10-3.3	Same container as pH	None	Not established
Saturation Percentage	USDA Handbook 60, Method 27A	Same container as pH	None	Not established
Texture	ASA No. 9, Method 15-2.2	Same container as pH	None	Not established
Rock Fragment Percentage	ASA No. 9, Method 15-2.2	Same container as pH	None	Not established
Sodium Adsorption Ratio (SAR)	ASA No. 9, Method 10-3.4	Same container as pH	None	180 days
Nitrate as N	ASA No. 9, Method 38-8.1	Same container as pH	None	28 days
Phosphorous	ASA No. 9, Method 24-5.1	Same container as pH	None	28 days
Potassium	ASA No. 9, Method 13-3.5	Same container as pH	None	180 days
Chloride	ASA No. 9, Method 10-2.3.2	Same container as pH	None	28 days
Sulfate	ASA No. 9, Method 28-5.1	Same container as pH	None	28 days
Organic Carbon	ASA No. 9, Method 29-3.5.2	Same container as pH	None	Not established

5.2.2.2 Secondary Laboratory

Splits of the samples collected from the on-site and off-site survey areas and the background areas will be collected at a rate of 10 percent per survey area. These samples will be submitted to EPA's laboratory.

5.3 FIELD METHODS AND PROCEDURES

5.3.1 Surface Soil and Sediment Samples

Surface soil grab samples will be collected by carefully removing the top layer of soil or debris to the desired sample depth with a decontaminated spade, shovel, or equivalent. Unless instructed otherwise, samples received by the laboratory will be analyzed "as received." Therefore, extraneous material (e.g., rocks greater than ½-inch in diameter, leaves, sticks) will be removed at the time of sample collection.

Samples collected from the arroyo may contain large grain sizes (e.g., gravel and cobbles). An attempt will be made to select locations in the arroyo that are free of any particularly large pieces. Once the sample has been collected, extraneous material (e.g., rocks greater than ½-inch in diameter, leaves, sticks) will be removed at the time of sample collection.

The soil samples will be placed into new, appropriately sized stainless steel bowls or aluminum pie tins. Sample splitting will be necessary where multiple types of analysis will be used to characterize one sample location. Therefore, in order to ensure proper representation of the material being sampled, homogenization and fractional splitting will be used. The soil sample will be placed in a bowl or aluminum pie tin. The sample will be mixed approximately one minute or until thoroughly mixed. The sample will be placed in its respective containers using an alternate scooping/shoveling method and labeled accordingly.

Each soil sample will be recorded on the *Surface Soil Sample Log Form* provided in Appendix B. Samples will be labeled and handled following the sample preservation and chain-of-custody protocols described in Section 5.4. Sampling equipment will be decontaminated as described in Section 5.3.7. Additional details regarding surface soil sampling are provided in SOP-15 located in Appendix C.

5.3.2 Subsurface Soil Samples

Subsurface samples (deeper than 0.5 feet) will be collected in one of two ways. Samples collected from 10 feet or less and are accessible by heavy equipment will be collected using test pits dug with a backhoe. Once the desired interval is reached, an 18- to 24-inch interval of material will be collected from the test pit using the backhoe bucket.

Samples collected from depths greater than 10 feet, which are only anticipated at two or three locations within the northwestern portion of NECR-1, will be collected using a hollow-stem auger drilling rig. The drill cuttings will be described by field personnel using the USCS and recorded using the *Soil Classification Form* and *Soil Boring Log Form* located in Appendix B. The augers will be advanced to the desired interval. Representative samples will then be collected using a split-spoon sampler, as described below and in SOP-14, *Subsurface Soil Sampling*, provided in Appendix C. If refusal is met by the split-spoon sampler, then the augers will be advanced approximately one foot and the soil resampled.

5.3.2.1 Hollow- Stem Auger

Hollow-stem augers are commonly used for drilling as deep as 150 feet in unconsolidated materials with little or no cobbles and boulders. Hollow-stem augers consist of two parts: a tube with flights attached to the outside and connected to the lead auger, and a center rod and bit which prevents soil from entering the center of the auger. The individual auger flights are five feet in length and about eight inches in diameter. The lead auger bit is about 0.5 to 1 foot in length and varies in diameter. The drill rig rotates the augers clockwise and downward pressure is applied to drill the augers into the ground.

Soil sample collection for logging and analytical purposes can be completed by driving a 18- to 24-inch split-spoon sampler. The split-spoon sampler is either driven with a calibrated automatic hammer or using a manually operated slide hammer. The split-spoon is lowered to the bottom of the boring, driven and retrieved using metal rods through the augers.
The drill hole will be advanced to the desired interval. When the desired sample interval is reached, the split-spoon sampler will be lowered into the bottom of the drill hole and driven 18 to 24 inches

with blows from a 140-pound hammer falling 30 inches in general accordance with ASTM D 1586. The number of blow counts for each six-inch interval may be recorded on the boring log.

If refusal is met before the targeted sampling depths are achieved, the borehole will be backfilled and relocated up to two times per location within a five-foot radius of the original sampling location. Sampler refusal is generally indicated if more than 50 blows are required to advance the sampler 6 inches. If any samples are successfully collected prior to refusal, these samples will be retained.

Once the sample interval has been retrieved, soil samples will be collected for the required analyses. The sample will be handled and homogenized according to the methods described in Section 5.3.1. Remaining soil not submitted for analysis will be used for visual inspection/logging. A geologist, hydrogeologist, or engineer will log soils in general accordance with USCS protocol on the *Soil Boring Log Form* provided in Appendix B. Soil cuttings and soil samples not submitted to the laboratory will be handled according to the IDW protocol in Section 5.5. Split-spoon samplers will be decontaminated according to the methods described in Section 5.3.7 prior to use and stored in clean plastic bags until use.

5.3.2.2 Test Pits

Test pit excavation is carried out by using standard motorized equipment such as a rubber-tired backhoe or track-mounted excavator. A typical backhoe with an extending arm can excavate to a depth of approximately 15 feet. If investigations are required to penetrate beyond 10 feet, test pits may not be the most appropriate method of investigation and the use of other methods (e.g., soil borings) will be used. A detailed description of test pit excavations and safety considerations is found in SOP-11, *Trenching and Test Pits* located in Appendix C. All site personnel such as geologists, subcontractors and visitors are not permitted in excavations. In the event that it is necessary to enter an excavation greater than five feet deep, the walls of the trench will be properly shored, sloped or will be shielded with a trench box.

Soil samples will be extracted from the excavation using the bucket of the backhoe or excavator. Samples will be handled and homogenized according to the methods described in Section 5.3.1. A geologist, hydrogeologist, or engineer will log soils in general accordance with USCS protocol. A *Test Pit Log Form* is located in Appendix B. After sampling and logging has been completed the excavation will be backfilled with soil from the excavation. Soil will be replaced in roughly the order it was removed. Replacing the soil will be completed in one to two-foot lifts with each lift being compacted using the backhoe or excavator bucket.

5.3.3 Radiological field scan

5.3.3.1 Field Direct Gamma Radiation Level Correlation for Surface Soil

Surface soils are potentially impacted by former stockpiles of low-grade ore, milling byproduct materials (e.g., tailings), and non-economic materials, as well as by operations at the adjacent former Kerr McGee mine. The radiological characterization for the surface soil will consists of stationary direct gamma radiation level measurements as well as scans for additional characterization of the survey area and boundaries. The survey methods will provide aerial extent of Ra-226 contamination in the top six-inch soil layer that will allow greater characterization of the Site compared to relying on surface soil sampling alone. Ra-226 is primarily an alpha-emitting radionuclide with a gamma radiation emission of 186 keV at about 4% intensity. Field measurement of alpha radiation from soil using radiation detection instruments is an inadequate technique due to its short range and self-absorption. The low energy and intensity of Ra-226 gamma radiation emission makes field determination of Ra-226 by gamma radiation measurement a difficult task. However, Ra-226 content

in soil can be determined by measuring gamma radiation levels of its decay product (Bismuth-214 [Bi-214]). Bi-214 emits gamma radiation with a higher energy of 609 and 1,764 keV at about 80% intensity, which are easily detected and quantified by a sodium iodide (NaI) scintillation detector. The field survey consisting of direct gamma radiation level measurement is consistent with the flow diagram for selection of field survey instrumentation for direct measurements presented in Figure 4.2 of the MARSSIM (EPA, 2000a).

Residual levels of radioactive material that correspond to acceptable radiation dose limits are calculated by analysis of various pathways and scenarios. These DCGLs ($DCGL_W$ and $DCGL_{EMC}$) are presented in terms of mass activity concentration. When applied to soil, these DCGLs are expressed in units of activity per unit mass of soil, typically pCi/g. The direct gamma radiation measurements, using a NaI scintillation detector, provide radiation levels in counts per unit time. The counts per unit time for a given radioactivity depend on the efficiency of the detector. Therefore, a site-specific correlation between direct gamma radiation levels and Ra-226 soil concentrations, as discussed in Section 6.6.2 of the MARSSIM (EPA, 2000a), will be performed to convert the counts per minute (cpm) readings to the Ra-226 soil concentration in pCi/g. The conversion factor, pCi/g/cpm, is dependent upon several factors, as described below.

- Efficiency of a particular detector. The 2-inch x 2-inch NaI scintillation detector provides the highest efficiency for gross gamma radiation level measurements in the field.

- The direct gamma radiation level survey for Ra-226 in soil is a surrogate for gamma measurement of Bi-214, similar to the measurement described in Section 4.3.2 of the MARSSIM. Bi-214 is a decay product of Ra-226 through radon-222, a gaseous form, some of which emanates from soil. This phenomenon results in activity disequilibrium between Ra-226 and Bi-214 in the soil. The fraction of Rn-222 emanation varies with different geometric characteristics of a particular soil. Therefore, a site-specific calibration is necessary.

- Other gamma-emitting naturally occurring radionuclides in soil, such as potassium-40 and thorium-232 decay series, and cosmic gamma rays will be included in this gross gamma radiation level measurement. Therefore, this interference needs to be corrected. These interferences are generally constant and allow for the use of linear regression to determine the correlation.

Prior to conducting the gamma radiation measurements, the operating high voltage levels of the NaI detector will be established in accordance with manufacturer instructions. The operating high voltage that will yield the lowest noise, optimum efficiency and least sensitivity to voltage fluctuations in the field will be established by determining the high voltage plateau of the detector.

The field gamma radiation correlations, static measurements, and scans for Ra-226 content in soil will be performed using an Eberline ESP or Ludlum 2221 Ratemeter/Scaler. The Ratemeter/Scaler is connected to a 2-inch by 2-inch NaI crystal scintillation detector (SPA-3 or Ludlum 44-10), which detects gamma radiation emitted from Bi-214, a decay product of Ra-226 in the soil. Gamma radiation measurements for the correlation will be performed according to SOP-2 in Appendix C using static gamma radiation survey locations. Approximately 15 sample locations will be identified by gamma ray count rate to retrieve a broad range of concentrations from background to about 25 pCi/gm for the correlation regression. The selected sampling location areas will be relatively flat terrains, and large enough so that moving around several steps in each direction should not affect readings significantly. For the selected sample location, three one-minute counts will be obtained at each location. The detector will be approximately 18 inches from the ground surface.

Soil samples for the correlation will be collected using surface soil sampling SOP-15. A five-point

composite sample at a depth of 0" to 6" will be collected from each of the gamma radiation level measurement location. One soil sample aliquot point will be from the center point directly under the detector, and the other four aliquots from four points that are 18 inches from the center points in four directions (90 degrees apart). Each soil sample aliquot will be approximately 200 grams, collected by using the hand scoop method if soil texture is loose, or a using a hand augur if soil texture is sufficiently compacted. The sampling locations will be marked with flags. The five 200-gram soil sample aliquots will be combined (total of 1000 gram) in a mixing bowl, homogenized and placed in a sample bag. Each sample bag will be marked and labeled with appropriate sample identification. Soil sampling equipment will be decontaminated between each sampling location using SOP-5. All soils samples will be shipped to Energy Laboratories, Inc. (ELI) for Ra-226 on a dry basis using EPA gamma spectroscopy method 901.1.

Due to the potential for different correlation factors for the different survey areas, a separate correlation may be necessary. Soil correlation samples will be collected from the Ponds, Sand Backfill and NECR shaft areas. The selection of soil sample locations will also include background samples. This survey along the unnamed arroyo may require a different correlation as the geometry changes signifcantly.

Due to probable elevated activity of materials in the vicinity of NECR-1 and NECR-2, radiation shine may interfere with and overestimate Ra-226 soil concentrations of soils in areas near the dumps. If it is determined based on radiation level measurement next to the dumps that any radiation shine interference exists, radiation level survey in these areas will be performed with a detector with lead collimator to minimize the interference. This is consistent with the technique described in Section 6.4.1.1 of MARSSIM (EPA, 2000a). A separate correlation calibration will be performed for the collimator shielded detector.

To determine the correlation between gamma radiation level counts and corresponding Ra-226 concentration in soil content (i.e. to determine a calibration factor) a linear regression analysis will be performed on the sample Ra-226 concentration in pCi/gm, and the associated gamma radiation count rate (cpm)from all the sample locations.

5.3.3.2 Field Direct Gamma Radiation Level Measurements for Surface Soil

NaI scintillation detectors will be used for stationary direct radiation level measurements and scans for determining Ra-226 content in surface soils for this characterization survey. A 2-inch by 2-inch NaI detector is an appropriate detector for this type of survey (Section 6.7.2 of MARSSIM [EPA, 2000a]).

A static and scan MDC were estimated as shown in SOP-3 located in Appendix C. A static MDC of 0.47 pCi/g was estimated and this value is below 50 percent of the $DCGL_w$ (0.62 pCi/g). A scan MDC of 1.51 pCi/g was estimated, which is above 50 percent of the $DCGL_{EMC}$ (1.0 pCi/g). However, the site-specific MDC will be developed during the correlation study. A lower site-specific background count rate can lower the MDC. Site-specific integration counts may be adjusted in order to attempt to achieve a scan MDC of 1 pCi/g and a static MDC of 0.6 pCi/g.

The 2-inch by 2-inch NaI detector will be connected to a single-channel rate meter, which provides necessary operating voltage to the detector. The rate meter receives signals from the detector and reports in terms of counts of radiation detected per minute. The rate meter will be setup to report gross counts, as recommended in Section 4.7.3 of the MARSSIM (EPA, 2000a). A DGPS will be used to establish systematic grids. The DGPS coordinates will be referenced to the New Mexico State Plane Coordinate System. The DGPS grids and the integrated counts will be used to develop radiological isopleth contours of raw and concentration data in various ranges of Ra-226 concentrations in soil on a map to evaluate aerial extent of contamination.

Stationary Measurements

Static surveys will be performed at specified grid nodes within survey areas or other locations, such as correlation sampling points as needed in the field. The grid nodes were determined using VSP on a 80-foot triangular grid cast on a random origin. The 80-foot triangular grid will be extended beyond the initial survey area boundary to assist with the boundary delineation evaluation. A technician will hold the detector at approximately 18 inches from the ground surface above the desired survey point to obtain a one minute integrated count. The technician will perform the static (stationary) gamma radiation survey according to the methods detailed in SOP-3 located in Appendix C.

Scan Surveys

Scan radiation surveys (walkthrough surveys) will be performed by walking at a rate of about three feet per second with the detector at about 18 inches from the ground surface. Scan surveys will be performed at coverage rate of up to 20% within survey areas to identify any hot spots by walking in serpentine shape along transects. The scan percentage of an area will be determined based on the static survey of the grid nodes in that survey area as follows:

- If over 80% of the static survey within a survey area exceeds the screening level (equal to DCGL plus background), there would be no scan survey in that area.
- If 60 to 80% of the static survey exceeds the screening level, 5% of that area would be scanned.
- If 40 to 60% of the static survey exceeds the screening level, 10% of that area would be scanned.
- If 20 to 40% of the static survey exceeds the screening level, 15% of that area would be scanned.
- If less than 20 % of the static survey exceeds the screening level, 20% of that area would be scanned.

Scans will consist of random transects and may also include judgmental scanning of elevated areas and locations of suspected elevated contamination. In addition, a minimum of 20% of the Boneyard will also be scanned.

The scan radiation surveys will also be performed at survey area boundaries to delineate lateral extent of Ra-226 contamination. This scan survey will be performed by walking along the 80-foot spacing transects perpendicular to the initial perimeter of each survey area. These transects would run between the most outer 80-foot static grid node inside the initial boundary to the next 80-foot grid node outside the survey area boundary.

In addition, the scan survey will also be performed in the unnamed arroyo for surveying the bed sediments by walking in serpentine shape along the bed with collimated detector at about 18 inches above the sediment bed.

For the scan surveys within the on-site survey areas, the homesites, and the unnamed arroyo, the Ludlum 2221 with external RS232 output connector will be coupled to a Trimble XRS Pro mapping grade GPS receiver/data logger to collect and store the survey data. The GPS receiver will store in the electronic data file the gamma radiation count rate to its corresponding location coordinates. This

configuration can provide a gamma radiation intensity level in counts per minute (cpm) at approximately every three feet along the scan path based on a scan rate of three feet per second. The GPS receiver/antenna will be carried in a backpack. At the end of each survey day, the field data will be downloaded to a laptop computer for processing.

5.3.4 Leachate Samples

Potential impacts to surface and groundwater will be determined using the dynamic leaching procedure SPLP, EPA Method 1312. The leachate quality of the soil and sediment samples upon contact with meteoric precipitation will be evaluated using this method. This procedure was designed by the EPA to evaluate the potential for leaching metals from wastes to groundwater and surface water as the result of contact with rainwater or snow melt. The procedure is a batch test where the solid sample is agitated with a volume of simulated rainwater equal to 20 times the mass of the solid sample for approximately 18 hours. A sulfuric/nitric acid mixture is used to adjust the pH of the reagent water to a pH typical of rainwater. After agitation, the samples are filtered and the liquid is analysed for the parameters of interest. Metals analyses were conducted using the adjusted pH 5.0 solution for the analytes listed in Table 5.1. TCLP analysis will be performed according to EPA Method 1311.

In the interest of obtaining a representative sample for accurate characterization of the leaching potential of the material, at least one kilogram of material will be collected per sample and rocks greater than approximately 1.5 inches will be discarded from the sample. All sampling collection protocols described above in 5.3.1 will be followed.

5.3.5 Surveying

Surveyed locations will include stationary and scan gamma measurements, surface soil samples, soil borings, excavations (trenches and test-pits) and other physical features, such as roads and survey area boundaries. It is anticipated that the surveying will be completed using a backpack GPS unit.

All measurements will be referenced to the State Plane Coordinate System, North American Datum 1983 and North American Vertical Datum 1988. Each sampling location will be marked with a wooden stake, a wooden lath or pin flag, and will have the corresponding sample identification number written on the marker. During surveying, the northing, easting and elevation will be stored in the GPS unit and downloaded onto a computer. In addition, the northing, easting and elevation will be recorded in a bound field notebook.

The GPS unit will be checked daily for accuracy at a control point or benchmark with a known northing, easting and elevation. The northing, easting and elevation will be recorded on a field form. Other information reported on the *GPS Benchmark Elevation Form*, located in Appendix B, will include date, time, weather, problems, repairs and comments.

In the event that the horizontal accuracy of the GPS does not meet the required one- to three-meter accuracy (typical accuracy of a resource-grade, backpack GPS), a licensed surveyor may be required for increased accuracy. The surveyor will be licensed in the State of New Mexico. Data collected by the surveyor will be provided in an electronic format.

5.3.6 Field Quality Control Samples

Equipment rinsate samples and field replicates will be collected for all soil sampling events. Field replicate soil samples will be collected at a rate of five percent for the primary laboratory and at a rate

of 10 percent for the EPA's secondary laboratory. The field replicate soil samples will be splits of the original grab sample.

To the extent possible and practical, dedicated sampling equipment will be used. However, equipment rinsate blanks will be prepared at the Site by passing laboratory-provided reagent water of known quality through decontaminated non-dedicated sampling equipment. At the end of each day, the sampling team will take one equipment rinsate sample from each set of non-dedicated sampling equipment just before its final use.

The field log will identify the team members, date, and sampling area. This identification procedure will associate the equipment rinsate samples with a specific team's field decontamination procedure on each day. The rinsate sample sets from the team will be submitted each day along with the field samples. Equipment rinsate samples will be collected at a frequency of one each day per analysis type. It is assumed that the non-disposable sampling equipment may include stainless steel bowls, hand trowels, shovels, split-spoon samplers, excavator bucket, and auger flights. Collection of rinsate blanks is summarized as follows:

- Rinsate blanks will be collected by pouring contaminant-free reagent-grade water directly over decontaminated sample collection equipment and into sample containers.

- The sample containers used for rinsate blanks are summarized in the QAPP location in Appendix A.

- Rinsate blanks will be labeled and transported to the analytical laboratory using the same procedures used for primary samples.

- Rinsate blanks will be analyzed for the same analytes that are specified for associated field samples.

- The laboratory will conduct the analyses of rinsate blanks in an identical fashion to the associated field samples (i.e. aqueous rinsate blank samples for soil samples will be prepared and analyzed as soil samples and reported accordingly).

Whenever rinsate blanks are sampled for VOCs and SVOCs, trip blanks will accompany the samples to the laboratory and analyzed for VOCs and SVOCs.

In addition to the rinsate samples, sample replicates (splits) of all of the surface and subsurface soil samples will be collected at a rate of 10%. The EPA will prepare an in-house split sampling plan to describe who in the EPA would verify the sampling and splitting procedures and selection. The samples will be submitted to EPA's laboratory for analysis.

5.3.7 Decontamination Procedures

All soil sampling equipment will be cleaned and decontaminated prior to use at each location. Additional details on decontamination procedures are located in SOP-5, *Equipment Decontamination*, provided in Appendix C. Large equipment such as drill rig augers and the backhoe bucket will be decontaminated using a pressure washer, if possible. Smaller equipment such as trowels and shovels will be decontaminated as follows:

- Wash the equipment in low- or non-phosphate detergent (e.g., Alconox® or Liqui-Nox® solutions made as directed by the manufacturer);

- Rinse with dilute nitric acid;
- Rinse with potable water;
- Rinse twice with deionized or distilled water; and
- Rinse water will be handled as IDW.

5.4 SAMPLE CONTAINERS, PRESERVATION AND STORAGE

After collection, samples will be properly stored to prevent degradation of the integrity of the sample prior to its analysis. As applicable, this includes adding the appropriate chemical preservative to the sample, storing the sample in a refrigerated environment, and analyzing the sample within prescribed holding times. Where practicable, MWH may electronically document sample handling, preservation, and storage. Sample preservation and holding times are to be maintained from the time of sampling until the time of analysis.

All samples designated for off-site laboratory analysis will be packaged and shipped in accordance with applicable U.S. Department of Transportation regulations. Samples will be sealed in the appropriate sampling container. A chain-of-custody seal will be placed on the sample container. The samples will be packed securely in an ice chest and samples will be preserved in accordance with the specifications set forth in Table 5.2 through Table 5.4.

Samples collected for SPLP analysis will be collected in accordance with the above description of soil and sediment sampling procedures in 5.4.1. Soils collected for SPLP analysis do not require preservation or refrigeration. Once collected and placed in the sample container, it will be catalogued and properly labeled to be shipped to the laboratory accompanied with the necessary chain of custody.

5.5 DISPOSAL OF INVESTIGATION DERIVED WASTE

Generation of IDW such as equipment decontamination wastewater, rinsate, soil cuttings, sample containers, and personal protective equipment (PPE) will be minimal. Soil cuttings generated from excavation of test pits and from drilling at NECR-1 will be put back into the test pits and boreholes once excavation or drilling is complete at each location. Any residual cuttings will be evenly spread on the ground surface on top of the test pit or drill hole from which they came.

Decontamination wastewater, rinsate sample containers, and PPE will be characterized, as necessary, and disposed of in accordance with State and Federal Regulations.

5.6 SAMPLE DOCUMENTATION AND SHIPMENT

5.6.1 Field Notes

The on-site geologist/environmental scientist will use a weather-resistant, bound, survey-type field logbook with numbered, non-removable pages to record in black or blue indelible ink all field activities including soil sampling, trenching, drilling, etc. Daily information entered in the logbook will include:

- Dates and times
- Name and location of the work activities.
- Weather conditions

- Personnel, subcontractors and visitors on site
- Sample locations and methods (including sampling equipment)
- Time of sample collection, and sample depths
- Samples submitted to the laboratory for analyses
- Sample type (e.g., soil, rinsate water, co-located, or trip blanks)
- Name of carrier transporting the sample (e.g., name of laboratory and shipping carrier)
- Photograph numbers and descriptions (if applicable)
- Description of decontamination activities
- Schematic drawings of sample locations (if not done on field forms)
- Any deviations from the field sampling plan
- Health & Safety meetings, including topics discussed and attendees
- Accidents, including near misses
- Other relevant observations as the field work progresses
- Problems and corrective actions
- Field equipment calibration methods
- Investigation Derived Waste

At the end of each field day, the project field book will be dated and signed by the field person who took notes during the day. If the entire page is not used a line will be drawn through the unused portion of the page. If pages are accidentally skipped, a line will be drawn through the entire page. All corrections will be made by drawing a line through the erroneous information and initialing the change. "White-out" or its equivalent will not be used.

If electronic record-keeping systems are employed, procedures will ensure that:

- All original entries recorded are sufficiently backed up to avoid loss.
- A system that preserves both the original record and any changes to the record, inclusive of the identification of the individual making the change, exists and will be implemented.
- An archived record of all data entries will be protected to prevent unauthorized access or amendment of the electronic data.
- Entries will be complete enough to allow for the historical reconstruction of all records.
- The review of the records will be documented.

Additional details for the project field books are located in SOP-4, *Field Documentation*, located in Appendix C.

After collecting the required samples for chemical analyses the field geologist will make a visual description of the soil type and other lithologic or physical characteristics. Lithologic or physical characteristics will include but will not be limited to the color, grain size, plasticity, density, soil moisture, odors, bedding, interface between fill and native, and other information needed to accurately describe the soil. Detailed information for soil logging procedures is provided in SOP-8, *Soil Classification*, located in Appendix C. Soil borings and test pits will be logged for fill material type and depth, soil classification, and the interface between fill and native soil material. As well as providing a visual description of the soil, other information required on the *Soil Boring Log Form* and *Test Pit Log Fo*rm will include:

- Location identification number
- A sketch of the sampling location
- Project name and job number
- Date drilled and date completed
- Logged by
- Total depth of the soil boring
- Diameter of soil boring or dimensions of test pit
- Drilling contractor
- Drilling method
- Survey information including northing, easting and ground surface elevation
- Abandonment procedure
- Number of blows to drive sampler (if applicable)
- Soil sampler type
- Amount of soil recovered in sampler

Copies of the *Soil Boring Log Form* and *Test Pit Log Form* are included in Appendix B.

5.6.2 Sample Identification

All samples will be labeled in a clear, precise way for proper identification in the field and for tracking in the laboratory. The samples will have identifiable and unique numbers. Detailed sampling handling procedures are provided in SOP-12, *Sample Handling and Shipping*, located in Appendix C. At a minimum, the sample labels will contain the following information:

- Facility name
- Sample number
- Sample depth
- Date of collection
- Time of collection
- Initials or name of person(s) collecting sampling
- Analytical parameter(s)
- Method of sample preservation

A coding system will be used to uniquely identify each sample collected. The system will allow for quick data retrieval and tracking to account for all samples.

5.6.3 Labeling

The sample designation will be recorded on the sample label and logbook, and will comprise three parts or fields.

- Samples will be numbered sequentially for each type of sample collected (i.e., surface sampling, soil boring, field gamma measurement).
- Part 1 will be designated as the survey area
  - NECR1
  - NECR2
  - POND12
  - POND3
  - SAND1

  - SAND2
  - SAND3
  - SEDPAD
  - NEMSA
  - YARD
  - HOME1 through HOME9
  - ARROYO

- Part 2 will be a field that begins with alphabetic characters that identify the type of sample. Sample-type codes include the following:
  - ER = equipment rinsate blank
  - SS = surface soil
  - SB = soil boring
  - TB = trip blank
  - GM = gamma measurement
  - SPLP = synthetic precipitation leachate procedure
  - TCLP = toxicity characteristic leachate procedure

- Three digits will follow the alphabetic character(s) and will be sequential (e.g., "001" for the first sample location collected, "002" for the second sample location collected, "003" for the third sample collected). In the case of a soil boring, Part 2 will end with depth interval, referenced to below ground surface (bgs) in parentheses.

As an example, sample designation NECR1-SS004(0-0.5') is the 4th surface soil sample collected from 0 to 0.5 feet bgs from NECR-1. Duplicate and replicate samples will be hidden from the laboratory by using a "200" identifier in the sample designation. The duplicate or replicate sample designation for the example described above would be NECR1-SS204(0-0.5').

5.6.4 Chain-of-Custody

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

Chain-of-custody forms will be used to ensure that the integrity of samples is maintained. Each form will include the following information:

- Sample number
- Date of collection
- Time of collection
- Sample depth
- Analytical parameter
- Method of sample preservation
- Number of sample containers
- Shipping arrangements and airbill number, as applicable

- Recipient laboratories
- Signatures of parties relinquishing and receiving the sample at each transfer point

Whenever a change of custody takes place, both parties will sign and date the chain-of-custody form, with the relinquishing person retaining a copy of the form. The party that accepts custody will inspect the custody form and all accompanying documentation to ensure that the information is complete and accurate. Any discrepancies will be noted on the chain-of-custody form.

5.6.5 Packaging and Shipment

After collection, samples will be properly stored to prevent degradation of the integrity of the sample prior to its analysis. As applicable, this includes adding the appropriate chemical preservative to the sample, storing the sample in a refrigerated environment, and analyzing the sample within prescribed holding times. Where practicable, MWH may electronically document sample handling, preservation, and storage. Sample preservation and holding times are to be maintained from the time of sampling until the time of analysis.

All samples designated for off-site laboratory analysis will be packaged and shipped in accordance with applicable U.S. Department of Transportation regulations. Samples will be sealed in the appropriate sampling container. Sample containers will be placed in clean protective foam or bubble pack sleeves. The caps of all sample bottles shall be checked for tightness to prevent sample leakage during transport. Care will be taken to prevent over-tightening and breakage of bottle caps. Custody seals will be placed on each sample container after collection such that it must be broken to open the container.

The samples will be packed securely in an ice chest or other appropriate container, and samples will be preserved in accordance with the specification. For those samples requiring preservation at 4 °C, the samples will be placed on ice in coolers in the field. Sufficient water ice (not "blue ice" or similar products) will be utilized to cool the samples during shipment. Sufficient ice shall be placed in each cooler such that: 1) some ice is still present upon arrival at the laboratory, and 2) the samples are cooled to 4 °C or below. The ice will be double wrapped in resealable plastic bags. Sufficient packing material will be placed in each ice chest to minimize the potential for sample bottles to shift and become damaged or broken during shipment. Packing material may include bubble pack or foam material. Samples should be thoroughly cooled before placing in packing material so the packing material serves to insulate the pre-cooled sample. Each cooler will contain a temperature blank consisting of a 40 millimeter vial. The drain plug on the shipping container will be closed and sealed on the inside and outside with duct tape.

Sampling personnel will inventory the sample bottles from the Site prior to shipment to ensure that all samples listed on the chain-of-custody form are present. All bottles collected from a specific sampling interval will be packed and shipped together in the same shipping container. The originals of the analysis request and chain-of-custody forms will be sealed in a waterproof plastic bag and placed inside the shipping container prior to sealing of the container. The cooler will be taped shut using strapping tape over the hinges and custody seals placed across the top and sides of the cooler lid. Custody seals will be used to preserve the integrity of each sample container and cooler from the time the sample is collected until it is opened by the laboratory. Two or more custody seals will be signed, dated, and placed on the front and back of the sample cooler prior to transport. Clear tape will be placed over the custody seals to prevent inadvertent damage during shipping. The tape should not allow the seals to be lifted off with the tape and then reaffix without breaking the seal.

6.0 HUMAN HEALTH RISK ASSESSMENT

This section describes the approaches and methods to be used during preparation of a HHRA for the Site. Risks to public health and the environment will be evaluated in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Remedial Response process, as amended by the Superfund Amendments and Reauthorization Act (SARA), and in consideration of State of New Mexico risk assessment guidance (NMED, 2005). The HHRA will evaluate potential public health risks associated with contaminants present at the Site, as well as potential historic releases of contaminants from the Site to the surrounding environment. Potential public health risks associated with current levels of radionuclides and metals present will be evaluated assuming external radiation exposure, direct exposure to contaminated media, and indirect exposures through the food chain, as applicable, as described in Sections 6.2 and 6.3, below.

Risk assessment activities to be conducted for the Site will involve a tiered approach. The first step (Tier I) will include a screening-level risk evaluation to assess whether maximum detected levels of radionuclides, metals, or organic constituents in site media pose a potential risk to human health. The Tier I screening-level evaluation will include a comparison of maximum detected levels of radionuclides, metals, or organic constituents to published, health-protective screening benchmarks, as described in more detail in Section 6.2, below. Any radionuclides, metals, or organic constituents that contribute to a cumulative cancer risk or noncancer hazard in excess of health-protective screening criteria will be identified as Site COPCs (refer to Section 6.2.3).

A Tier II evaluation of risk will be conducted for all COPCs identified during the Tier I risk evaluation. The Tier II risk evaluation may include refinements to the screening-level risk evaluation approach including, but not limited to, use of statistically derived media concentrations and dose modeling based on site-specific exposure scenarios and pathways. The Tier II evaluation will include the calculation of "total" risk and hazard estimates based on site-related contamination and background levels of radionuclides and metals, as well as risk and hazard estimates to excluding background. Risk and hazard estimates in excess of background are termed "incremental" risks or hazards. Results of the Tier II risk evaluation will be used to identify constituents of concern (COCs) for applicable Site media. Radionuclides, metals, or organic constituents that contribute to an incremental risk or hazard in excess of EPA's risk management range of 1×10^{-6} to 1×10^{-4} and hazard index (HI) of 1 will be identified as Site COCs, in accordance with EPA (1991a). The final step of the risk assessment process will involve the calculation of site-specific and media-specific cleanup goals for any COCs identified for the Site.

Specific guidance to be considered during preparation of the HHRA for the Site includes, but is not limited to, the following documents and reference materials:

- *Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual, Part A. Baseline Risk Assessment* (EPA, 1989).
- *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors* (EPA, 1991a).
- *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decision* (EPA, 1991b).
- *Exposure Factors Handbook, Volume I: General Factors* (EPA, 1997a).
- *Exposure Factors Handbook, Volume III: Activity Factors* (EPA, 1997b).
- *Soil Screening Guidance for Radionuclides: User's Guide* (EPA, 2000b).
- *Soil Screening Guidance for Radionuclides: Technical Background Document* (EPA, 2000c).

- *EPA Region 9 PRGs – 2004 Update* (EPA, 2004a).
- *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (EPA, 2004b).
- *New Mexico Environmental Department Technical Background Document for Development of Soil Screening Levels – Final Report. Revision 3* (NMED, 2005).

Screening risk assessment methods and procedures for radionuclides and metals, respectively, are documented in *Soil Screening Guidance for Radionuclides: Technical Background Document* (EPA, 2000b) and *EPA Region 9 PRGs – 2004 Update* (EPA, 2004a), respectively. The general framework for conducting HHRAs under CERCLA is provided in *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A. Baseline Risk Assessment* (EPA, 1989).

The risk assessment process begins with the development of a Conceptual Site Model (CSM). The site-specific CSM for the Site is described in Section 6.1. Tier I and Tier II risk assessment approaches and methods are described in Sections 6.2 and 6.3, respectively.

6.1 CONCEPTUAL SITE MODEL

The CSM is a descriptive and graphical presentation of the physical, chemical, and biological relationships between sources of contaminants and potentially exposed populations. As such, the CSM describes and integrates information on the following (EPA, 1989):

- Contaminant sources, contaminated media and COPCs;
- Contaminant fate and transport pathways;
- Potentially exposed populations under current and future scenarios; and
- Potentially complete exposure pathways between contaminated media and receptors.

Each of these components of the CSM for the Site are described below.

6.1.1 Contaminated Media and Preliminary COPCs

Sources of contamination and potentially impacted media associated with the Site, and downgradient off-site areas, are described in this subsection.

As described in Section 3.1.1, the primary ore mineral that was mined at the Site was coffonite (U(SiO4)1-x(OH)4x), which was placed in small temporary stockpiles at NECR-1 and NECR-2 before transport to the Church Rock mill site. A level pad was created at NECR-1, and fill material consisting of non-economic material was placed to a depth of approximately 20 to 30 feet in the northwestern corner of NECR-1. The pad for NECR-2 was made of native material and did not require material from processing of the ore at the Church Rock mill. Ore and low-grade ore stockpiles were temporarily stored on the NECR-1 and NECR-2 pads prior to offsite transport to, and processing at, the Church Rock mill. Following New Mexico's approval of a license amendment to permit placement of tailings in mine stopes for structural reinforcement in 1978, tailings material from ore processing at the mill was stored in three areas referred to as Sand Backfill Areas No. 1, No. 2 and No. 3 (see Figure 1-2). The bulk of the tailings material from the sand backfill areas was placed in the mine stopes; the remaining tailings were removed and disposed of offsite during the 1986 NRC cleanup. In addition, rainfall runoff from the sand backfill areas and water from the mine dewatering operations (see Section 1.2.2) was routed to three sediment ponds. Sediment in these ponds was periodically removed and temporarily placed on the Sediment Pad prior to off-site transport to the

mill. The water in these ponds was treated and then discharged down the unnamed arroyo pursuant to an NPDES permit.

Residual tailings material in the three sand backfill areas and in the sediments in the ponds and Sediment Pad were removed and taken off-site in 1986, pursuant to NRC License No. SUA-1475, Condition 33 (UNC, 1989b), as discussed in Section 3.1.1. The tailings material was identified based on the ratio of natural uranium to Ra-226, which was less than 0.75 for tailings. Low-grade ore and non-economic material had a ratio of greater than 0.75 and native ground had low concentrations of all radionuclides. The bulk of the tailings material from the sand backfill areas was placed in the mine stopes pursuant to State approval. Because the NRC cleanup removed only tailings, materials with elevated levels of radionuclides may still reside in these areas, as suggested by the verification results shown in the *Tailings Sand Backfill Cleanup Verification Report* (UNC, 1989a).

Non-economic material was also placed in the NEMSA. Refuse and other discarded equipment was placed in the Boneyard. Both of these sites were reclaimed in 1994 (UNC, 1994), which included placement of one foot of topsoil over the non-native materials and then seeding.

Groundwater from the mine workings was pumped to the surface and treated in three ponds to reduce suspended solids and radionuclide concentrations and then sent through the IX unit (see Section 1.2.2). The spent water was then discharged to the northeast along the unnamed arroyo, in accordance with a NPDES permit, which restricted the discharge of preliminary COPCs into the unnamed arroyo.

In addition to the non-economic materials that may still be present at the Site, impacts may have occurred off-site to the northeast due to the transport of suspended sediments in mine water or storm water into the unnamed arroyo (under the NPDES permit) as well as the transport of material by wind, or to a lesser extent human and animal activities. Due to the potential for wind transport, there is concern about whether impacts to nine home sites near the confluence of the unnamed arroyo and the next unnamed arroyo may have occurred, and whether those impacts are attributable to historical site operations, operations at the Kerr McGee mine, or background conditions.

Based on the potential sources of contamination identified above, preliminary COPCs for the Site have been identified as Ra-226 and daughters; five metals (i.e., arsenic, molybdenum, selenium, uranium, and zinc); and organic constituents (VOCs and SVOCs only in the Boneyard).

6.1.2 Contaminant Fate and Transport Pathways

The radionuclides and metals identified in the previous subsection are naturally occurring elements in the Earth's crust. Radium is naturally-occurring and is almost ubiquitous in soil, water, geologic materials, plants and foods at low concentrations (ATSDR, 1990). Radium is only moderately soluble in water and can enter surface water or groundwater by desorption from rock surfaces, dissolution of geologic materials, and by ejection from minerals during radioactive decay (USGS, 1998). However, radium solubility is controlled by adsorption to, or co-precipitation within, sulfate minerals (e.g., barite and gypsum). In experiments on radium bioavailability in contaminated soils and sediment, leaching of radium from waste pit materials was observed to be low (DeLaune et al., 1994). The adsorptive behavior of radium is similar to that of other divalent cations including barium, calcium and strontium, and solubility in water generally increases with increasing pH (ATSDR, 1990). Consequently, radium is not a very mobile constituent in the environment (ATSDR, 1990). For radionuclides including radium, radioactive decay is the only degradation process that results in conversion of a radioisotope to more or less harmful daughter products. The radioactive half-life of Ra-226 is 1,602 years, and the decay products include radon-222 and alpha/gamma emissions (ATSDR, 1990).

For the stable metals, weathering of metal-containing ore and/or anthropogenic metals, dissolution of weathered metal ions and particulates in storm water, and transport of dissolved ions or particulates in storm water runoff to surface water (including the unnamed arroyo) represent a potential fate and transport pathway. This potential migration pathway is also applicable to radionuclides. Dissolution of radionuclides or metals in storm water, and infiltration/percolation is a method for transporting surficial contaminants to subsurface soil and groundwater. As described above, however, radium is resistant to significant transport via this pathway except under conditions of elevated pH. Entrainment of dust that contains radionuclides or metals adsorbed to the surface, or contained within soil particles may be a method for off-site transport. Dust generation and wind transport, or to a lesser extent by human and animal activities, may have resulted in the unexpected transport of preliminary COPCs to off-site areas, including Navajo home sites located north of the Site.

Finally, uptake of radionuclides or metals into plants, and subsequent transfer to human and wildlife receptors through the food chain is another potential fate and transport mechanism. Uptake of radium by plants is dependent upon soil and plant type (ATSDR, 1990). Soil-to-plant transfer coefficients are reported to range from 1.1×10^{-3} to 6.5 (Watson et. al., 1984, as cited in ATSDR, 1990). A partition coefficient for Ra-226 in forage and hay was estimated as 0.1. Because radionuclides including radium may be absorbed by plants, there is the potential for human exposure through consumption of meat and milk derived from animals that graze on forage grown in soils containing these substances. Mean ratios of radium-226 in milk and beef to that in the animals diet has been estimated to be 3.8×10^{-3} and 6.8×10^{-3}, respectively (Watson et. al., 1984, as cited in ATSDR, 1990). Once ingested, radium tends to partition into bone due to its similarity to calcium, and may bioaccumulate in humans and animals (USGS, 1998).

6.1.3 Land Uses and Potentially Exposed Populations

The Site is the former location of an underground uranium mine. The Site is currently inactive, and human receptors at the Site are limited to facility oversight, security personnel, and unauthorized visitors (there is evidence that unauthorized visitors have been on-site, based on the presence of cut fencing); wildlife also use the Site. With cooperation of the NNEPA, access to the Site for the foreseeable future, will be secured and limited to allow only periodic inspections, and wildlife access. No development or grazing is currently planned for the Site for a period of at least twelve years as required by the New Mexico Mining Act so that revegetation programs have sufficient time to restore a self-sustaining ecosystem. If consistent with any applicable mineral rights or grazing permits, and if such historical land uses are established, future use may include Navajo traditional and cultural land uses, including medicinal plants. All lands to the north of the Site are part of the Navajo Indian Reservation. These lands include home sites, and are also used for cattle grazing and hunting. The former United Nuclear Corp mill is located southeast of the Site, and the former Kerr-McGee Quivira Mine is located northeast of the Site.

6.1.4 Potentially Complete Exposure Pathways

Based on future land uses for the Site, human receptors may be exposed to preliminary COPCs through ambient air, soil, surface water, sediment, and biota (i.e., plants and animals). Exposures to preliminary COPCs in ambient air may occur through inhalation of dust entrained in air, as well as deposition onto plant surfaces and subsequent consumption of plant parts by humans. Potentially complete soil exposure pathways include external radiation, incidental ingestion of soil particles, dermal contact with soil particles, root uptake and translocation of preliminary COPCs to above-ground plant parts and subsequent consumption; and uptake by cattle and wildlife that are subsequently harvested and consumed by humans. Sediment exposure pathways for human receptors are similar to soil pathways, because the unnamed arroyo is dry for the majority of the year.

Potentially complete surface water exposure pathways include incidental ingestion and dermal contact of surface water by off-site residents, and potential uptake of preliminary COPCs in surface water by plants or animals that are subsequently harvested and consumed by humans.

Currently, there are no potable or non-potable uses of groundwater beneath the Site. In addition, there are no plans to install wells on-site during the foreseeable future, or to use groundwater beneath the Site for potable or other uses. It is possible that off-site groundwater may be used for potable or agricultural uses (e.g., irrigation of plants or watering cattle). Groundwater associated with the Westwater Canyon Sandstone Member of the Morrison Formation is present at a depth of 1,500 to 1,800 feet bgs, and is separated from alluvial, non-potable groundwater by an aquitard, as discussed in Section 1.3.3. Therefore, potential domestic and agricultural groundwater exposure pathways are considered incomplete.

A CSM diagram that graphically depicts the relationship between potential sources of contamination, exposure media, and human receptors for the Site is presented in Figure 6-1.

6.2 TIER I SCREENING RISK ASSESSMENT

A Tier I HHRA will be conducted to evaluate whether or not detected concentrations of the preliminary COPCs identified for the Site (refer to Section 6.1.1) may pose a current or potential future risk or hazard to public health based on protective, screening-level assumptions. The general approach to the screening-level HHRA will be to compare detected concentrations of radionuclides and metals/organics to EPA PRGs for Radiologicals (EPA, 2004c) and EPA Region 9 PRGs (EPA, 2004a), respectively. Screening-level, cumulative cancer risk estimates and noncancer hazard indices (HIs) will be calculated under both residential and industrial scenarios, in order to evaluate the need for potential future institutional controls at the Site. Chemical-specific cancer risk estimates, the "probability of an individual developing cancer as a result of a lifetime of exposure to a particular level of a potential carcinogen" (EPA, 1989), will be calculated for each preliminary COPC in each appropriate medium. Next, chemical-specific cancer risk estimates will be sorted by media type and summed to estimate medium-specific cumulative cancer risk estimates. Total cumulative cancer risk estimates will be calculated by adding media-specific cancer risk estimates. A similar procedure will be used to estimate total noncancer HIs. Total HIs, which represent the cumulative hazard from "multiple substances and/or multiple exposure pathways" (EPA, 1989), will be calculated by summing media-specific HIs.

Results of the screening-level HHRA will be used to evaluate whether detected concentrations of preliminary COPCs represent no significant risk to human receptors and the Site is appropriate for no further action (NFA) in regard to human health, or the Site requires further risk evaluation.

6.2.1 Exposure-Point Concentrations

In the screening-level HHRA, an exposure-point concentration (EPC) is typically defined as the maximum concentration to which receptors are potentially exposed (EPA, 1989). In cases where there is adequate characterization, however, the 95 percent upper confidence limit (95% UCL) on the arithmetic mean concentration may be used in place of the maximum detected concentration (EPA, 2002b). The 95% UCL of the mean concentration will be calculated consistent with methods described in EPA (2002b).

EPCs will be identified based on the following:

- Potential exposure. Soil and sediment EPCs will be selected from samples collected from between zero and 10 feet bgs (inclusive). Data from soil samples collected from below 10

feet bgs will be excluded, as it is assumed that potential construction activities would not extend below this depth.

- Qualified data. Only validated, qualified data will be reviewed in the EPC selection process. All data with "B" (analytes detected in an associated field or laboratory blank) or "R" (result unusable because quality control criteria were not met) qualifiers will be eliminated.

- Naturally occurring metals. Concentrations of all preliminary COPCs detected in soil or sediments will be included in the risk assessment, regardless of whether or not they represent background conditions (i.e., are naturally occurring). Attribution of risk to background or source-related contamination will be evaluated during the risk characterization phase, as described below.

6.2.2 Risk and Hazard Quantification

All positively identified analytes that are not naturally occurring are screened against residential and industrial PRGs in a screening level HHRA. Analytes with PRGs based on carcinogenic effects are grouped into a separate category from those with PRGs based on non-carcinogenic effects. For purposes of illustration, arsenic will be included in both categories because it has both cancer- and non-cancer-endpoint PRGs. PRGs based on soil saturation or ceiling limit parameters are assumed to be non-carcinogenic.

Screening level ILCRs (for carcinogens) and HQs (for non-carcinogens) for each relevant medium (i.e., soil and sediment) and scenario (residential or industrial) are derived by dividing the chemical-specific EPC by the corresponding soil PRG (EPA, 2004b). The EPC:PRG ratio for a carcinogenic chemical is multiplied by a factor of 1×10^{-6} to estimate the chemical-specific ILCR. Chemical-specific risk estimates are then summed for each land-use scenario within each medium at each AOC to estimate cumulative cancer risk estimates (EPA, 2004b). The EPC:PRG ratio for a non-carcinogenic chemical equals the HQ. Chemical-specific HQs are summed to estimate the HI. Cumulative cancer risk and noncancer HI estimates are summed across all media having complete exposure pathways to derive total cumulative cancer risk and noncancer HI estimates. The Tier I risk evaluation will include the calculation of "total" risk and HI estimates based on site-related contamination and background levels of radionuclides and metals, as well as risk and HI estimates attributable to background, alone. Risk and HI estimates above background are termed "incremental" risks or hazards. Total risk and incremental risk estimates will be reported concurrently.

No surface water or groundwater samples will be collected during the RSE; therefore, surface water and groundwater are excluded from the screening level risk evaluation. Potential impacts of preliminary COPCs on groundwater will be evaluated using leachate modeling and comparison of modeled concentrations to applicable surface water and drinking water standards, as described in Section 7.3.

Region 9 soil PRGs are not currently available for radionuclides. For screening radionuclides in soil, PRGs published in EPA's *Radionuclide and Toxicity Preliminary Remediation Goals for Superfund* (EPA, 2004c) will be used. The screening-level risk for Ra-226 will be calculated using the PRG for 'Ra-226 and daughters', as published in EPA (2004c).

6.2.3 Risk Characterization

Various "acceptable" incremental carcinogenic risk ranges may be employed under different circumstances. The EPA (1991b) has established a risk management range of 1-in-1,000,000 (1×10^{-6}) to 1-in-10,000 (1×10^{-4}) for evaluating carcinogenic risk results derived from baseline risk assessments. Risk levels within the risk management range may be considered acceptable by risk managers, depending upon current and future land uses, exposed populations, and other site-specific considerations (EPA, 1991b). For evaluating non-carcinogenic hazards, a total HI of 1 or less is considered acceptable (EPA, 1991b).

For screening-level risk assessments, EPA Region 9 (2004a) considers a carcinogenic risk estimate of less than 1×10^{-6}, and a non-carcinogenic HI equal to or less than 1 to be acceptable. These threshold criteria will be used to evaluate results of the Tier I screening-level HHRA for the Site. Any preliminary COPCs contributing to carcinogenic risk or non-carcinogenic HI estimates in excess of these criteria will be identified as COPCs for the Site. Identified COPCs will be evaluated further in a refined, Tier II, risk assessment as described in Section 6.3, below.

6.3 TIER II REFINED RISK ASSESSMENT

A Tier II risk evaluation will be performed for the Site, in the event that COPCs are identified based on results of the Tier I screening-level HHRA. The Tier II risk evaluation may include refinements to the screening-level risk evaluation approach including, but not limited to, use of statistically derived media concentrations and dose modeling based on site-specific exposure scenarios and pathways. Results of the Tier II risk evaluation will be used to identify COCs for applicable Site media.

For any identified radiological COPC, the Tier II HHRA will involve refinement of EPA's screening-level PRGs for Radiologicals (EPA, 2004b). EPA PRGs for Radiologicals (EPA, 2004b) are available for both residential and industrial exposure scenarios. As described in Section 6.1.3, however, there are no plans to develop the Site in the foreseeable future, and the proposed future land use involves mining and/or cattle grazing. Therefore, refinements to EPA PRGs for Radiologicals (EPA, 2004b), such as Ra-226 and daughters, could be made to consider this site-specific scenario and applicable exposure assumptions. Refined PRGs for radionuclides will be developed using EPA's PRG Calculator (EPA, 2006b), with site-specific input variables.

For any identified non-radiological COPC, the Tier II HHRA will involve a refined evaluation of risk consistent with methods published in EPA's *Risk Assessment Guidance for Superfund, Volume I: Human Health Evaluation Manual, Part A. Baseline Risk Assessment* (EPA, 1989). Cumulative carcinogenic risk and non-carcinogenic HI estimates will be calculated across non-radiological metals and exposure media, and compared to EPA's risk management range of 1×10^{-6} to 1×10^{-4} for carcinogenic risk and non-carcinogenic HI of 1 (EPA, 1991b). Again, total and incremental cancer risk and noncancer HI estimates will be calculated and reported concurrently.

Radionuclides, metals, and organic constituents in excess of EPA's risk management range (EPA, 1991b) will be identified as COCs for potential evaluation of remedial alternatives.

7.0 DATA EVALUATION

7.1 RADIOLOGICAL ANALYES

Soil samples will be analyzed for Ra-226. The screening level for Ra-226 is developed from the $DCGL_W$ of 1.24 pCi/g plus background.

The correlation between radiological field scan results and Ra-226 concentrations in soil will be conducted with a linear regression analysis. The linear regression analysis will involve mathematically plotting the soil Ra-226 concentration against the associated gamma radiation level counts rate from all locations. Linear regression is summarized by the generalized equation, which takes the form:

$$Y = mX + b$$

Where: Y = soil Ra-226 concentration, pCi/g
m = slope of regression line
X = gamma radiation level count rate at associated sample location
b = constant, Y intercept

The linear regression will identify a constant, b, which would correct for constant interference from other gamma emitting radionuclides in soil and cosmic rays, and provide the appropriate conversion equation. The correlation coefficient for the linear regression must be equal to or greater than 0.80.

Direct gamma radiation level measurement data from the receiver will be retrieved either when the receiver memory is full or at the end of each day. Each of the direct gamma radiation level measurements collected in cpm will be converted to Ra-226 soil concentration using the gamma radiation level – Ra-226 concentration conversion equation derived from the correlation calibration of the detector as described above. Results of the raw uncorrected data and converted radiation survey will be used to produce isopleth contour maps. The isocontours of Ra-226 concentrations in pCi/g will be divided in several ranges including the MDC. The survey raw uncorrected and converted radiation survey data will also be tabulated, as needed, with Ra-226 concentrations corresponding to each coordinate.

A comparison of measurements from the background and survey area laboratory data will be made using the WRS test. This test is used to test for a shift in location between two independent populations to see if measurements from one population tend to be consistently larger (or smaller) than those from the other population. Individual sample results will also be compared against the screening level and a 95 percent upper confidence level will also be developed for Ra-226 in background soils to assist with the HHRA.

In addition, the radionuclide laboratory data and field data will also be used to establish cleanup levels based on background and risk scenarios. These cleanup goals will be calculated based on risk exposure and land use scenarios as they are described in Section 6.0.

7.2 TOTAL METALS

Soil samples will be analyzed for the five metals, including natural uranium. The list of metals for analyses are presented in Section 5.2.1. All five of the metals chosen for characterization, are listed on the EPA Region 9 PRG table and include both residential and industrial remediation goals.

A comparison of measurements from the background and survey area laboratory data will be made using the WRS test. This test is used to test for a shift in location between two independent

populations to see if measurements from one population tend to be consistently larger (or smaller) than those from the other population. Individual sample results will also be compared against the screening level and a 95 percent upper confidence level will also be developed for each metal in background soils to assist with the HHRA.

Once all analytical results are available from the total metals analysis, a review of the data in comparison to the PRGs will help determine which samples will need further analysis using a dynamic leaching procedure in order to determine the potential impacts to surface water and groundwater that could occur. For each sample, the percent or factor difference between the metal concentration and screening level will be determined. This percent or factor difference will be summed for each metal associated with the soil sample. The two surface or subsurface samples from each survey area with the highest percent or factor difference will be selected for SPLP analysis.

7.3 ORGANIC CONSTITUENTS

Subsurface soil samples will be analyzed VOCs and SVOCs in the Boneyard. Individual sample results will be compared against the screening levels for constituents that have an industrial PRG as listed in the EPA Region 9 PRG table (EPA, 2004a).

7.4 LEACHATE ANALYSIS

These SPLP and TCLP data will be evaluated using several benchmarks, which may include the following:

- State of New Mexico groundwater quality standards;
- National Primary Drinking Water Standards;
- EPA Region 9 PRGs;
- TCLP standards;
- Navajo Nation's Drinking Water standards; and
- Reference water quality from the southwest alluvium at the adjacent Church Rock mill site.

The results of this comparison will be used to evaluate management options for soil as they pertain to protection of groundwater and surface water.

7.5 AGRONOMIC TESTING

Agronomic data will only be used in mitigation of exposure during site reclamation and will not be used to determine exposure.

Results from laboratory analysis can be used to evaluate the presence and impact of constituent levels on plant growth and germination within the tailings and borrow source material. The level of constituents present can be used to gauge the potential for direct revegetation within the tailings, as well as determine the necessity of soil cover for plant growth. When elevated levels of constituents are present, soil cover provides a suitable medium for root growth and plant establishment. The amount and thickness of soil cover needed is dependent upon the root architecture, tolerances of the native plant species, and the physical and chemical characteristics of both the borrow soil and underlying material.

8.0 REFERENCES

Agency for Toxic Substances and Disease Registry (ATSDR), 1990. *Toxicological Profile for Radium.* Agency for Toxic Substances and Disease Registry, U.S. Public Health Service in collaboration with U.S. Environmental Protection Agency. December

Batelle, 1982. *Potential Contaminant Transport from Uranium Mill Tailings Deposited in the Church Rock Mine.* Pacific Northwest National Laboratory. September, 1982.

DeLaune, R., J. Pardue, W. Patrick, Jr., and C Lindau (DeLaune, et al). 1993. *Research Brief #2: Mobility and Transport of Radium in Sediment and Waste Pits.* Hazardous Substance Research Centers (HSRC) South and Southwest

EPA, 2006a. *Guidance on Systematic Planning Using the Data Quality Objectives Process*, EPA/240/B-06/001, February 2006.

EPA, 2006b. *Soil Screening Guidance for Radionuclides: PRG Calculator,* accessed via the web at http://risk.lsd.ornl.gov/rad_start.shtml.

EPA Region 9, 2004a. *EPA Region 9 PRG Table*, October 2004

EPA, 2004b. *Risk Assessment Guidance for Superfund (RAGS), Volume I: Human Health Evaluation Manual* (Part E, Supplemental Guidance for Dermal Risk Assessment).

EPA, 2004c. *Radionuclide Toxicity and Preliminary Remediation Goals for Superfund*, U.S. Environmental Protection Agency, August 4, 2004, accessed via the web at http://epa-prgs.ornl.gov/radionuclides/download.shtml.

EPA, 2002a. EPA *Guidance for Quality Assurance Project Plans*, EPA/240/R-02/009.

EPA, 2002b. Calculating Upper Confidence Limits for Exposure Point Concentrations at Hazardous Waste Sites, OSWER 9285.6-10, December

EPA, 2001. *EPA Requirements for Quality Assurance Project Plans*, EPA/240/B-01/003.

EPA, 2000a. *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM), EPA 402-R-97-016, Rev. 1.

EPA, 2000b. *Soil Screening Guidance for Radionuclides: User's Guide*, OSWER No. 9355.4-16A

EPA, 2000c. *Soil Screening Guidance for Radionuclides: Technical Background Document*, OSWER No. 9355.4-16

EPA, 1997a. *Exposure Factors Handbook, Volume I: General Factors.*

EPA, 1997b. *Exposure Factors Handbook, Volume III: Activity Factors.*

EPA, 1991a. *Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors.*

EPA, 1991b. *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decision.*

EPA, 1989. *Risk Assessment Guidance for Superfund. Volume I: Human Health Evaluation Manual, Part A.*

ITRC, 2002. *Technical and Regulatory Document, Determining Cleanup Goals at, Radioactively Contaminated Sites: Case Studies,* Prepared by The Interstate Technology and Regulatory Council, Radionuclides Team.

MWH, 2005. *Northeast Church Rock Storm Water Pollution Prevention Plan.*

MWH, 2004a. *Closeout Plan*, Northeast Church Rock Mine.

MWH, 2004b. *Materials Characterization Work Plan*, Northeast Church Rock Mine.

MWH, 2004c. *Groundwater Quality in the Westwater Canyon Member at the Northeast Church Rock Mine*, August 2004.

MWH, 2003. *Northeast Church Rock Mine Site Assessment*, July 2003.

NMED, 2005. *New Mexico Environmental Department Technical Background Document for Development of Soil Screening Levels*, Final Report. Revision 3.

UNC, 1989a. *Tailings Sand Backfill Cleanup Verification Report*, Northeast Church Rock Mine, United Nuclear Corporation, License SUA-1475, Condition No. 33, April 27.

UNC, 1989b. *NRC License No. SUA-1475*, Condition 33.

U.S. Geological Survey (USGS), 1998. *Radium-226 and Radium-228 in Shallow Groundwater, Southern New Jersey*, Fact Sheet FS-062-98, June