2.0 FIELD INVESTIGATION METHODS

2.1 INTRODUCTION

This RSE investigation was conducted in a manner consistent with the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM, EPA, 2000a), as described below. MARSSIM is a comprehensive survey guidance for soils impacted by radionuclides. It is a performance-based approach for demonstrating compliance with a dose- or risk-based regulation. Consistent with MARSSIM, the RSE included processes to identify data quality needs and any limitations to conducting the survey. The survey design used in this RSE was developed and documented using the Data Quality Objectives (DQO) Process, as described in detail in Section 3.0 of the RSEWP, in accordance with MARSSIM. This represents the planning phase of MARSSIM. A quality assurance and quality control (QA/QC) plan was also include in the RSEWP, which incorporated the DQOs and integrated all technical and quality aspects for the life cycle of the project, including planning, implementation, and assessment.

The RSE was carried out in accordance with the SOPs and QAPP, and resulted in the generation of raw data (the Implementation Phase). The data collection techniques used were consistent with MARSSIM (see Chapters 6 and 7, and Appendix H of MARSSIM).

This report represents the Assessment Phase of the MARSSIM process. The data included were first verified to ensure that the SOPs specified in the QAPP were actually followed and that the measurement systems were performed in accordance with the criteria specified in the QAPP. Then the data were validated to ensure that the results of data collection activities support the objectives of the survey as documented in the QAPP, or permit a determination that these objectives should be modified. The data quality assessment (DQA) process was then applied using the validated data to determine if the quality of the data satisfied the intended use.

The Site was initially divided into eleven individual survey areas, which included NECR-1, NECR-2, Ponds 1 and 2, Pond 3/3a, Sandfill 1, Sandfill 2, Sandfill 3, Sediment Pad, Boneyard, NEMSA, and the Unnamed Arroyo. Two additional areas were added for limited investigation during the field work based on the results of preliminary radiological scans. These areas are Vent Hole 3/8 and Trailer Park. Additionally, nine home sites located northeast of the Site were also investigated as part of the RSE. These fourteen survey areas are shown on Figure 1-3, and Figure 1-4, *Locations of Home Sites.*

Several methods were employed in conducting this field investigation. Initially, static gamma measurements were conducted on random triangular grids. Surface soil samples were collected at several of the gamma measurement sites. Subsurface samples were collected using a hollow-stem auger drill rig, test pits excavated with a backhoe, and a hand-auger.

2.2 RADIOLOGICAL SURVEYS AND FIELD SCANS

The radiological characterization for the surface soil consisted of stationary (static) direct gamma radiation level measurements and radiation gamma scans for additional characterization of the survey area and boundaries. These two survey methods provided for detailed coverage of the aerial extent of Ra-226 within the top six inches of soil, which allowed for a more thorough characterization of the Site compared to relying on surface soil sampling and laboratory analysis alone. The field gamma radiation correlations, static measurements, and scans for the Ra-226 content in soil were performed using a Ratemeter/Scaler (Ludlum 2221) connected to a 2-inch by 2-inch sodium iodide (NaI) crystal scintillation detector (Eberline SPA-3), which detects all gamma radiation above a specific selected energy, including gamma radiation emitted from bismuth-214 (Bi-214), a decay product of Ra-226 in the soil. Prior to conducting the gamma radiation measurements, the operating high voltage levels of

the NaI detectors were established in accordance with manufacturer instructions. The operating high voltage yielding the lowest noise, optimum efficiency and least sensitivity to voltage fluctuations in the field was established by determining the high voltage plateau of the detector.

The presence of radiation containing material on a side slope or in a pile can cause radiation shine at a location near that body of material (i.e., gamma rays are emitted in three dimensions and can impact areas laterally away from the source as well as vertically). Due to the elevated activity of materials at the Site, as discussed in Section 3.0, radiation shine could interfere with and cause an overestimation of Ra-226 soil concentrations at certain locations. A lead collimator was used to minimize this interference (it blocks lateral radiation shine), and a separate correlation calibration was performed for the collimated detector. This detector was held eighteen inches above the survey point to obtain a one-minute integrated count.

Static measurements were taken at all locations on a triangular grid, except at Vent Holes 3/8, the Trailer Park and the Home Sites. Vent Holes 3/8, the Trailer Park and the Home Sites were scanned first to locate elevated areas, and then static gamma measurements were taken at the highest readings to get more precise readings and locations for judgmental soil sample locations. The measurement results, field forms and function check forms are located in Appendix B.

2.2.1 Field Gamma Radiation Survey

The field radiation survey at the Site included the measurement of field gamma radiation levels to characterize the nature and lateral extent of Ra-226 concentration in surface soils. The field gamma radiation level measurements were performed using a 2x2 NaI scintillation detector coupled with a scaler/ratemeter as specified in the Standard Operating Procedures (SOPs) included in the RSEWP. The gamma radiation level measurement consisted of gamma radiation static (stationary) surveys and gamma radiation scan surveys for additional characterization of the survey areas and boundaries. These field gamma radiation surveys provided greater aerial extent of Ra-226 contamination for the top six inches of soil for 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. This low energy and intensity of the Ra-226 gamma radiation emission makes direct determination of Ra-226 in the field a difficult task. However, bismuth-214 (Bi-214), a Ra-226 decay product, emits three high-energy (609 to 1764 KeV) gamma radiations at a total of approximately 80% intensity. The gamma radiation of Bi-214 can be readily and adequately measured in the field utilizing a NaI scintillation detector having high sensitivity. If soil geometry and other parameters such as moisture are consistent, the ratio of Bi-214 to Ra-226 would be consistent. This means there would be a direct relation (correlation) between Bi-214 gamma radiation levels and Ra-226 concentrations in the surface soil. The gamma radiation from other naturally occurring isotopes in soil, such as thorium-232 (Th-232) decay products and postassium-40 (K-40), may contribute to gross gamma radiation intensity. In addition, background gamma radiation from cosmic rays also contributes to gross gamma radiation intensity. However, the Th-232 decay products, K-40, and gamma radiation levels from cosmic rays are generally at a constant level. A linear regression would identify such a constant to correct for and minimize interference with the gamma radiation level and Ra-226 soil concentration correlation. Therefore, to calibrate the 2x2 NaI detector for Ra-226 measurement, a site-specific correlation between the gross gamma radiation level in counts per minute (CPM) and surface soil Ra-226 concentration (pCi/g) was performed in accordance with SOP-02 (see RSEWP) prior to the field survey.

The gamma radiation level instrumentation configuration consisted of an Eberline SPA-3, 2x2 NaI Scintillation detector connected to a Ludlum 2221 Scaler/Ratemeter. Minimum Detectable Concentration (MDC) is the activity level that the instrumentation is expected to detect 95% of the time. The RSEWP specified a gamma radiation survey instrument MDC of 50% of the Derived

Concentration Guideline Limit (DCGL). The $DCGL_W$ was specified in the RSEWP to be 1.24 pCi/g corresponding to the 10^{-4} risk criterion assuming a residential exposure scenario. Therefore, an instrumentation MDC of 0.61 pCi/g (50% of the 1.24 pCi/g) was specified for the static gamma radiation survey. Detailed descriptions of the instrumentation and the MDC calculations are included in Appendix B.

A correlation between the gamma radiation levels in CPM and surface soil Ra-226 concentrations was performed prior to the field gamma radiation survey for a site-specific calibration of the 2x2 NaI detectors. The results were provided in *Results of Background and Radium Correlation Sampling Northeast Church Rock Mine Site Technical Memorandum* (MWH, 2006b). The gamma radiation CPM equivalent to the Ra-226 field screening level (FSL) was necessary prior to conducting the actual surveys in order to identify area boundaries and identify locations above the FSL during the radiation survey. This required performing the necessary gamma radiation level measurements and soil sampling for Ra-226 to determine a correlation between gamma radiation level CPM and Ra-226 concentration in surface soils. A detailed discussion of the correlations that were developed is included in Appendix B.

The FSL (2.24 pCi/g) for Ra-226 was defined as the $DCGL_w$ (1.24 pCi/g) above the mean background Ra-226 concentration (1.0 pCi/g), as discussed in more detail in Section 2.4.

The field gamma radiation survey results and soil sampling results for the applicable correlations are provided in Table 2.2, *Gamma Radiation Levels Versus Surface Soil Ra-226 Concentrations Regression Data.* The summarized linear regression for <10,000 CPM and >10,000 CPM are shown on Figure A-5, *Gamma Radiation Levels vs Surface Soil Ra-226 Concentration Regression Data, NECR-1 Step Out Survey Points for <10K CPM Correlation with Collimated 2x2 NaI Detector,* and Figure A-6, *Gamma Radiation Level to Surface Soil Ra-226 Regression On-site Areas >10K Survey Points for >10K CPM Correlation with Collimated 2x2 NaI Detector,* respectively, included in Appendix B. All static gamma radiation survey readings were converted to surface soil Ra-226 concentration using the following equations, and are discussed in Section 3.1:

- Surface soil Ra-226 pCi/g = (0.0024 x CPM) – 11.608 (R^2 = 0.98) for collimated 2x2 NaI detectors (shown on Figure A-5 of Appendix B) with gamma radiation levels below 10,000 CPM. (2.24 pCi/g FSL equivalents to 5,770 CPM)

- Surface soil Ra-226 pCi/g = (0.0016 x CPM) – 13.909 (R^2 = 0.74) or collimated 2x2 NaI detectors (shown on Figure A-6 of Appendix B) with gamma radiation levels above 10,000 CPM. (2.24 pCi/g FSL equivalents to 10,093 CPM)

The first linear regression analysis shown above was used to estimate low levels of surface soil Ra-226 concentrations (i.e., near the FSL) in areas such as the step-outs where Ra-226 impacts were expected to be in surface soil only with gamma radiation levels generally below 10,000 CPM, yielded a regression with a low R^2 value significantly below the specified value of 0.80. This could be due to elevated variance and error associated with measurements at low levels. Therefore, two survey points collected from the step-out survey area (where Ra-226 contamination is in surface soil only) with Ra-226 concentrations above 10,000 CPM were included in the liner regression to improve the R^2 value. Although, this biased regression produced an R^2 value of 0.98, the data obtained by the field instrumentation was of estimated quality for field screening purposes.

The second linear regression analysis shown above which was used for correlation at locations with gamma radiation measurements above 10,000 CPM for the on-site areas, had an R^2 value of 0.74, lower than the 0.80 value specified in the RSEWP. A revision to the correlation was necessary to minimize interference and over estimation of surface soil Ra-226 from significantly elevated levels of subsurface Ra-226.

Despite the potential for over-estimation due to interference, the field gamma radiation survey measurements provided data of a quality sufficient for field screening. The data collected with field

instruments have the potential for error and low accuracy and are considered to be estimated values, especially, in areas with different contamination distribution than the instrument calibration/correlation assumptions. This was the case for most of the on-site survey areas, where significantly elevated levels of Ra-226 are present in the subsurface. The initial correlation was developed prior to the field survey for Ra-226 in surface soils (less than six inches deep) with fairly homogeneous distribution. The initial correlation did not expect and account for the elevated gamma radiation shine from the subsurface Ra-226, and thus, the Ra-226 concentrations for surface soils determined by the gamma radiation survey using the initial correlations were higher compared to the single point soil sampling results. The correlations were revised and biased to account for the elevated gamma radiation levels in the subsurface, and to obtain more representative Ra-226 surface soil concentrations and improve the quality of the gamma radiation survey data. However, the revised correlation, which would account for subsurface Ra-226 interference, does not account for any variation in gamma radiation shine interference due to variation in subsurface Ra-226 concentrations at different on-site area locations. Therefore, the data obtained by field instrumentation with revised correlations is estimated data suitable for field screening purposes.

2.2.2 Field Direct Gamma Radiation Levels for Surface Soil Ra-226

The field gamma radiation survey for surface soil Ra-226 was performed between November 7 and December 1, 2006 in accordance with the RSEWP. The field gamma radiation survey included a static (stationary) survey and a scan survey. The static gamma radiation surveys were designed primarily to characterize the nature and extent of Ra-226 in surface soils. The gamma radiation scan survey was intended primarily to aid with investigation and characterization of the lateral extent of Ra-226 and to identify elevated areas in surface soils. The selected instrumentation for the gamma radiation survey provides gross gamma radiation levels in counts per unit time. As discussed above, the initial site-specific correlation for calibration of the instrumentation gamma radiation level in CPM to surface soil Ra-226 concentration, and the Ra-226 field screening level (2.24 pCi/g) equivalent gamma radiation level CPM were established.

2.2.2.1 Static Gamma Radiation Survey

Static gamma radiation surveys were performed at specified grid nodes within the survey areas. The grid nodes were determined using Visual Sampling Plan (VSP) on an 80-foot triangular grid cast on a random origin. Initially, a total of 543 80-foot triangular grid nodes (sample locations) were generated that extended beyond the initial survey area boundaries to assist with the boundary delineation evaluation, as presented in Section 3.0. The locations of the static gamma measurements are shown on Figure 2-1, *Static Gamma Measurement Locations*. The following on-site survey areas were included in the survey:

- NECR-1 (156 grid points)
- NECR-2 (75 grid points)
- Pond 1/2 (85 grid points)
- Pond 3/3a (73 grid points)
- Sandfill 1 (76 grid points)
- Sandfill 2 (21 grid points)
- Sandfill 3 (28 grid points)
- Sediment Pad (29 grid points)

Colored flags were used in the field to indicate static gamma measurement and soil sample locations. Each of the grid points was located using a Differentially Corrected Global Positioning System (DGPS). The DGPS consisted of either the Trimble Geo XT or the Starlink Invicta GPS receiver with real time differential correction using OMNI STAR satellite, Tripod Data System (TDS) Ranger

data logger with SOLO surveying software capable of navigating to a point. The differential correction provided submeter accuracy of point locations.

When the grid point was located where the survey would be difficult or inappropriate, such as a building foundation or pad, tree or big shrub, or unsafe terrain, the point was moved to the closest appropriate location and the new point location coordinates were obtained. The grid point was marked with a pin flag with survey area description and grid point number. A one-minute static gamma radiation level measurement was performed with a collimated SPA-3 2x2 NaI detector at each grid point as specified in Section 5.1 of SOP-03 (see RSEWP). The survey information, which included the point number and gamma radiation counts, was logged in the TDS data logger. The data logger automatically logged the corresponding date, time and coordinates. Also, the survey date, survey point ID and the gamma radiation reading in CPM, with any comment, were recorded in the Static Gamma Radiation Survey Field Forms, which are included in Appendix B. The survey information from the data logger files and the field forms are summarized and presented in Section 3.0.

Following completion of the static gamma radiation survey for all of the initial 543 grid points (see Figure 2-1) in the above specified survey areas on November 10, 2006, the gamma radiation counts for the grid point at or near the survey area boundaries were reviewed against the FSL of 4600 CPM for the survey area boundary evaluation. The survey area boundary delineation included the scan survey described in Section 5.2 of SOP-03 (see RSEWP) by walking along the 80-foot spaced transects perpendicular to the initial perimeter of each survey area. These transects were to be run between the most outer 80-foot static grid node with a gamma radiation level above the FSL to the next 80-foot grid node below the FSL outside the survey area boundary. However, the review indicated that the gamma radiation levels were above the 4,600 CPM FSL at most of the survey area boundary grid points. Therefore, a step-out static gamma radiation survey was started on November 13, 2006 beyond the survey area boundary grid points to locate points below the FSL readings for boundary delineation scan surveys.

The step-out static gamma radiation surveys for boundary delineation was performed along transects until the gamma radiation level counts were below the FSL, or other limiting features were encountered, such as a cliff or the boundary of another survey area. Additionally, features such as unimpacted ground (e.g., wooded areas with native soils), roads, structures, and fences were used to help estimate the locations of the FSL boundary. The results of the gamma radiation surveys and the soils sample analyses were used to confirm or adjust the FSL boundary subsequent to the field determination using more definitive data.
Gamma radiation readings at some of the outer step-out static survey points were slightly above the FSL. Nevertheless, the static survey for area boundary delineation was ceased after discussions and agreement with the EPA's on-site representatives based on the criteria listed above in conjunction with levels at or below the FSL. The surface soil sampling results were used in conjunction with the gamma radiation levels for final boundary delineation. A total of 238 step-out static gamma radiation surveys were performed for the area boundary delineations, as listed below.

- NECR-1: 149 step-out survey points
- NECR-2: 43 step-out survey points
- Pond 1 and Pond 2: 0 step-out survey points
- Pond 3/3a: 20 step-out survey points
- Sandfill 1: 0 step-out survey points
- Sandfill 2: 0 step-out survey points
- Sandfill 3: 15 step-out survey points
- Sediment Pad: 11 step-out survey points

A static gamma radiation survey with a collimated SPA-3 2x2 NaI detector was performed at 38 points along the banks of the Unnamed Arroyo, starting at the IX Plant (See Figure 1-2) and moving downstream. This area was not included originally in the RSEWP; however, discussions with the on-site EPA-representatives led to include this survey for boundary delineation along the banks of the Unnamed Arroyo, as documented in FCR#001 (see Appendix C).

Static gamma radiation surveys with a bare (uncollimated) SPA-3, 2x2 NaI detector were also performed at the nine home sites (total of 45 survey points), and the newly identified areas: Vent Hole 3/8 (35 survey points) and the Trailer Park (40 survey points). An uncollimated detector was selected for these areas to fully utilize the detector's lateral range for investigation purposes. A scan gamma radiation survey with uncollimated detector in these areas, as discussed in the following section, was performed to identify locations for further investigation.

Overall, static gamma radiation measurements were obtained at a total of 939 points from all areas at the Site between November 7 and December 1, 2006. All of the static survey readings recorded in the Static Gamma Radiation Survey Field Forms are included in Appendix B. The static gamma radiation reading counts were converted to surface soil Ra-226 concentrations using appropriate correlation linear regression equations, as discussed in Section 2.2.3. Results of the gamma radiation static survey are presented and discussed in Section 3.0.

2.2.2.2 Gamma Radiation Scan Survey

Gamma radiation scan surveys were specified in the RSEWP to identify any hot spots (areas with elevated levels), and to delineate the lateral extent of contamination. The scan survey was conducted judgmentally around areas with elevated gamma readings from the static survey, and at site-specific locations. The gamma radiation scan surveys (walkthrough surveys) were performed as described in Section 5.2 of SOP-03 (see RSEWP) by walking at a rate of about one foot per second in serpentine shape along transects with a bare (uncollimated) 2x2 NaI detector at about 18 inches from the ground surface.

NECR On-Site Survey Areas

The RSEWP specified gamma radiation scan surveys at a coverage of up to 20% of the gamma radiation static surveys that exceeded the FSL to identify any hot spots. The RSEWP specified that if over 80% of the static survey within a survey area exceeded the FSL (equal to $DCGL_w$ plus background), there would be no scan survey in that area. Over 80% of the static gamma radiation survey measurements in all on-site survey areas exceeded the FSL, therefore no scan gamma radiation survey was performed in any of the original on-site survey areas.

NEMSA and Boneyard

The RSEWP specified that a gamma radiation scan survey be conducted at the NEMSA and Boneyard. Prior to implementing the survey, an inspection of these areas was conducted on November 11, 2006 by AVM, MWH and EPA representatives. The NEMSA appeared to contain a clean soil cover, however, the cover had been eroded at several locations and non-economic material was visible The gamma radiation exposure rates in the NEMSA ranged from about 25 μR/hr in areas with unimpacted cover to above 120 μR/hr where the soil cover was eroded and non-economic material was exposed. Elevated gamma exposure rates near 100 μR/hr were also observed at several locations in the Boneyard where subsidence and voids were present in the cover. A gamma radiation scan, which is meant to characterize surface soil, would not have provided any meaningful data as it would have been skewed by the deeper gamma radiation. Therefore, a decision was made to suspend the gamma radiation scan survey in these areas (see FCR#002 in Appendix C). Instead,

characterization of these areas is based on surface and subsurface soil sampling, and visual observations made during the subsurface investigation.

Home Sites

Gamma radiation scan surveying was performed on November 15, 2006 at the nine home sites. The four corners of the half-acre square area around each home were marked with pin flags. The scan survey was performed by walking at a rate of about one foot per second in a serpentine pattern along transects spaced 10 feet apart with an uncollimated 2x2 NaI detector (#408522-33) at about 18 inches from the ground surface. The scans were used to identify areas with gamma levels above the 16,600 CPM FSL. EPA on-site representatives provided oversight and assisted with the survey.

Locations with levels above the FSL, or a total of five locations with the highest readings, were identified and marked with pin flags at each home site. A gamma radiation static survey and soil sampling was then conducted at each of these locations. The gamma radiation static survey readings were recorded in the Field Data Forms, which are included in Appendix B; the results are discussed in Section 3.0.

Based on the preliminary results from this RSE investigation, the EPA conducted a soils removal action at Home Sites 4 and 6 through 9. Soils were excavated to a depth of three to 12 inches around these five Home Sites. Following excavation, EPA conducted confirmation sampling and analysis for Ra-226. A summary report was prepared by the EPA that included hand-sketch drawings showing the lateral extent of the soils removal, the locations of the post-excavation confirmation samples, and analytical results; a copy of the report is included in Appendix D. The EPA's removal boundaries showing the lateral extent of excavation are illustrated on Figure 2-1. It should be noted that these boundaries were surveyed and are of unknown accuracy. The results of the post-confirmation sampling were used in the risk assessment (Section 4), but are otherwise only included in Appendix D; Sections 2.0 and 3.0 of this report include the results of the RSE investigation only.

Vent Hole 3/8 and Trailer Park

The EPA's on-site representative identified Vent Hole 3/8 and the Trailer Park during the field survey as additional areas requiring investigation and characterization. The addition of these two areas was documented in FCR#004 (see Appendix C). A scan survey was performed by walking at a rate of about one foot per second in serpentine pattern along transects spaced 10 feet apart with a bare (uncollimated) SPA-3 2x2 NaI detector (#408522-33) at about 18 inches from the ground surface. The scan survey was used to identify areas with elevated exposure rates, as specified in the RSEWP. Following the scan survey, a gamma radiation static survey was performed with the uncollimated detector at the areas with elevated gamma levels. The scan results (sketches and the Static Gamma Radiation Survey Field forms) are included in Appendix B. The results of the scan survey in these areas are summarized in Section 3.0

Unnamed Arroyo

The RSEWP specified that a gamma radiation survey be conducted of the surface sediments in the channel of the Unnamed Arroyo. The RSEWP indicates that the scan be conducted with a collimated 2x2 NaI detector to identify areas with exceeding the 2.24 pCi/g Ra-226 FSL, equivalent to 5,200 CPM for the collimated SPAS-3 detector #408522-33. The 5,200 CPM FSL (detector 408522-33) was derived from the regression analysis performed for the Unnamed Arroyo gamma radiation survey correlation, as presented in Figure 7 of the document *Results of the Background and Radium Correlation Sampling Technical Memorandum* (MWH, 2006b), which included the Ra-226 correlation sampling results. The regression analysis indicated that 5,200 CPM is equivalent to 2.24 pCi/g of Ra-226. Due to the presence of radiation containing materials on side-slopes or in a pile that can cause radiation shine

(potentially causing an overestimation of Ra-226 soil concentrations), a lead collimator was used on the field detector to minimize interference.

The correlation survey that was conducted revealed that all fifteen locations in the arroyo sediment bed had Ra-226 concentrations significantly above the FSL. The fifteen sampling locations extended from the edge of NECR-1 to the area around the home sites (see Technical Memorandum). The converted Ra-226 concentrations ranged from 9.7 pCi/g to 26.4 pCi/g. The survey results indicated that surface sediments along the entire length of the Unnamed Arroyo included in the RSEWP for surveying were likely to be above the FSL. Therefore, in consultation with the on-site EPA representatives, a decision (see FCR#001 in Appendix C) was made to eliminate the gamma radiation scan survey in the Unnamed Arroyo, and instead perform subsurface sediment sampling for laboratory analysis. As discussed in Section 2.2.4.1, a gamma radiation static survey at 80-foot grid transect locations along the arroyo bank was performed.

2.3 SURFACE SOIL FIELD INVESTIGATION

Surface soil sampling was initially performed at the individual survey areas listed below. Surface soils for the purpose of the RSE are defined as less than or equal to 0.5 feet below ground surface (feet bgs).

- NECR-1
- NECR-2
- Sandfill 1
- Sandfill 2
- Sandfill 3
- Ponds 1 and 2
- Pond 3/3a
- Sediment Pad
- NEMSA
- Boneyard

Surface soil sampling was also conducted at the nine home sites.

Two additional areas were added during the field investigation, because preliminary radiological scans yielded sufficiently high results. These areas are Vent Hole 3/8 and the Trailer Parks (See Figures 1-2 and 1-3). Sample locations at eight of the on-site survey areas were based on predetermined grids. Sample locations at the Boneyard, NEMSA, Trailer Park, Vent Hole 3/8, and the nine home sites were collected at judgmental locations, as described in this Section. Surface soil sample locations are shown on Figure 2-2, *Surface Soil Sample Locations Mine Site.* A tabular summary of the surface soil samples collected from each survey area is included in Table 2.3, *Summary of Soil Sampling Program*, and a more detailed summary of samples collected is included in Appendix B.

From eight of the on-site survey areas, surface soil samples were collected from 20% of the static gamma measurements or a minimum of 13 samples per area, whichever was greater. VSP was originally used to locate the surface soil samples on a triangular grid cast on a random origin. In order, to have the static gamma measurements and surface soil samples on the same grid, the surface soil locations were randomly co-located with the static gamma measurements that were cast on the 80-foot triangular grid. Surface soil samples were collected manually as grab samples from 0 to 0.5 feet and analyzed for the preliminary COPCs.

Initially, a total of 132 surface soil samples were co-located with static gamma measurements in eight of the on-site survey areas. The number of original surface soil samples for each area is summarized as follows (see also Appendix B):

- NECR-1 (31 surface soil samples)
- NECR-2 (15 surface soil samples)
- Sandfill 1 (15 surface soil samples)
- Sandfill 2 (13 surface soil samples)
- Sandfill 3 (13 surface soil samples)
- Pond 1 and No. Pond 2 (19 surface soil samples)
- Pond 3/3a (15 surface soil samples)
- Sediment Pad (14 surface soil samples)

As a result of FCR#003 (see Appendix C), 30 additional soil samples were collected at the step-out static gamma locations, as well as boundary confirmation samples. The numbers of step-out and boundary confirmation surface soil samples collected in each survey area were as follows:

- NECR-1 (16 step-out surface soil samples)
- NECR-2 (4 step-out surface soil samples
- Sandfill 1 (3 boundary confirmation surface soil samples)
- Sandfill 3 (2 boundary confirmation surface soil samples)
- Pond 1/2 (4 boundary confirmation surface soil samples)

Because the Boneyard and NEMSA were reclaimed in 1994 and covered with a one-foot layer of topsoil, they were unlikely to have preliminary COPCs at the surface. Therefore, only five judgmental surface samples were collected from each of these areas to evaluate if any impacts subsequent to reclamation have occurred. The sample locations were chosen based on field observations or evidence that impacts may have occurred (e.g., buried materials, stressed vegetation, eroded ground, areas with sediments deposited from storm water run-on). If no such evidence existed, the samples were collected randomly. Surface samples from the Boneyard and NEMSA were analyzed for preliminary COPCs and agronomic parameters.

The Trailer Park and Vent Hole 3/8 areas were added as per FCR#004 (see Appendix C). Five judgemental locations were selected from the Trailer Park and and five from Vent Hole 3/8 based on the gamma radiation scan survey and static gamma measurements. Surface soil samples were co-located with static gamma measurements, collected as grab samples from 0 to 0.5 feet bgs and analyzed for preliminary COPCs.

Sample locations at the nine home sites were developed judgmentally, based on the highest readings from the gamma radiation scan survey. Five samples were collected for the analysis of preliminary COPCs from each of the nine home sites (total of 45 samples) in a judgmental manner within approximately a one-half acre buffer around each home site, as shown on Figure 2-3, *Surface Soil Sample Locations, Home Sites*. The samples were located on native ground and were collected from the top three inches of soil. If grass was covering the soil, a small patch of grass was cleared down to the soil surface, as that would likely be the zone that wind borne particles from the Site would deposit if they were to make it to that location. The sample locations were biased to the five highest gamma measurements that resulted from the gamma radiation scan survey. The surface sample locations were refilled and leveled to grade after sampling with remaining soil.

Samples collected from the Unnamed Arroyo were initially planned to be taken as surface soil samples. However, as per FCR#001 (see Appendix C), subsurface soil samples were collected instead

as discussed in Section 2.2.4.2. The collection methods for these samples are described in section 2.4.3.

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

- Five samples from the Pond 1/2, Pond 3/3a and the Sediment Pad;
- Five samples from Sandfill 1, Sandfill 2, and Sandfill 3;
- Five samples from NECR-1 and NECR-2; and
- Five samples from the Boneyard and the NEMSA.

This equated to a total of 20 samples. The samples collected in a judgmental manner from locations 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.

Samples were also selected for the analysis of preliminary COPCs in leachate using the EPA Method 1213, Synthetic Precipitation Leaching Procedure (SPLP). Two samples were selected in a judgmental manner from each of the on-site survey areas that were not reclaimed (i.e., not including the NEMSA or the Boneyard). The sample locations were chosen at the surface or subsurface locations in each of the survey areas based on the highest total metal results. For each surface sample collected, the percent difference between the metal concentrations and the screening levels was determined. This percent difference was summed for each metal associated with the soil sample. Then the two samples from each survey area with the highest percent difference were selected for SPLP analysis. Of the 16 samples selected for SPLP analysis, 13 of the samples were selected from surface soil sample locations, and the other three were selected from subsurface soil sample locations. These survey areas and soil samples for SPLP are summarized below.

- NECR-1 (2 surface soil samples)
- NECR-2 (2 surface soil samples)
- Sandfill 1 (2 subsurface samples
- Sandfill 2 (2 surface soil samples)
- Sandfill 3 (1 surface soil sample, and 1 subsurface soil sample)
- Pond 1/2 (2 surface soil samples)
- Pond 3/3a (2 surface soil samples)
- Sediment Pad (2 surface soil samples)

Surface soil samples were collected, packaged, and handled according to the protocols in the RSEWP. All surface soil samples were collected using dedicated field equipment. Surface soils were sampled to a depth of 0.5 feet bgs in the on-site survey area and to depth of three inches at the nine home sites. The samples were collected using dedicated stainless steel teaspoons. These samples were placed in one-gallon Ziploc bags, and labeled with date, time, and sample identification. Field duplicates were collected at five percent of the sample locations, and the EPA took field duplicates at ten percent of the sample locations. Homogeneity was achieved by sampling twice the amount in one bag, then mixing and dividing into a separate bag. Additional sample volume was required for samples requiring agronomic analysis. Surface soil samples were submitted to ELI, Casper, Wyoming for analysis of preliminary COPCs, agronomic parameters, and SPLP analyses.

2.4 SUBSURFACE SOIL FIELD INVESTIGATION

Subsurface soil samples were collected from on-site survey areas specified in the RSEWP. In addition, subsurface samples were also collected from the Unnamed Arroyo as a result of FCR#001 (see Appendix C). Subsurface soil sample locations are shown one Figure 2-4, *Subsurface Soil Sample Locations.* A summary of the subsurface soil samples collected from each survey area is included in Table 2.3, *Summary of Soil Sampling Program* (See also Appendix B summary).

For the on-site areas, a total of five locations were selected judgmentally from each survey area and were co-located with surface soil sample locations. These subsurface soil sample locations were selected based on elevated surface gamma measurements, as well as the spatial distribution within the survey area (i.e., not clustered). Grab samples were collected from non-native materials every five feet until native soil was reached. At least one grab sample of the native soil was also attempted from each location. In several locations, the presence of sandstone bedrock made collection of a native soil sample not feasible. If the depth of non-native material was less than five feet at any location, one sample of non-native material was collected at approximately the middle of the vertical extent of non-native material, and one sample of the native soil was also collected, where possible. Subsurface soil samples collected at the Boneyard and NEMSA included one sample of the pre-cap material at each subsurface location.

Subsurface samples were collected using three methods. Locations where native soil was anticipated to be at depths greater than ten feet bgs were collected using a drilling rig fitted with hollow-stem augers. Locations where native soil was anticipated to be less than 10 feet and were accessible by heavy equipment were collected using test pits dug with a backhoe. A hand auger, the third method, was used in the Unnamed Arroyo. The sample collection methods are outlined in the sections below. A total of 146 subsurface soil samples were collected. A summary of the number of subsurface samples and subsurface sample intervals follows:

- NECR-1: six locations (28 samples); sample depths ranging from 4 to 45 feet bgs
- NECR-2: five locations (6 samples); sample depths ranging form 0.5 to 5 feet bgs
- Sandfill 1: five locations (9 samples); sample depths ranging from 0.5 to 4 feet bgs
- Sandfill 2: five locations (5 samples); sample depths ranging from 0.5 to 2 feet bgs
- Sandfill 3: five locations (7 samples); sample depths ranging from 0.5 to 2 feet bgs
- Pond 1/2: five locations (14 samples); sample depths ranging from 4.5 to 20 feet bgs
- Pond 3/3a: five locations (14 samples); sample depths ranging from 9 to 25 feet bgs
- Sediment Pad: five locations (9 samples); sample depths ranging from 1 to 10 feet bgs
- NEMSA: five locations (13 samples); sample depths ranging from 4 to 8.5 feet bgs
- Boneyard: five locations (11 samples); sample depths ranging from 1 to 9.5 feet bgs
- Unnamed Arroyo: 10 locations (30 samples); sample depths ranging from 0 to 3 feet bgs

Samples were also selected for the analysis of preliminary COPCs in leachate using the SPLP method, as discussed in Section 2.3. Of the total 16 samples selected for SPLP analysis, three were selected from subsurface soil sample locations, the remaining were selected from surface soil sample locations (see Section 2.3). The three subsurface soil samples were collected from Sandfill 1 (two samples) and Sandfill 3 (one sample).

During drilling at soil boring number SB-131, which was located along the northeastern edge of NECR-1, as shown on Figure 2-4, a dark gray clayey material was encountered that had a distinct petroleum odor to it. Consequently, one sample was collected from 22.0 to 23.5 feet bgs and submitted for analysis of Total Petroleum Hydrocarbons by EPA Method 8015B and VOCs by EPA Method 8260B.

Subsurface soils were visually classified in the field in accordance with the Unified Soil Classification System (USCS), and any soil horizons observed during the sample collection were noted in the field books and field logs located in Appendix C. Subsurface soil samples were collected, packaged, and handled according to the protocols in the RSEWP. Subsurface soil samples were placed in the appropriate container, and labeled with date, time, and sample identification. Field duplicates were collected at five percent of the sample locations. Homogeneity was achieved by sampling twice the amount in one bag, then mixing and separating into a separate bag. The EPA did not collect field splits from the subsurface sample locations.

Subsurface soil samples were sent to ELI in Casper, Wyoming for analysis of COPCs and SPLP. Soil samples for SVOC analysis were sent to ELI in Billings, Montana for analysis. The soil samples were analyzed for preliminary COPCs at nine of the on-site survey areas and the Unnamed Arroyo. At the Boneyard, samples for VOCs, SVOCs, and TCLP analysis were also collected.

2.4.1 Hollow-Stem Auger

At subsurface locations where native soil was anticipated to be greater than the depths achievable by a backhoe (greater than 10 ft bgs), sampling was conducted with a drill rig fitted with hollow-stem augers. The hollow-stem auger drill rig was used to collect samples at eight subsurface sample locations, as listed below:

- NECR-1 (five locations)
- Pond 1/2 (two locations)
- Pond 3 (one location)

Water Development Corporation (WDC) was the contractor hired to conduct the drilling. For each soil boring, the soil boring was advanced to the desired interval and an 18-inch split-spoon sampler was lowered into the bottom of the soil boring and driven with blows from a 140-pound hammer falling 30 inches in general accordance with ASTM D1586. The number of blow counts for each six-inch interval was recorded on the boring logs. Sampler refusal is generally indicated if more than 50 blows are required to advance the sampler six inches. This occurred several times, but only after native soil was reached, so there was no need to relocate any of the soil borings. Samples were collected every five feet to total depths from 14 feet to 45 ft bgs.

The split-spoon samplers were decontaminated between each sample interval using Alconox® and distilled water, as per the RSEWP (nitric acid was not used). This assured there would be no cross-contamination of the split-spoon samples. The augers were also decontaminated using a pressure washer and Alconox®.

2.4.2 Test Pits

Test pits were used where native soil was anticipated to be less than ten feet bgs. A total of 43 test pits were excavated, as listed below:

- NECR-1 (one test pit)
- NECR-2 (five test pits)
- Pond 1/2 (three test pits)
- Pond 3/3a (four test pits)
- Sandfill 1 (five test pits)
- Sandfill 2 (five test pits)
- Sandfill 3 (five test pits)
- Sediment Pad (five test pits)

The test pits were excavated using a rubber-tired backhoe that was capable of reaching a maximum depth of ten feet bgs. Dedicated stainless steel spoons were used to collect the soil samples. For test pits that were less than three feet in depth, soil samples were collected by multi-increment scoops along the test pit wall or bottom at the desired interval. For test pits greater than three feet in depth, soil samples were extracted using multi-increment scoops from the bucket of the backhoe. After samples were collected, the excavated soil was used as backfill and the backhoe was used to compact the area.

2.4.3 Hand Auger

A hand-auger was used to collect subsurface soil samples from the Unnamed Arroyo. Initially, only soil samples from zero to one foot bgs from ten transects (three locations per transect) were planned for collection, but as per FCR#001 (see Appendix C), a deeper subsurface investigation was required. As per FCR#001, samples were collected from ten transects oriented perpendicular to the arroyo, from the former NPDES discharge point to its confluence with the next downstream arroyo. The transects are shown schematically on Figure 2-4. One location from the midpoint of each transect was selected and samples were collected in one foot intervals from 0 to 3 feet, for a total of three samples at each of the ten locations.

The hand auger was decontaminated in between every sample interval. The decontamination was conducted in three stages using an Alconox® wash, nitric acid, and de-ionized water. A rinsate blank was also collected at the end of each day by pouring laboratory-grade de-ionized water on the hand auger in order to ensure thorough decontamination.

2.5 DEVELOPMENT OF FIELD SCREENING LEVELS

Screening levels for Ra-226 and arsenic were developed using the background concentrations of the COPCs, as presented in the Technical Memorandum (MWH, 2006). Soil samples for background determination were collected on August 17, 2006 and submitted to ELI of Casper, Wyoming for chemical analysis. The location of the background reference area and the sampling design were selected based on MARSSIM (EPA, 2000a). The area was located to the northwest of the Boneyard, as shown on Figure 2-5, *Surface Soil Sample Locations Background Refrence Area,* and 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.

A total of 25 surface soil samples and two duplicate samples were collected from the background reference area. The samples were collected using the methods described in the Technical Memorandum. EPA representatives were present during sampling and confirmed background sample locations. Analytical results are summarized in Table 2.4, *Summary of Analytical Results from Background Sampling*; laboratory reports are included in the Appendix B. The concentrations of all analytes were less than the applicable Preliminary Remediation Goals (PRGs), except arsenic and Ra-226. Arsenic and Ra-226 concentrations exceeded both the industrial and residential PRGs in all samples (see Table 2.4). Table 2.4 also shows the mean and standard deviation for each of the COPCs. Screening levels were based on the EPA Superfund Preliminary Remediation Goals (PRGs) for radionuclides (EPA, 2004c) and the EPA Region 9 PRGs for metals and organic constituents (EPA, 2004a).

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 FSL was developed for Ra-226. As stated in the RSEWP, the FSL for Ra-226 was based on an acceptable risk range of 10^{-4} for residential scenarios, which results in a FSL of 2.24 pCi/g; (1.24 pCi/g plus the mean of the Ra-226 background concentration 1.0 pCi/g]. The background concentration was determined based on the results of background sampling conducted for the background determination (MWH, 2006b). The results for Ra-226 ranged from 0.6 to 1.3, with an average of 1.0 pCi/g. . However, it is important to note that at the nearby Church Rock I, IE and II Mines, the background gamma exposure rate is 9 uR/hr (Quivera, 1987), which is approximately equivalent to 4.5 pCi/g, as discussed in the following paragraph. Additionally, the average background concentration of Ra-226 throughout the Colorado Plateau is reportedly about 2 pCi/g (EPA, 2005).
Exposure rate levels above background levels at former uranium facilities are primarily from Ra-226 in soil. A linear regression between gamma exposure rate and Ra-226 soil concentration was performed to estimate the Ra-226 soil concentration at a gamma exposure rate of 57 uR/hr. The regression was based on exposure rate measurements collected around soil sampling locations obtained during the August 2006 correlation sampling activities at the Site. Based on this informal correlation, a location with 57 uR/hr would have approximately 27 pCi/gm Ra-226 in soil. However, the exposure rates were made at a reconnaissance level, and so were of the general area around each sampling location, not right above the location, which averages the concentration for that specific location. Also, a correlation between exposure rate and soil concentration can be affected by gamma shine related to the area geometry and contamination distribution.

The Site background value of 1.0 pCi/g appears to be on the low end of the range of concentrations seen in the region. The background value at the adjacent Quivera Mines is approximately 4.5 pCi/g (see discussion above). Other examples include: the NRC approved a Ra-226 soil background value for the Bluewater Mill Site (approximately 10 miles from Grants) of 1.9 pCi/g, and both the NRC and EPA approved a Ra-226 soil background value for the Homestake Mining Company Mill Site (approximately six miles from Grants) of 5.5 pCi/g (Nat Patel, personal communication). Additionally, the average background concentration of Ra-226 throughout the Colorado Plateau is about 2 pCi/g. (EPA Detailed Comments on EIS for Moab Uranium Mill Tailings Site). One possible explanation for the lower background value observed in the background reference area, is that the soils there are near an arroyo and may be largely of alluvial origin where the finer-grained material (silts and clays) may have been washed out. Radionuclides tend to adhere or bond to the finer grained particles, and so can be washed out of the coarser material.

Since all of the background arsenic concentrations exceeded the PRGs, the mean of the background arsenic concentrations (3.7 mg/kg) was used as the screening level for arsenic. The residential non-cancer PRG for arsenic is 22 mg/kg, and the industrial non-cancer PRG is 260 mg/kg. The screening levels for vanadium, molybdenum, and selenium were based on the EPA Region 9 PRGs, as shown on Table 2.4.

2.6 SITE RECONNAISSANCE

During the course of site reconnaissaince and site walk-overs, the following new survey areas were identified based on obvious mining-related activity or structures, as listed below.

- Vent Holes 3 and 8 – surficial disturbance and mounded soil.
- Trailer Park – surficial distubance

- NECR-2 Drainage - at less than two meters bgs, partially buried drums were observed on the ground surface.
- Magazine - at less than two meters bgs, construction debris and trash was observed.
- Fuel Oil Storage Area - at less than 2 meters bgs, no known material.

All of these areas were investigated during the RSE. Both the Vent Hole 3/8 area and the Trailer Park were investigated using gamma radiation scan surveys, judgmental gamma radiation static surveys, and judgmental surface soil sampling. The NECR-2 Drainage and the Magazine area were investigated coincidentally during the step-out investigation of NECR-2. Static gamma measurements were collected in both areas and step-out surface soil samples from NECR-2 were collected in the Magazine area. The Fuel Oil Storage Area was investigated coincidentally during the step-out investigation of NECR-1.