Prepared for:

United Nuclear Corporation
P.O. Box 3077
Gallup, NM 87305

FINAL

REMOVAL SITE EVALUATION REPORT
RED WATER POND ROAD
NORTHEAST CHURCH ROCK MINE SITE

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Prepared by:

MWH
1475 Pine Grove Road
P.O. Box 774018
Steamboat Springs, Colorado 80477
(970) 879-6260

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ACRONYMS

bgs	below ground surface
Bi-214	bismuth-214
CPM	counts per minute
DCGL	Derived Concentration Guideline Level
DQA	Data Quality Assurance
DQO	Data Quality Objective
EDD	electronic data deliverable
EPA	Environmental Protection Agency
FSL	field screening level
MARSSIM	Multi-Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
MDL	method detection limit
NaI	sodium iodide
NCP	National Contingency Plan
NECR	Northeast Church Rock
NNEPA	Navajo Nation Environmental Protection Agency
pCi/g	picoCurie per gram
QA/QC	quality assurance/quality control
Ra-226	radium-226
RPM	Remedial Project Manager
RSE	removal site evaluation
RWPR	Red Water Pond Road
UCL	upper confidence limit
UNC	United Nuclear Corporation
USCS	Unified Soil Classification System
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
WMW	Wilcoxin-Mann-Whitney

1.0 INTRODUCTION

This report describes the objectives, scope of work, and results of the Removal Site Evaluation (RSE) conducted along Red Water Pond Road (RWPR) in 2007 and 2009. The RSE of RWPR was conducted in accordance with the *Interim Removal Action (IRA) Construction Plan* (MWH, 2009) and the *Removal Site Evaluation Work Plan* (MWH, 2006). The RSE area for RWPR (Study Area) is located primarily on the Navajo Reservation (see Drawing 1, *Site Map*) and includes the roadway itself plus a 50-foot wide area on both the west and east sides of the roadway (50-foot buffers), that could have been impacted through historic use of the roadway as a haul road and/or by drainage from the road. The area extends from Highway 566 to the first arroyo that crosses RWPR (east-west arroyo) near the reclaimed Quivira Mine. The study area is adjacent to the NECR-1 step-out area for the Northeast Church Rock (NECR) mine.

The objectives of this work were to:

(1) confirm the prior sampling results and statistical evaluation (see February 19, 2009 correspondence to USEPA) that showed that the mean/median of the data from the southern and northern sections of RWPR are statistically higher than the adjacent NECR-1 step-out area immediately to the west; and

(2) evaluate the vertical limits and distribution of elevated subsurface activity levels within RWPR and the adjacent 50-ft buffers.

The investigation activities contributing to the RWPR RSE and used in the prior statistical evaluation (February 2009) were conducted in two phases. The first phase consisted of static radiation gamma surveying and surface soil sampling during the Supplemental RSE (SRSE) between November 5 and 14, 2007, described in detail in the *Supplemental Removal Site Evaluation Report* (MWH, 2007) and summarized in this report as they apply to RWPR. The second phase consisted of static radiation gamma surveying of surface soils, gamma radiation screening of subsurface soils, and surface and subsurface soil sampling conducted between September 8 and 10, 2009 as part of the IRA for the NECR mine.

In addition to the data obtained during the SRSE and the RWPR RSE, the interpretations included in this report also considered the preliminary results of Weston's investigation of RWPR (draft results, December 2009), which indicated that high activity levels (many times greater than their reported background level) were present in and adjacent to RWPR north of the east-west arroyo at the base of the Quivira Mine. While these results reflect conditions north of the east-west arroyo and therefore just outside of the Study Area, they indicate the potential for ongoing impacts to the Study Area from the Quivira Mine due to wind-borne transport and indicate that Quivira is a source of the contamination. In addition, there is the potential for traffic, plowing and maintenance activities on the roadway to transport materials into the Study Area.

2.0 FIELD INVESTIGATION SCOPE OF WORK

2.1 DATA QUALITY OBJECTIVES

As described above, the Study Area includes the roadway and adjacent area within 50 feet of the edges of the actual road on both the west and east sides (50-foot buffers) from Highway 566 to the first (east-west) arroyo that crosses RWPR near the reclaimed Quivira Mine. The Study Area may have been impacted by vehicular transport associated with the former Quivira Mine, which used RWPR as a haul road for the mine, or by wind or water transport of materials (soil and sediments) associated with the formerly active NECR and/or Quivira Mines, indicating that the Quivira Mine is a source of the materials. Radionuclides are also present naturally in the rocks and soils of this region, as observed in the background reference area used for the NECR RSE (MWH, 2007).

The roadway itself consists of a compacted sand and gravel road with some evidence of layering (i.e., slightly different soils), as discussed in Section 3.2. The road is active and is managed by the Navajo Division of Transportation. It is our understanding that road maintenance activities include regrading, infill of potholes, addition of new road base, and snow plowing. Because of these activities, as well as stormwater/snowmelt runoff, the surface of the road is continuously being reworked, cleaned and mixed. Additionally, the IRA conducted during and after this RSE in 2009 resulted in a temporary increase in vehicular and heavy equipment traffic and additional regrading of the road surface south of the east-west arroyo. Because of the continuous changes the roadway surface has and continues to undergo, investigation activities were limited to subsurface soils (<0.5 ft bgs) within the roadway (except for the static gamma measurements from the RWPR RSE). Both surface (0 to 0.5 ft bgs) and subsurface soils (>0.5 ft bgs) were sampled in the 50-foot buffers.

Previous investigation activities have suggested that while there may be some impacts along the southern portion of the road closer to Highway 566 that may be partially attributable to drainage from NECR, there is evidence that past and current activities associated with the Quivira Mine have significantly impacted RWPR, particularly the northern portion of the Study Area. Statistical analysis using the Wilcoxon-Mann-Whitney (WMW) Test (MARSSIM, 2000) was conducted on Ra-226 concentrations in soil samples (EPA Method 901.1) from the SRSE (MWH, 2007) to compare results from the 50-ft buffers to those from the step-out area adjacent to the roadway (see February 16, 2009 Memorandum in Appendix C). The conclusion of that analysis was that the mean/median of Ra-226 concentrations along RWPR is greater than the mean/median within the step-out area (prior to the IRA) within a 95% confidence interval. This suggests that the source of Ra-226 along RWPR is different than in the step-out area, and likely includes impacts from past activities along RWPR associated with the Quivira Mine.

All investigation activities conducted along RWPR by UNC have been restricted to areas south of the east-west arroyo, since any impacts on the northern side of the arroyo can be assumed to be attributable to the immediately adjacent Quivira Mine. The results from Weston's recent gamma survey of the Quivira Mine and RWPR north of the east-west arroyo support this assumption, as the highest activity levels were present at the base of the Quivira Mine at RWPR.

Since previous RSE investigation activities (e.g., the SRSE static gamma surveying and surface soil sampling and analysis) indicated that elevated levels of Ra-226 were present in soils along RWPR, at least in surface soils within the 50-ft buffers, the Study Area was considered a Class 1 survey area, as per MARSSIM (EPA, 2000). The principal questions for this investigation were:

1) What are the levels and extent of Ra-226 within the Study Area?

2) Are elevated levels of Ra-226 present in surface (0 to 0.5 ft bgs) and subsurface soils (>0.5 ft bgs)?

3) Are the levels such that they warrant further characterization or evaluation for a removal action to prevent direct exposure or further transport of contaminants?

4) What are the likely sources of elevated levels of Ra-226 in soils?

5) Do the results confirm that the mean/median of the data from the southern and northern sections of RWPR is statistically higher than in adjacent step-out areas immediately to the west?

In order to make decisions based on the above questions, it was necessary to collect the following data:

- Vertical and lateral extent and concentrations of Ra-226 in surface and subsurface soils;

- Spatial location (horizontal and vertical) of samples and measurements (Ra-226 concentrations);

- Count rate of collimated surface static gamma radiation (field gamma survey); and

- The applicable Derived Concentration Guidance Levels ($DCGL_W$ and $DCGL_{EMC}$), and the Minimum Detectable Concentrations (MDCs).

As per MARSSIM, a *release criterion* is a regulatory limit expressed in terms of dose or risk. Exposure pathway modeling is used to calculate a radionuclide-specific predicted concentration or surface area concentration of specific nuclides that could result in a dose or specific risk equal to the release criterion. Such a concentration is termed the *derived concentration guideline level (DCGL)*. DCGLs are often obtained from responsible regulatory agency guidance based on default modeling input parameters; otherwise site-specific parameters can be used to determine DCGLs. The DCGLs are used as *investigation levels* that, if exceeded, trigger some response such as further characterization or remediation. MARSSIM defines two potential DCGLs based on the area of contamination:

- If the residual radioactivity is evenly distributed over a large area, MARSSIM looks at the average activity over the entire area. The $DCGL_W$ (the DCGL used for the statistical tests) is derived based on an average concentration over a large area. The "W" in $DCGL_W$ stands for WMW Test.

- If the residual radioactivity appears as small areas of elevated activity within a larger area, typically smaller than the area between measurement locations, MARSSIM considers the results of individual measurements. The $DCGL_{EMC}$ (the DCGL used for the elevated measurement comparison (EMC)), is derived separately for these small areas and generally from different exposure assumptions than those used for larger areas.

For the NECR RSE, the $DCGL_W$ *of* 1.14 pCi/g was based on the EPA Region 9 Preliminary Remediation Goal (PRG) for Ra-226 for a residential use scenario and a 1×10^{-4} risk level, while the $DCGL_{EMC}$ was specified by EPA Region 9 during development of the *Removal Site Evaluation Work Plan* (MWH, 2006).

The parameters of interest are the absolute and mean concentrations of Ra-226 in surface and subsurface soils within the Study Area. The null hypothesis (H_o) is that the mean/median concentration of Ra-226 is greater than the NECR Field Screening Level (FSL) of 2.24 pCi/g, the $DCGL_W$ plus the background mean (1.0 pCi/g). The alternative hypothesis (H_a) is that the mean/median concentration of Ra-226 is less than the FSL. The hypotheses will be tested using statistical methods consistent with the assumptions supported by the data. All statistical estimators (e.g., means) will have acceptable confidence limits (see Section 3.6. of the *Removal Site Evaluation Work Plan*).

Based on the principal study questions for the Study Area discussed above, the decision statements are:

- If concentrations of Ra-226 do not exceed the DCGLs then the area will not require any further action.

- If concentrations do exceed the DCGLs, evaluation of removal action alternatives and/or additional investigation will be required.

All statistical significance tests (e.g., the WMW test) were 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 had a significance level, α, equal to 0.05 and a Type II error, β, equal to 0.10. Evaluation of the data and the selection of the appropriate statistical testing procedure was made in accordance with the Data Quality Assessment (DQA) process, as discussed in Section 7.0 of the RSE Work Plan. The number of samples required to meet the DQOs (13) was developed as part of the RSE Work Plan (MWH, 2006). The sampling design described in the following sections was designed to support the individual DQOs and to meet these tolerance criteria.

This investigation was conducted in accordance with the Quality Assurance Project Plan (QAPP) that was developed for the NECR RSE, as described in the *Removal Site Evaluation Work Plan*. The QAPP was prepared to describe the project requirements for all field and Contract Laboratory Program (CLP) activities and data assessment activities associated with the RSE. 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 report. 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) and the EPA guidance document *Guidance for Quality Assurance Project Plans* (EPA, 2002).

2.2 STATIC GAMMA RADIATION SURVEY OF SURFACE SOILS

Static gamma surveying has been conducted along RWPR twice: first in November 2007 during the SRSE (MWH, 2008) and second during the RWPR RSE in September 2009 and reported here. During the SRSE, forty-six static gamma measurements were collected within the 50-ft buffers (MWH, 2008). Surveying was conducted using a Ludlum 2221 with a 2-by-2-inch sodium iodide (NaI) crystal scintillation detector (Eberline SPA-3) fitted with a lead collimator to minimize the effects of radiation shine, according to the Standard Operation Procedures (SOPs) included in the *Removal Site Evaluation Work Plan* (MWH, 2006) and the *Supplemental Removal Site Evaluation Work Plan* (MWH, 2008). The detector was held eighteen inches above the ground to obtain a one-minute integrated count. The gamma measurements were collected on an 80-foot triangular grid cast on a random origin.

During the RWPR RSE, 30 additional gamma radiation measurements were collected within the roadway and 50-ft buffers at the same locations as the subsurface soil sampling locations (soil borings and test pits) discussed in Section 2.4. These measurements were collected in September 2009 at the beginning of the IRA, before any regrading of RWPR was conducted for the IRA.

The static gamma radiation survey results were converted to Ra-226 concentrations using the regression equation developed from the correlation between the supplemental gamma survey results and co-located surface soil samples analyzed for Ra-226 during the SRSE. The resulting regression analysis showed an R^2 value of 0.92, exceeding the minimum specified value of 0.8 (see Appendix A of the *Supplemental Removal Site Evaluation Report*) and resulted in the following regression equation:

Ra-226 pCi/g = (0.0013 × gamma radiation level, CPM) – 4.5378

The static gamma radiation levels in counts per minute (CPM) from the SRSE were converted to surface soil Ra-226 concentrations using the above equation. The equivalent Ra-226 concentrations provide data of a quality sufficient for field screening.

2.3 SURFACE SOIL SAMPLING

During the SRSE in 2007, seven surface soil samples were collected from within the 50-ft buffers (based on a sampling frequency of 20% of the static gamma measurements collected from the NECR-1 step-out area), as presented in the *Supplemental Removal Site Evaluation Report* (MWH, 2008). The sample locations were randomly selected over a regular grid covering the same area as the gamma survey points and then co-located with the static gamma measurements by moving each randomly selected soil sample location to the closest gamma point. The surface soil samples were collected manually as grab samples from 0 to 0.5 feet bgs.

An additional nine surface soil samples were collected from the test pits within the 50-foot buffers in 2009 as part of the RWPR RSE. The sample locations were randomly selected over the RWPR Study Area within the 50-ft buffers and then co-located with the closest test pits, excluding locations already sampled during the SRSE. The samples were collected as grab samples from the test pits described in the following section.

2.4 SUBSURFACE SOIL SAMPLING

In order to evaluate subsurface soils (greater than 0.5 feet bgs), soil samples were collected in the roadway from boreholes using a drilling rig and in the 50-ft buffers from test pits using an excavator. Sample locations were placed along transects across the roadway and 50-ft buffers that were spaced 200 feet apart. At each transect, three equally spaced locations were selected: one in the roadway and two in the 50-ft buffers on either side. The initial transect (origin) was selected randomly. Sample locations in the 50-ft buffers were placed in the center of each buffer and locations in the roadway were placed on alternating lanes of the road to allow passage of traffic during sampling. Ten soil borings were drilled using a rotary rig fitted with augers. Soil samples were collected using a modified 18-inch California split-spoon sampler in order to maximize sample size. Twenty test pits were advanced with an excavator within the 50-ft buffers. Soil samples were collected manually from the bucket of the excavator. Drilling, excavating and soil sampling was conducted in accordance with the SOPs described in the *Removal Site Evaluation Work Plan*.

Soil samples were collected and retained in plastic bags for gamma scanning and submittal to the laboratory for analysis of Ra-226. Gamma scanning during drilling and excavating was conducted using the same type of meter as for the static gamma radiation surveying (Section 2.2). The detector was mounted vertically with the crystal on top in a six-inch diameter cylinder. A reference sample with known Ra-226 activity (1.9 pCi/g) was placed in a sample container or plastic bag and placed around the probe and a one-minute count was performed. The subsurface soil samples collected from the soil borings or test pits were placed in the same style of sample container and in similar quantity as the reference sample. The counts per minute for the sample were compared to the data for the reference sample as a screening tool to estimate Ra-226 concentrations in soil while drilling or excavating. A single reference sample count was used for each location; at each new location a new reference sample count was used for the comparison. The results of the gamma scanning were used to evaluate whether Ra-226 concentrations exceeded the FSL, and if so, the depths of impacts and to guide sampling locations (e.g., to target the depth at which concentrations were just below the FSL).

Drilling or excavating was continued until equivalent Ra-226 concentrations were estimated to be below the FSL using the gamma meter. A minimum of two samples were collected for laboratory analysis from each borehole using the following protocol:

- Boreholes - an upper soil sample at one foot bgs and a lower sample where equivalent Ra-226 concentrations as per the gamma scan were just below the FSL.

- Test pits - an upper surface soil sample (<0.5 ft bgs) and a lower sample where equivalent Ra-226 concentrations as per the gamma scan were just below the FSL.

At each location, drilling or excavating was advanced until native soils were observed.

2.5 CHEMICAL ANALYSES AND DATA VALIDATION

Soil samples were documented, prepared and packaged for shipment to the laboratory according the SOPs included in the RSE Work Plan (MWH, 2006). The samples were submitted to ALS (formerly Paragon) and analyzed for Radium-226 by gamma spectroscopy (EPA Method 901.1) with a minimum reporting limit of at last 1.0 pCi/g. The analyses were conducted, verified and validated in accordance with the RSE QAPP (MWH, 2006). Data validation included 90% using Level III and 10% using Level IV (EPA Contract Laboratory Program), as per the QAPP.

2.6 STATISTICAL HYPOTHESIS TESTING

Statistical comparisons between datasets, such as Ra-226 concentrations in soils along RWPR versus background concentrations, or between concentrations along RWPR versus concentrations in the NECR-1 step-out area, were conducted using the methods recommended in MARSSIM. Since Ra-226 is present in the background and has a non-normal distribution, the primary statistical test that was used was the WMW Test.

Prior to conducting the WMW test, verification of the assumptions of the test was first conducted. The first assumption is that the samples were collected randomly. Each of the sample locations were placed on a regular grid cast on a random origin. Samples were then collected at regular intervals vertically depending on the sampling method (i.e., test pits versus soil borings), except for the deepest sample at each location (see Section 2.0). The depth of the deepest (last) sample at each location was targeted to be just below the FSL using the gamma screening, which is a biased (non-random) sampling design. However, samples above the deepest sample were collected randomly and overall the data appear to be representative of Ra-226 concentrations in soil. Therefore, for the purposes of this analysis, it is assumed that the randomness assumption is met.

The second assumption is that the data are spatially independent. As discussed in Section 3.2 and observed on Drawing 2, 3 and 4, there appear to be several groupings or clusters of higher Ra-226 concentrations (elevated measurements). Therefore, it does not appear that the assumption of spatial independence is met, which is likely related to higher concentrations along the northern portion of the road, associated with the Quivira Mine.

The third assumption has to do with symmetry. For the Students-t test, it is assumed that the distribution of the data is nearly normal (symmetric and unimodal) and that the variances are similar, whereas this is not a required assumption for the WMW test, which is a non-parametric test (not dependent on normality). The distribution of Ra-226 in both surface and subsurface soils is non-symmetrical and both are skewed to the right (towards higher concentrations), as presented in section 3.0. Using the full datasets, the appropriate statistical test to use as per MARSSIM is the WMW test. The non-parametric Quantile Hypothesis Test can also be used. The Quantile Hypothesis Test is more sensitive to right tails in skewed distributions. The subsurface soils dataset, with apparent outliers removed, is nearly normal, and so both parametric (e.g., Student's-t test) and non-parametric (e.g., WMW and Quantile tests) are applicable.

The fourth assumption is that the sample sizes determined for the tests are sufficient to achieve the data quality objectives (DQOs) set for the Type I (α = 0.05) and Type II (β = 0.10) error rates, and the power of the tests (1-β) to detect adequate remediation is sufficient. If the hypothesis that the residual radioactivity in the Study Area exceeds the release criterion is accepted, there should be reasonable assurance that the test is equally effective in determining that a survey unit has residual contamination less than the $DCGL_W$; otherwise, unnecessary remediation may result. The number of samples required to meet the DQOs was developed as part of the *Removal Site Evaluation Work Plan*. Since the total number of samples collected for this investigation for both surface and subsurface soils exceeded the minimum required as per the DQOs (n = 13), it is assumed that a sufficient number of samples were collected and the WMW test is of sufficient power. However, dividing the datasets into subgroups (e.g., north versus south) results in smaller datasets, and so in these cases the power of the tests is diminished.

In addition to conducting the appropriate hypothesis test, the elevated measurement concentration (EMC) should be performed (MARSSIM, 2000) against each measurement to ensure that none exceed the $DCGL_{EMC}$ + background concentration of 3.0 pCi/g. If any measurement in the Study Area exceeds 3.0 pCi/g, then MARSSIM recommends additional investigation, at least locally, regardless of the outcome of the WMW test.

The WMW test is designed to detect whether or not the activity (Ra-226 concentrations) exceeds the $DCGL_W$. The advantage of the nonparametric WMW test is that it does not assume that the data are normally or log-normally distributed (MARSSIM, 2000). The hypotheses that are used in the WMW, as applied to the RWPR data, are listed below.

For comparison to background:

- Null Hypothesis (H_O): the mean concentration in the Study Area exceeds that in the background reference area by more than the $DCGL_w$.

- Alternative Hypothesis (H_A): the mean concentration in the Study Area exceeds that in the background reference area by less than the $DCGL_W$

For comparison to the adjacent NECR-1 step-out area or between different areas of RWPR:

- Null Hypothesis (H_O): Study Area mean/median is less than or equal to the reference area mean/median.

- Alternative Hypothesis (H_A): Study Area mean/median is greater than the reference area mean/median.

Note that the forms of the null and alternative hypothesis statements included with ProUCL 4.0 are worded slightly different than in the MARSSIM manual, but the results lead to the same conclusions.

The null hypothesis (H_o) is assumed to be true unless the statistical test indicates that it should be rejected in favor of the alternative hypothesis (H_a). It is assumed that any difference between the reference area and the Study Area concentration distribution is due to a shift in the survey unit concentrations to higher values (i.e., due to the presence of residual radioactivity in addition to background). Some or all of the Study Area measurements may be larger than some of the reference area measurements (some by more than the $DCGL_W$ in the case of background comparisons), while still meeting the release criterion. The result of the hypothesis test determines whether or not the survey unit as a whole is deemed to meet the release criterion when comparing to background, while the EMC is used to screen individual measurements (MARSSIM, 2000).

The statistical tests were run using ProUCL 4.0 to evaluate the results for both surface and subsurface soils. The statistical parameters that were used in ProUCL are consistent with the DQOs, as described in the *Removal Site Evaluation Work Plan*. The Confidence Coefficient was set to 95% (alpha = 0.05) and when comparing to background, a Substantial Difference ($DCGL_W$) of 1.24 pCi/g was used.

3.0 FINDINGS AND DISCUSSION

3.1 STATIC GAMMA RADIATION SURVEY RESULTS

Forty-six static gamma radiation measurements were collected in November 2007 during the SRSE (MWH, 2008), all from the 50-foot buffers except one from the middle of the roadway at the north end of the Study Area. The results of these gamma measurements are shown on Drawing 2, *SRSE Static Gamma Measurements*. Gamma measurements were converted to equivalent Ra-226 concentrations using the SRSE regression equation (see Section 2.1). Here is a statistical summary of the results as Ra-226 in pCi/g:

- Quantity 46
- Minimum 2.70
- Maximum 29.95
- Mean 10.15
- Median 6.36
- Standard deviation 7.74
- 75^{th} percentile 13.32

These results indicated that 100% of the static gamma radiation measurements collected within the 50-ft buffers exceeded the NECR FSL of 2.24 pCi/g ($DCGL_W$ + background) and all but four exceeded 3.0 pCi/g ($DCGL_{EMC}$ + background). Statistical hypothesis testing was previously conducted on these measurements from the SRSE using the WMW test (see the February 16, 2009 memorandum in Appendix C). The conclusion of that analysis was that mean/median gamma measurements as Ra-226 (pCi/g) along RWPR were greater than in the step-out area adjacent to RWPR.

Comparison of gamma measurements from the northern versus southern portions of RWPR shows that there are differences in the data distributions along the road, which can be seen on Drawing 2 and in the boxplots included in Appendix C. As seen on the boxplots, the mean and interquantile range of gamma measurements are greater in the northern portion. The highest measurements (above the 75^{th} percentile) are clustered in three general areas:

1. at the northern end of the road near the east-west arroyo and the Quivira Mine;
2. around the small drainage that crosses the central portion of the investigation area; and
3. at the very southern end of the road there was one measurement above the 75^{th} percentile.

Six of the nine highest readings occurred in a cluster along the northern 500 feet of the road before it crosses the east-west arroyo (see Drawing 2). The gamma level in the one measurement from the roadway was 11.1 pCi/g. The preliminary data from the Weston survey (December 2009) also showed elevated activity levels on and adjacent to RWPR north of the east-west arroyo adjacent to the Quivira Mine.

Thirty more static gamma radiation measurements were collected during the RWPR RSE in September 2009 over the same general area as the SRSE along RWPR, and included 10 measurements in the roadway, as shown on Drawing 3, *RWPR RSE Static Gamma Measurements*. As during the SRSE, the gamma measurements were converted to equivalent Ra-226 concentrations using the SRSE regression equation (see Section 2.1). Here is a statistical summary of the results as Ra-226 in pCi/g:

- Quantity 30
- Mean 11.60
- Median 8.31
- Standard deviation 9.09

- Minimum 3.42
- Maximum 40.55
- 75th percentile 12.57

These results indicated that 100% of the gamma measurements exceeded the FSL and 3.0 pCi/g ($DCGL_{EMC}$), including the 10 measurements within the roadway. The distribution of gamma measurements along RWPR is similar to what was observed in the SRSE gamma survey, discussed above. Gamma measurements were only collected from along RWPR during the RWPR RSE in 2009, and so a comparison of these gamma measurements to measurements from the step-out area (SRSE) was not conducted. However, the mean and distribution of gamma measurements along RWPR from the RWPR RSE (2009) are similar to those from the SRSE (2007), as seen on Drawings 2 and 3, and the boxplots included in Appendix C. Therefore, these results were consistent with the previous conclusion that the mean/median gamma measurements as Ra-226 (pCi/g) along RWPR were greater than in the step-out area adjacent to RWPR prior to the IRA (see the February 16, 2009 in Appendix C).

The distributions of gamma measurements from the northern versus southern portions of RWPR were also consistent with measurements from the SRSE, and indicated that gamma levels are generally higher in the northern portion. This can be seen on Drawing 3 and the boxplots in Appendix C. Of the eight measurements that exceeded the 75th percentile (12.57 pCi/g), six were from the northern end of the road and two were adjacent to the drainage that crosses the central portion of the road (see Drawing 3). Only one measurement was collected from the roadway at the very northern end of the road nearest to the Quivira Mine; this measurement also exceeded the 75th percentile.

Comparing the gamma measurements from the 50-ft buffers to those from the roadway reveals that those from the 50-ft buffers appear to be generally higher and with a greater range of values than those from the roadway. Concentrations in the 50-ft buffers ranged from 3.42 to 40.55 pCi/g (mean = 13.4), while in the roadway they ranged from 3.7 to 18.0 pCi/g (mean = 7.9).

3.2 SURFACE AND SUBSURFACE SOIL SAMPLE RESULTS

3.2.1 Soil Analytical and Lithologic Data Summary

Seventy-six surface (<0.5 feet bgs) and subsurface (1 to 6 feet bgs) soil samples were collected from the test pits and soil borings along RWPR, as shown on Drawing 4, *Soil Analytical Results*. The soils that were observed during drilling within the roadway (SB-1 though SB-10) were described by a geologist and recorded on boring logs, which are included in Appendix A. Soils appeared relatively similar throughout, consisting primarily of fine to medium grained sand and silty sand with some gravel. At each location, there was evidence of layering, typically with more gravel in the top layer and more fine silty sand in the lower layer(s). Soils within the 50-ft buffers were similar, consisting primarily of fine grained sand, with some silt and gravel. The upper one foot or so consisted of a gravely sand at some locations, and some areas contained silty sand. Native material consisting of very dense silty sand was encountered at 5.5 feet in soil boring SB-05 and possibly at 2.5 feet in SB-07. Bedrock was encountered at 2.5 ft in TP-22; bedrock was not encountered in any of the soil borings.

A gamma meter was used during drilling and excavation to screen the soils every foot (see Section 2.3). The results of both the gamma screening measurements and the soil analytical results are included in Table 2, *Soil Analytical and Gamma Screening Results*, and the analytical results are shown on Drawing 4. The analytical results were validated in accordance with the RSE Work Plan (see Section 2.4). The results of the data validation indicated that the data are acceptable and useable for their intended purpose. Here is a statistical summary of the Ra-226 concentrations (pCi/g) for all soil samples:

Parameter	All Samples	Surface	Subsurface	RSE Background
Quantity	76	16	60	25
Minimum	0.75	2.38	0.75	0.60
Maximum	69.0	69.0	30.8	1.30
Mean	5.33	18.04	1.95	1.04
Median	1.30	14.5	1.24	1.00
Standard deviation	10.72	19.20	1.40	1.20
75th Percentile	2.76	17.25	3.88	0.18

Eighteen of the analytical results were flagged as estimated (J+) and considered potentially biased high because the density of the sample was not within fifteen percent of the standard used to calibrate the instrument (see the Validation Report in Appendix B). All of those flagged J+ were results less than the FSL, except one just above the FSL.

The statistical distribution of the Ra-226 concentrations in soil can be seen in the histogram included in Appendix C. The histogram shows that the distribution of Ra-226 in soil is non-normal and skewed to the right toward higher concentrations.

3.2.2 Surface Soil Data Summary

Sixteen surface soil samples were collected from the 50-ft buffers during the SRSE and the RWPR RSE (see Drawing 4). Concentrations of Ra-226 were greater than the NECR FSL at 100% of the locations and all but two exceeded 3.0 pCi/g, as can be seen on the histogram and boxplots included in Appendix C and Table 1. Concentrations ranged from 2.4 to 66.6 pCi/g with a mean of 18.0 pCi/g (see above).

A comparison of Ra-226 concentrations in surface soil from the 50-ft buffers along RWPR (RWPR RSE, 2009) versus the step-out area (SRSE, 2007) reveals that their distributions are different. Statistical hypothesis testing was conducted on these two datasets using the WMW Test (ProUCL 4.0). The conclusion of that analysis was that the mean/median concentrations of Ra-226 (pCi/g) in surface soil along RWPR were greater than in the step-out area adjacent to RWPR (see ProUCL results in Appendix C). Additionally, these two datasets were compared using both the Student's-t Test and the Quantile Hypothesis Test, using parameters consistent with the DQOs. Both tests reached the same conclusion that concentrations were higher along RWPR than they were in the RSE step-out area, prior to the IRA (see Appendix C).

The distribution of Ra-226 concentrations along RWPR (south to north) appears similar to the pattern of gamma measurements (see Drawing 4 and the boxplots in Appendix C). Of those that exceeded the 75th percentile, two were adjacent to the east-west arroyo at the northern end of RWPR, one was adjacent to the small drainage that crosses the central portion of the area, and one was at the southern end of the area on the east side near Highway 566. Two of the three highest concentrations were the closest to the Quivira Mine (see Drawing 4).

3.2.3 Subsurface Soil Data Summary

Sixty subsurface soil samples were collected from along RWPR, 20 from the roadway (soil borings) and 40 from the 50-ft buffers (test pits) during the RWPR RSE (2009), as shown on Drawing 4. Ra-226 concentrations were less than the FSL in 100% of the 20 samples collected in the roadway (soil boring samples from 1 to 6 ft bgs), as shown on the histogram and boxplots in Appendix C and on Table 1. Concentrations from within the roadway ranged from 0.8 to 2.1 pCi/g, with a mean of 1.3 pCi/g, all below the FSL.

Within the 50-ft buffers, six of the 40 samples contained Ra-226 greater than the FSL; (four of them greater than 3.0 pCi/g), as shown in Table 1 and on Drawing 4. Concentrations ranged from 0.75 to

30.8 pCi/g, with a mean of 2.28 pCi/g. The highest concentrations (i.e., those exceeding the FSL) in subsurface soil along RWPR were all located in the northern portion of the Study Area, closest to the Quivira Mine, consistent with the gamma measurements and surface soil measurements; as is clearly seen on the boxplots included in Appendix C. The six samples that exceeded the FSL came from depths of 1 to 3 ft bgs; three (4.3 to 30.8 pCi/g) from two test pits near the east-west arroyo (east side of RWPR), and the other three (2.5 to 3.1 pCi/g) from two test pits south of the home sites driveway (west side of RWPR). The highest concentration (30.8 pCi/g) was observed at 1.0 feet bgs in TP-30, the northeastern-most sample location for the Study Area (closest to the Quivira Mine). Ra-226 concentrations were all below the FSL in other portions of the Study Area.

4.0 SUMMARY AND CONCLUSIONS

The results of the RSE conducted in the Study Area along RWPR indicated the following:

- Surface static gamma measurements collected during both the SRSE and the RWPR RSE, reported as equivalent Ra-226 concentrations using the SRSE correlation, **exceeded** the FSL at 100% of the locations within the 50-ft buffers and the roadway; all but four exceeded 3.0 pCi/g.

- Surface soil Ra-226 concentrations were **greater than** the FSL at 100% of the locations within the 50-ft buffers;

- Subsurface soil Ra-226 concentrations were **less than** the FSL at 100% of the locations (1 to 6 ft bgs) within the roadway;

- Subsurface soil Ra-226 concentrations were **less than** the FSL at all locations within the 50-ft buffers, except four test pits located along the northern portion of RWPR within approximately 600 feet of the east-west arroyo crossing to the Quivira Mine.

These results do not change the conclusions of the February 2009 statistical evaluation of the previous RSE gamma survey and surface data sets. The results of the evaluation indicated that the mean/median of the data for both the southern and northern sections of RWPR are statistically higher than adjacent areas immediately to the west in the NECR-1 step-out area. Overall, the results offer further indication that RWPR and the immediate buffer areas on either side of the roadway were likely impacted by historic use of the road by the operators of the Quivira Mine; impacts within the Study area may also have been impacted by wind-or water-borne transport from the Quivira Mine. Due to the proximity of NECR to the southern portion of RWPR and based on local drainage patterns in this area, past operations at the NECR site could also have caused some impact along the southern portion of the Study Area in addition to the impacts from past use of RWPR as a haul road for the Quivira Mine. Impacts from NECR are considered unlikely to extend beyond the small drainage that crosses the central portion of the Study Area. Impacts along the northern portion of the Study Area are likely associated with the Quivira Mine due to the proximity of the mine, past use of RWPR as a haul road, and the potential for ongoing road use and maintenance to transport materials from the north side of the east-west arroyo into the Study Area.

Based on the results of the Weston investigation and the RWPR RSE results from the northern portion of RWPR, further investigation of the continuing impacts to RWPR from the Quivira Mine is warranted. Unless the continuing impacts to RWPR are addressed, any removal action conducted on RWPR is likely to only be temporarily effective.

5.0 REFERENCES

AVM, 2009. Technical Memorandum*, Results of Correlation Study Between Gamma Radiation Level and Soil Ra-226 Concentration IRA Excavation Control.*

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

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

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

MWH, 2007. Supplemental Removal Site Evaluation Report, Northeast Church Rock Mine Site.

MWH, 2006a. *Northeast Church Rock Removal Site Evaluation Work Plan.*

MWH, 2006b. *Results of Background and Radium Correlation Sampling Northeast Church Rock Mine Site Technical Memorandum.*