- Calculate an Upper Tolerance Limit (UTL) on the ranges of background data.

The first option is to use two times the average background value. This is the approach used by the NNEPA in their Radiological Scoping Survey Summary Report for the Old Church Rock Mine Site (NNEPA, 2007). Following guidance from the EPA's Hazard Ranking System Guidance Manual, NNEPA measured gamma values at 24 background locations, resulting in an average gamma value of 13,800 cpm. The resulting screening level (27,600 cpm, or two times background) defines the lower boundary of *observed contamination* as defined by the EPA Guidance Manual. Based on measured gamma values at 6,483 background locations (imparting a high degree of statistical confidence in the results) during the course of the current study, the average gamma value of 15,535 cpm (Table 1) would result in an *observed contamination* screening level of 31,070 cpm. While this method is useful in determining where contamination exists, it may not have the sensitivity required to serve the purposes of this study, which requires an understanding of the underlying processes driving off-site transport.

A somewhat more sensitive option for selecting a background value to screen Site-impacted areas from unimpacted areas is to choose the maximum value in the background data set (Table 1). The logic underlying this method assumes that if a maximum gamma value of 20,191 cpm (the highest observed value for this study) could occur in natural background, the same value occurring at the Site is unlikely to represent impact from OCRM. While this method is useful for screening, it provides no information on how often the value of 20,191 cpm was observed or if it was an anomalously high value.

An even more sensitive and conservative approach that is widely accepted by the regulatory community, and based on sound statistical methods, is the UTL approach (a statistical method that incorporates information to answer the question of whether or not the high value is an anomaly. For these reasons, the UTL approach was used to provide a screening value for this Site Characterization.

UTLs are designed to incorporate 95 percent of the background data at a 95 percent level of confidence. The EPA (1992) describes the procedures for calculating UTLs and contains the following quote explaining their use:

> *"In detection monitoring, the compliance point samples are assumed to come from the same distribution as the background values until significant evidence of contamination can be shown. To test this hypothesis, a 95 percent coverage Tolerance interval can be constructed on the background data. The background data should first be tested to check the distributional assumptions. Once the interval is constructed, each compliance sample is compared to the upper Tolerance limit. If any compliance point sample exceeds the limit, the well from which it was drawn is judged to have significant*

evidence of contamination (note that when testing a large number of samples, the nature of a Tolerance interval practically ensures that a few measurements will be above the upper Tolerance limit, even when no contamination has occurred)."

The OCRM Site gamma survey data set is large and, therefore, the screening value derived using the UTL approach will likely over predict the existence of potential OCRM impacts. However, the purpose of this study is not to set cleanup levels but to delineate potential off-site impacts that may have occurred and understand the mechanisms that may have caused off-site contamination. The UTL approach provides a conservative guide to visually estimate the maximum possible extent of surface impacts from OCRM.

4.2 GPS-Based Site Gamma Survey

The following table summarizes the results of the Site gamma survey. Figures depicting the survey results are included in Figure 3 and in the gamma survey report (Appendix A).

Table 2: Gross Gamma Radiation Survey Data Statistics

Survey	Number of Records	Maximum Reading	Minimum Reading
Gross Gamma Radiation (cpm)	100,269	522,983	8,106
External Exposure Rate (μR/hr)	100,269	318.3	9.38
Ra-226 Concentration (pCi/g)	100,269	257.82	0.38

Appendix A of this report describes the methods used to develop correlations between gamma readings and exposure rates and gamma readings and Ra-226 in picocuries per gram (pCi/g). See Appendix A, Figures 3-1 and 4-1, respectively, for graphs showing the linear correlations between gamma cpm and exposure rate in uR/h and gamma cpm and Ra-226 in pCi/g. Each graph includes an equation describing the linear correlation which allows conversion of gamma readings to either exposure rates or Ra-226 in pCi/g.

Figure 3 reveals that potential offsite impacts (>17,429 cpm, the UTL) from the OCRM Site are relatively minor. With the exception of two small areas of discrete elevated gamma levels, the gamma readings outlining potential offsite impacts are less than 30,000 cpm, or less than 1.7 times the background UTL. A gamma reading of 30,000 cpm is approximately equivalent to 9.0 pCi/g Ra-226 or an exposure rate of 22.5 μR/h.

To put these values in context, the NRC Occupational Dose Limit for Nuclear Industry workers is 5,000 millirems (mrems) per year. In air, one Roentgen (R) is approximately equal to one roentgen equivalent man (rem). Therefore, there are approximately 0.001

mrem to one µR (Princeton University, 2007) so 22.5 µR/h is approximately equivalent to an exposure rate of 0.0225 mrem per hour. Assuming that a person had a full-time job (2,080 hours/year) that required standing on a spot with a gamma reading of 30,000 cpm, their yearly occupational exposure would amount to 46.8 mrem or two orders of magnitude below the NRC Occupational Dose Limit of 5,000 mrem per year. Further, this example of a person who stands on a 30,000 cpm gamma anomaly for eight hours every day, five days a week, for a full year results in an exposure that is less than half of the NRC Dose Limit for Members of the General Public of 100 mrem per year (10 CFR 20.1301).

4.2.1 Surface Soil Sampling

The results of the soil sampling were used to correlate Ra-226 in soil with the gamma count rate. After this correlation was made, approximate Ra-226 concentrations could be calculated from each gamma count recorded in the survey. Soil sampling results are summarized in Table 4 below. The laboratory analytical reports are located in Appendix C of the Gross Gamma Radiation Survey Report (Appendix A). Figure A-4 of Appendix A shows the soil sample locations and the Ra-226 concentrations across the Site.

Table 3: Radionuclide Concentrations in Soil Samples

Sample ID	Coordinates in NAD 83 New Mexico West		U-nat (pCi/g)	Ra-226 (pCi/g)	NaI Detector 1-Minute Scaler Count (cpm)
	Northing (m)	Easting (m)			
SID-01	512,535	763,868	2.03	1.45	15,754
SID-06	512,743	764,825	9.48	15.3	50,361
SID-07	512,533	764,447	19.63	30.1	58,606
SID-08	512,701	765,117	2.64	1.36	15,488
SID-09	512,672	764,651	6.03	3.04	25,109
SID-12*	512,774	764,825	21.33	35.25	88,644
SID-14*	512,051	763,943	10.15	21.7	38,263
SID-20	512,986	765,069	23.7	32.5	58,432
SID-21	512,387	764,251	1.76	1.27	13,322
SID-23	512,767	764,394	1.49	1.14	15,249
SID-25	512,203	764,067	14.22	14.6	19,249
SID-26	512,409	764,397	37.24	46.7	105,214
SID-28	512,508	764,638	11.51	17.6	76,587

* Duplicate sample concentrations are averaged

4.2.2 Distribution of Gamma Readings above the UTL

The surface gamma scan identified areas outside of the fenced OCRM facility that have gamma values above the background UTL (<17,429 cpm) (Figure 3). As will be explained below, one low-intensity, linear gamma high that is elongated to the southwest of the Site appears to be related to waterborne transport from the Site during early mine dewatering. Two areas of discrete elevated gamma levels occur outside of the OCRM facility, one directly north of the Site and one directly south (Figure 3), that appear related to historic operations and will be explained in more detail below. Both areas of discrete elevated gamma levels are associated with larger, low-intensity gamma anomalies that appear to be related to the same historic Site operations. Finally, an area of patchy low-intensity gamma readings west of the fenced OCRM boundary may also relate to historic Site operations.

A prominent linear gamma high south of the current alluvial channel, originating at the southwest boundary of the Site and extending to the southwest, apparently represents a former channel in the alluvium that was active during the first phase of mining. The bulk of potential waterborne surface impacts from the OCRM Site appear to be confined to this channel-like feature.

A 1962 aerial photograph (Figure 10) depicts the OCRM during early active mining, primarily by Phillips, that occurred during the years 1960 to 1963. The current highway (NM 566) south of the Site was not present in 1962 but has been overlain with the current location of the highway on Figure 10 for reference. The 1962 photo shows that the incised channel and the currently active channel downgradient of that were present in 1962. The 1962 photo also shows the area of active mine discharge originating at a discharge point 600-800 feet south of the incised channel that corresponds closely to the linear gamma anomaly, and not to the currently active incised channel.

To date, there have been two distinct periods of active mining and dewatering at OCRM; a period from1960 to 1963, mostly operated by Phillips, and a period from1979 to 1983, which was operated by UNC. During the period from 1960 to 1963, no Federal or State discharge permits were required and operators typically discharged untreated mine water to the surface. Untreated mine water carries radionuclides, primarily radium, and other metals in solution. Radium tends to be highly attenuated when it seeps into the subsurface, concentrating in the first few inches or feet of the soil column, which may explain the gamma signature in the area of 1960 to 1963 mine discharge.

When UNC began mining in 1979, NPDES discharge permits were required and discharge water was treated for radium in settling ponds (Figure 2), and then it was run through an ion exchange facility as further treatment for uranium and other metals. Water was then discharged to the incised arroyo directly west of the ion exchange facility (Figure 2), which feeds the currently active channel that also provides modern drainage from the Site. Treatment of mine water prior to discharge provides a logical explanation as to why the currently active channel displays consistently low gamma readings even though it carried mine discharge water during the 1979 to 1983 period. In other words, while there appears to be evidence of waterborne contamination resulting from the first period of mining there is no evidence of waterborne contamination resulting from the second period of mining. Moreover, the lack of an elevated gamma signature in the channel demonstrates that there has been no recent or current erosion of soils from the site into the watercourse.

The area of discrete elevated gamma levels directly south of the OCRM Site and south of NM Highway 566 can be explained by examination of the 1962 aerial photograph with the future location of NM 566 overlain. In 1962, the area of the ore pile extended considerably south of present day NM 566 (Figure 10), and it is apparent that the present day highway was built directly through the southern part of the ore pile without removing ore material prior to construction.

Assuming that the highway was built from south to north, construction of the highway is also a likely explanation for the low-intensity gamma anomaly extending from the ore pile and running along the south side of NM 566 to the northeast, and the low-intensity gamma anomaly extending from the main ore pile and running northeast along the north side of NM 566. Construction beginning southwest of the ore pile and incorporating ore material into the roadbed as it moved to the northeast would produce the low-intensity gamma signature seen in this study (Figure 3).

The low-intensity gamma anomalies appear to extend beyond the study area to the northeast (Figure 3) and may suggest that wind transport in that direction could have been an off-site transport mechanism. However, this study has yielded no evidence that wind has played an important role in transport of materials off Site. Dust storms observed during high winds result from transport of fine sand from sand dunes that occur up wind of the OCRM. Sand in these dunes is slowly migrating toward the OCRM Site from sources to the southeast that are unrelated to the ore material found at the OCRM Site. Currently, ore materials at the OCRM Site do not appear to be mobile, possibly due to low, flat relief and encroachment of vegetation in the ore pad area, and the presence of an armored soil surface (see below).

The low-intensity gamma anomalies along NM 566 do appear to extend from the Site in the direction of the prevailing wind and, certainly in the 1962 aerial photograph (Figure 10), ore materials appear to be fresh and unconsolidated, possibly with some material that could be transported by wind. However, by 1973 (Figure 11), ore materials appear to be approaching geomorphic stability, plant material has grown in many areas of the pile that were bare in

1962, and any ore material subject to transport by wind has likely been depleted, leaving only non-transportable sediments behind. The 2005 photograph (Figure 2) shows conditions similar those in 1973, and recent site visits indicate that the ore materials present a low relief, armored surface (a soil crust has formed due to micro-organisms in soil and the high clay content present in the ore materials) that has been stabilized by plant growth, suggesting that wind transport is not an important transport mechanism. The construction of NM 566, which also parallels the direction of the prevailing wind, appears to be the most likely explanation of the distribution of historic mine material.

More gamma data may have to be collected to the northeast to determine if wind has played any role in historic off-site transport. If the anomalies along NM 566 continue in the direction of the prevailing wind past the point where the highway turns more easterly, the argument for wind as a transport mechanism is supported. Note however, that the residences at the base of the cliffs to the northeast have been surveyed and no evidence of contamination was found. This is important because the base of the cliffs is an area of change in wind velocity, and therefore a place of wind deposition. The finding of no contamination at these locations lends support to a conclusion that wind transport has not been a mechanism.

The area of discrete elevated gamma levels to the north of the Site and patchy areas of low-intensity gamma anomaly that occur north of the current active channel and west of the Site (Figure 3) are unlikely to be related to waterborne transport from the Site. They are too dispersed and there is no obvious topographic channel connecting them to the Site. Further, they are distributed in areas opposite or orthogonal to prevailing wind directions and are unlikely to be related to windborne transport from the Site.

It is known that exploration boreholes were advanced to the Westwater Canyon prior to and during both phases of mining, each with associated mud pit and cutting material. As with early dewatering, the early phase (1958-1962) of exploration was almost entirely unregulated and pit closure, plugging, and abandonment practices are unknown. By the second phase of mining, pit closures and plugging and abandonment methods were regulated by the NMEMNRD. The location of exploration holes during the first phase of exploration is currently unknown. The location of second phase exploration holes is known (Figure 12), but few are in areas to the north and west of the Site. Gamma anomalies to the north and west of the incised channel and current active channel may potentially be related to these Site activities.

The northern area of discrete elevated gamma levels and low-intensity gamma anomalies to the west are likely to be related to Site activity and they may be related to early exploration boreholes, but currently available information does not allow for a direct explanation of their distribution. Further, various man-made features of unknown origin are visible in that area on aerial photographs (Figure 2) and it is not clear how they may have influenced the gamma distribution.

4.3 Downgradient Soil Pit Screening

Twelve soil pits were hand-dug to a depth of 4 feet below the dune soil interface. The pits were located downgradient of the fenced mine area. Each pit was screened at the ground surface prior to digging, at the dune soil interface, and at each foot interval. In addition to screening, the soil was described at each depth interval. The results of the soil pit screening are presented in Figure 4.

Figure 5 shows the location of downgradient soil pits with respect to results of the surface gamma scan. Four of the 12 soil pits have gamma values that exceed the maximum observed in background and those same 4 pits had gamma values above the UTL. The highest gamma value observed in any of the soil pits was 29,667 cpm which, based on the correlation study presented in Appendix A, corresponds to a Ra-226 concentration of 8.8 pCi/g which is below the NRC cleanup standard of 15 pCi/g for Ra-226 below 15 cm (10 CFR 40, Appendix A).

The distribution of pits with values greater than the UTL appears to have some correlation with the gamma surface scan. The two pits with elevated values that are closest to the Site appear to be associated with the channel-like linear gamma signature south of the current main channel of the wash. This channel-like linear gamma signature correlates to the active mine discharge visible on the 1962 aerial photograph (Section 4.2.2, Figure 10). The two soil pits with elevated values that are farther from the Site may be in the areas of isolated higher gamma readings that were identified in that general vicinity during the surface scan (Figure 3).

The two soil pits associated with the channel like gamma signature can be explained by infiltration of discharged mine water from the first phase of mining and adsorption and precipitation on alluvial materials. As explained above, radium tends to be highly attenuated when it seeps into the subsurface, concentrating in the first few inches or feet of the soil column.

The two soil pits that are farther from the Site are not connected to the Site by any obvious channel and they are well north of the current channel that has been geomorphically stable since at least 1973 (see Section 2.2.2). As described above, these soil pits may be related to patchy surface gamma anomalies that could be related to unknown Site operations such as exploration.

4.4 Paleochannel and Groundwater Determination

Four direct-push borings were advanced in the locations shown on Figure 2. The borings were advanced through the alluvium to the Mancos Shale or to a depth where the Geoprobe met refusal in low permeability sediments. Though some of the sediments were moist to wet, none were observed to be saturated; therefore, no groundwater was encountered. The soil in each 4-foot core sleeve was described and scanned using a gamma ratemeter/scaler (Appendix C). The direct-push soil boring gamma scan yielded no gamma measurement above the UTL. Thus, soil borings provided no evidence of migration of OCRM Site impacts to deeper soils and no evidence of groundwater.

Table 4: Soil Boring Exposure and Gamma Scan Readings

Depth (ft. bgs)	CRD-1		CDC-1		CDB-1		CDA-1	
	µR/hr	CPM	µR/hr	CPM	µR/hr	CPM	µR/hr	CPM
0-4	ND	ND	14	13924	11	13350	14	13553
4-8	12	15845	13	16163	11	14204	ND	ND
8-12	12-14	16502	13	16042	11	13125	ND	ND
12-16	13	17076	ND	ND	11	13359	13	16531
16-20	14	16425	ND	ND	11	13326	13	16608
20-24	14	15797	13	16129	11	13755	13	16187
24-28	13	17694	13	17687	11	13388	13	16095
28-32	13-14	16142	13	16580	11	13211	13	16001
32-36	13-15	16523	13	14971	11	14382	13	15586
36-40	14	16548	13	15232	11	14717	13	15572
40-44	15	16436	13	16891	11	13473	13	16757
44-48	14	16240	13	16346	11	13203	13	15749
48-52	ND	ND	13	16688	ND	ND	ND	ND

ND = No data available due to lost contents in core sleeve.

4.5 Residential Survey

NNEPA requested that INTERA perform residential gamma surveys on three residential areas located within Section 17 (Figure 2). Structures surveyed at each residential area were houses, hogans, storage sheds, and other enclosed structures that were used for purposes other than storing firewood. Table 5 is a summary of the total counts per minute and approximate Ra-226 concentrations at each residential area.

Table 5: Summary of Residential Gamma Survey

Site ID	Number of Readings	Average Reading (cpm)	Average Ra-226 (pCi/g)	Standard Deviation (cpm)	Maximum Reading (cpm)	Minimum Reading (cpm)	UTL (cpm)
Residential Area 1	68	14,605	3.7	797	17,247	12,983	17,782
Residential Area 2	80	15,361	4.0	777	16,659	10,175	17,782
Residential Area 3	121	13,293	3.0	1,042	15,774	10,220	17,782

Figures 6, 7, and 8 show each of the three residential areas with survey lines and individual gamma count rates plotted for the structures surveyed. Residential Area 1, located to the far west of the Site, was developed sometime after 1978 and prior to 1996. Residential Area 2, located just west of the Site was developed after 1962 and prior to 1973, although the configuration of buildings on that property has changed since the 1978 aerial photo. Residential Area 3, located to the southeast of the Site was developed sometime after 1978 and prior to 1996. Please see Figures 11, 13, and 14 to compare development of these residential areas.

The gamma readings collected during the residential survey are consistent with the background gamma survey. Additionally, there were no gamma counts that exceeded the UTL of 17,429 cpm. This data confirms that of the areas surveyed, there are no impacts from the OCRM Site onto adjacent residences.

In addition to the residential gamma survey, INTERA also performed an alpha frisk on equipment that was removed from the OCRM facility and now resides at these residential areas. The items frisked were at Residential Areas 1 and 3 and consisted of 2-inch pipes, 8-inch pipes, one large tank, one railroad tie, one metal I-beam, a metal table, and a second large tank used for water storage immediately after the release at Northeast Church Rock Mine. The Alpha meter read 0 cpm for all items except the metal table and the water storage tank, which were both located at Residential Area 3. These items read 100 cpm (680 dpm) and 60 cpm (408 dpm), respectively, which is well below the NRC mandated release criteria average of 5,000 decays per minute/100 square centimeters (cm^2) and maximum release criteria of 15,000 cpm/100 cm^2 (HRI, 1997).

5.0 CONCLUSIONS

This Site Characterization investigated the potential for transport of constituents from the fenced OCRM Site by a number of pathways including surface water, groundwater, and wind. The main conclusions drawn from this investigation are:

- Off-site mine-related impacts are minor.
- There is evidence of historic surface water transport to the southeast.
- There is evidence of transport to the northeast during road construction.
- Historic wind transport cannot be ruled out with current data but there is no evidence that it is occurring today.
- Gamma anomalies north and west of the Site may be related to historic Site activity.
- There is no evidence of groundwater transport.
- Additional residential surveys provided no evidence of impact.

Further discussion of these conclusions is provided in the following subsections.

5.1 Off-Site Mine-Related Impact Minor

The background survey requested by NNEPA resulted in collection of over 6,000 gamma readings at individual survey points. This number of points is sufficient to perform a statistical analysis of background gamma values with a high level of confidence. Site gamma readings were compared to the background UTL derived from that statistical analysis, indicating that, with the exception of two areas of discrete elevated gamma levels outside of the fenced facility boundary, off-site mine-related impacts are relatively minor.

Although use of a Tolerance Interval practically ensures that some measurements will be above the UTL even when no contamination has occurred, the result is a highly-sensitive screening for Site impacts. A comparison of the background UTL with the Site and surrounding area gamma survey indicated that off-site impacts are largely confined to surface gamma readings below 30,000 cpm. The measured correlation between gamma values and exposure rates described in Appendix A indicates that a gamma value of 30,000 cpm corresponds to an exposure rate of 22.5 μR/h or approximately to a yearly occupational exposure of 46.8 mrem. This is two orders of magnitude below the NRC Occupational Exposure Limit of 5,000 mrem/year. Further, this example of a person who stands on a 30,000 cpm gamma anomaly for 8 hours every day, five days a week, for a full year results in an exposure that is less than half of the 100 μR/h NRC Dose Limit for Members of the General Public (10 CFR 20.1301).

5.2 Evidence of Transport by Surface Water

The GPS-based gamma survey delineated areas outside of the fenced OCRM Site that have gamma values above the background UTL. One primary linear gamma anomaly that is elongated to the southwest of the Site is potentially related to waterborne transport from the Site during early mine dewatering. Examination of historical aerial photographs indicates that the gamma anomaly is coincident with a water course cased by discharge of what was likely raw untreated mine water during the period from 1960 to 1963. There is no evidence of contamination in the current channel (discharge point for the 1979 to 1983 phase of mining) from the Site and no modern off-site contamination. In addition, the entire south end of the OCRM is presently bermed so there can be no modern drainage into that 1960 to 1963 channel.

5.3 Evidence of Transport During Road Construction

The gamma survey revealed an area of discrete elevated gamma levels that exist south of the Site and south of NM 566. Further, low-intensity gamma anomalies exist on either side of NM 566 extending northeast from that area of discrete elevated gamma levels and the main ore pile. Examination of the 1963 aerial photograph overlain with the location of current NM 566 indicates that the highway was built across the southern end of the ore pile as it existed in 1963. The shape of the area of discrete elevated gamma levels closely resembles the shape of the southern portion of the 1962 ore pile and the low-intensity anomalies along the highway to the northeast are consistent with road construction using ore materials.

5.4 Wind Transport Cannot Be Ruled Out With Current Data

Low-intensity gamma anomalies appear to extend off of the study area to the northeast. They may be due entirely to construction of the State Highway using ore materials, but transport by prevailing winds cannot completely be ruled out. Present day ore materials present a low relief, armored surface that has been stabilized by plant growth, suggesting that wind transport is not currently an important transport mechanism. Further, historical aerial photographs depict a trend toward geomorphic stability of ore piles with time and residences that were surveyed downwind of the Site (on the adjacent Section 9, approximately 1,300 feet from the northern boundary of the study area) exhibited no evidence of contamination (Judy Moore of Iinà Bà, Personal Communication, 2009), suggesting that windborne transport may be minor if at all. Nevertheless, additional data would have to be collected to rule out the possibility of windborne transport and verify that gamma anomalies are only associated with construction of the highway.

5.5 Gamma Anomalies North and West of the Site

The northern area of discrete elevated gamma levels and patchy low-intensity gamma anomalies to the west are likely to be related to Site activity and they may be related to early exploration bore holes but currently available information does not allow for a direct explanation of their distribution. Additional historical information and possibly confirmatory scanning may be necessary to fully characterize these locations.

5.6 No Evidence of Groundwater Transport

The direct-push soil borings advanced to screen for the presence of groundwater in the alluvial materials encountered numerous clay lenses at various depths. All borings were advanced to refusal and no boring encountered groundwater leading to the conclusion that the alluvial materials do not contain groundwater near the OCRM Site.

5.7 No Evidence of Residential Impact

Additional scanning of three residences as requested by NNEPA resulted in gamma readings that were all below the UTL. The preliminary results from the Iinà Bà survey also conclude that there have been no impacts to residential areas from the OCRM Site (Moore, 2009).

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