

**Final Background Characterization Report**

**Gas Hills, Wyoming Site**

**FINAL**

**Umetco Minerals Corporation**  
2754 Compass Drive, Suite 280  
Grand Junction, Colorado 81506

**September 2000**

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## Acronyms and Abbreviations

<u>Acronym</u>	<u>Definition</u>
avg.	average
AGTI	Above-Grade Tailings Impoundment
AML	State of Wyoming Abandoned Mine Lands (program)
cm	centimeters
GM	geometric mean
GPS	Global Positioning System
IQR	Interquartile Range
n	sample number
NRC	U. S. Nuclear Regulatory Commission
pCi/g	picocuries per gram
PIC	Pressurized Ionization Chamber
Ra-226	Radium-226
s.d.	standard deviation
SMI	Shepherd Miller, Inc.
S-W	Site-Wide (e.g., referring to the data set used to characterize surrounding soils)
Th-230	Thorium-230
UCC	Union Carbide Corporation
UCL	upper confidence limit
Umetco	Umetco Minerals Corporation
U-nat	Natural Uranium
wtd. avg.	weighted average (e.g., of 0-5 cm and 5-15 cm sample results)

## 1.0 INTRODUCTION

This report presents the final characterization of background radionuclide concentrations in soil at the Umetco Minerals Corporation (Umetco) Gas Hills, Wyoming site. The representative background levels derived herein for radium-226 (Ra-226), thorium-230 (Th-230), and natural uranium (U-nat) will form the basis for the soil cleanup criteria to be applied in subsequent site cleanup and final status survey efforts.

### 1.1 Background

Since 1995, Umetco has conducted several scoping and background characterization investigations at and surrounding the Gas Hills site. The combined investigation results yield an extensive and spatially comprehensive background data set. Shepherd Miller, Inc. (SMI) prepared the most recent background conditions evaluation entitled *Background Radionuclide Concentrations at the Umetco Gas Hills Site* dated March 1999. Although extensive in terms of both the sampling scope as well as the analytical treatment, the data presentation and conclusions presented in this report were ambiguous. Additionally, some samples exhibiting apparent windblown impacts were erroneously included in the background database. Given these factors, this report was prepared to re-examine the validity of previous background sample results and, based on that assessment, define an updated, integrated final background data set.

### 1.2 Report Objectives and Scope

The purpose of this evaluation is to:

- 1) characterize the background concentrations distributions of Ra-226, Th-230, and U-nat in soil using both parametric and non-parametric statistical approaches; and
- 2) based on those analyses, derive representative background levels that will form the basis for the soil cleanup criteria applied in future site cleanup and final status survey efforts.<sup>1</sup>

Consistent with this intent, two sets of background levels were derived. The first set, based on the entire integrated data set, was developed to represent background conditions for surrounding (site-wide) soils. The second set was based on data collected in the northern portion of the background study area only, thereby excluding adjacent disturbed areas to the east and west of the site. This second (northern) background data set will be applied in the final status survey for the northern windblown cleanup area. In accordance with 10 CFR 20, this analysis assumes that background radiation includes naturally occurring radioactive materials, but excludes source, byproduct, or special nuclear materials.

As a preface to this evaluation, it is important to acknowledge that although several guidance documents address the assessment of background conditions (e.g., NRC 1994, NRC 1995, NRC

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<sup>1</sup>Criterion 6(6) of Appendix A, 10 CFR 40 specifies that residual Ra-226 activity in (0-6") surface material may not exceed 5 pCi/g above background.

1997), there is no single well-established method to define background soil concentrations, or more importantly, to assess the natural variability of background conditions. This finding is particularly true for data that are not normally distributed. Additionally, a concept implicit in much of the guidance related to background determinations is that wide variability in a background data set is not acceptable. The latter assumption holds for those sites characterized by a homogenous physical, geological, and radiological environment, but not for the Gas Hills site vicinity, which is highly heterogeneous. This heterogeneity is attributable to naturally occurring radioactive materials, as well as the well-documented disturbance of adjacent areas by mining activities and subsequent reclamation efforts. Given these factors, the background concentrations proposed herein are *not* intended to solely represent central tendency estimates. Rather, they account for central tendency as well as the intrinsic variability in the distribution of background radionuclide concentrations.

This analysis focuses on the results obtained for the 0-6" (or 0-15 cm) soil depth profile. Although results for individual depth profiles (e.g., 0-1", 1-6", and 6-12") are evaluated, only the 0-6" depth profile is used to establish the proposed background concentrations. This approach is consistent with the criteria specified in U. S. Nuclear Regulatory Commission (NRC) regulations (10 CFR 40, Appendix A). Detailed information regarding the Gas Hills site features, history, and geological setting is provided in the previous background characterizations (Umetco 1997, SMI 1999a) as well as in the recently submitted *Final Status Survey Plan* (Umetco 1999). This information is therefore not reiterated here. Determining background direct gamma exposure rates to be applied to the covered repositories is provided in Appendix A.

### **1.3 Organization and Contents**

Following this introduction, Section 2 summarizes the previous investigations that form the basis for the background evaluation presented herein. Section 3 defines the background data set and documents the procedures used to ensure the representativeness of those samples. Section 4 documents the data management procedures and statistical approaches used to characterize the background distributions. Section 5 summarizes the representative background radionuclide concentrations derived for both site-wide (surrounding) and northern area soils and documents the supporting rationales. References are provided in Section 6.

To facilitate review, the bulk of the information in this report is provided in the tables and figures, which detail the assumptions, methods, and results used to derive the site-specific background concentrations. The text is generally limited to discussing key assumptions and salient findings.

## 2.0 SUMMARY OF SUPPORTING INVESTIGATIONS

This section summarizes the previous background and scoping investigations that form the basis for the background data set defined herein. These investigations include the 1998 background characterization investigation, the 1998 windblown scoping survey, and the 1995-1996 background land conditions evaluation. Corresponding methods and results are documented in the following three reports:

- *Background Radionuclide Concentrations at the Umetco Gas Hills Site* (SMI 1999a),
- *Gamma Survey of Windblown Deposition Areas, Gas Hills, Wyoming* (SMI 1999b), and
- *Background Land Conditions at the Gas Hills Uranium Project* (Umetco 1997).

The general scope and overall findings of these investigations are summarized below. However, detailed information (e.g., analytical results and sample location maps) is provided in Section 3, which defines the background data set applied herein.

### 2.1 1998 Background Investigation

In the fall of 1998, Umetco initiated an extensive background characterization investigation (SMI 1999a). The purpose of this study was to complement Umetco's ongoing site characterization efforts (Umetco 1997), as well as to establish a basis for appropriate cleanup and final status survey methodologies for the Gas Hills site. Soil samples were collected at 157 locations within 3,000 meters of the site and analyzed for Ra-226, Th-230, and U-nat. The site was divided into two sections: a northern section (samples denoted by a "BN" prefix), and a southern section (samples denoted by a "BS" prefix). This distinction was made because preliminary field surveys and soil composition data indicated possible differences in the extent of mineralization exhibited in these two areas (SMI 1999a). Samples collected in the northern portion of the survey area (n=79) were analyzed for three depth intervals: 0-1" (0-2.5 cm), 1-6" (2.5-15 cm), and 6-12" (15 to 30 cm). The remaining southern area samples (n=78) were analyzed for surface soils only (i.e., 0-1" and 1-6" depths).

In analyzing these data, SMI focused on three primary endpoints:

- 1) characterizing background radionuclide concentrations in undisturbed areas according to soil type, based on data from the 157 sample locations described above;
- 2) characterizing background radionuclide concentrations in disturbed areas (i.e., areas impacted by former mining and/or reclamation activities), based on the data previously collected by Umetco (1997); and
- 3) establishing a site-wide average background Ra-226 concentration, based on a weighted estimate of the Ra-226 distributions obtained for both disturbed and undisturbed area background samples.

Based on this evaluation, SMI concluded that the undisturbed lands in the Gas Hills site vicinity (i.e., areas not impacted by mining activities) are composed of three distinct soil types: soil group 1, soil group 2, and soil group 3. Average 1-6" Ra-226 background values derived for these soil groups are summarized below, along with SMI's proposed disturbed area and site-wide average Ra-226 background values.

### Summary of Background Ra-226 Concentrations Determined by SMI (1999a)\*

Background Group	Sample Number	Assumed Fractional Area at Site	Ra-226 (pCi/g)	Background Value Basis
Undisturbed Group 1 <sup>H</sup>	63	0.388	4.6	mean 1-6" concentration
Undisturbed Group 2 <sup>H</sup>	42	0.186	6.2	mean 1-6" concentration
Undisturbed Group 3 <sup>H</sup>	24	0.049	2.5	mean 1-6" concentration
Disturbed Area 1 <sup>I</sup> (Ra-226 > 8 pCi/g)	18	0.117	19.0	mean concentration (depth not specified); see SMI (1999a), Section 6.3.2 re: the basis for defining sub-populations for the disturbed area data set
Disturbed Area 2 <sup>I</sup> (Ra-226 < 7 pCi/g)	37	0.24	4.2	mean concentration (depth not specified)
Rock Outcrops <sup>I</sup>	--	0.02	19.0	mean concentration
Site-Wide Average (SWA)	--	--	9.9	Although presented as the upper 90% confidence limit on the site-wide average in SMI's report, this value actually represents the 95 <sup>th</sup> percentile of the weighted site-wide Ra-226 distribution.

\* Source: Section 6 and Tables 6.5 through 6.12 of SMI's March 1999 background characterization report (SMI 1999a).

<sup>H</sup> Data obtained from SMI's 1998 background investigation. <sup>I</sup>Data obtained from preceding Umetco (e.g., 1997) investigations.

-- Data not provided or not applicable

Recent analysis of SMI's report indicates that these summary background values are inadequate for establishing a basis for future site cleanup and final status survey methodologies. This conclusion is based on three primary factors. First, summary values derived for disturbed and undisturbed areas are average concentrations, and thus ignore the variability in the data set. [A related issue is the fact that the average concentration may not be an appropriate estimator of central tendency given the underlying (erroneous) assumption of normally distributed data.] Second, summary values obtained for undisturbed areas, which would be used to determine cleanup goals for areas north of the site, exclude applicable data from the uppermost (0-1") soil depth interval. The third (and perhaps most important) reason that these values are not considered representative is that the data set used by SMI included affected samples collected in the area immediately north of the above-grade tailings impoundment (AGTI).

As documented in the following section, results from 30 SMI sample locations were ultimately excluded from the background data set used herein based on apparent impacts from 11e.(2) byproduct materials (i.e., windblown contamination). Although the number of samples obtained in SMI's background investigation was sufficient for data analysis, even after excluding data

from the apparently impacted areas, supplementary data were needed to address areas that were not sufficiently spatially represented. For example, a subset of the windblown scoping survey data was used to supplement the background data set for the north area (which was markedly reduced after removing data from the affected samples). Also, SMI southern area ("BS") samples were generally collected at locations outside the areas coinciding with former mining activities and/or areas exhibiting highly variable Ra-226 content due to naturally occurring ore. The previous Umetco (1997) data were therefore used to account for these areas, thus allowing a more representative characterization of surrounding soils. These supplemental investigations are summarized below.

## 2.2 1998 Windblown Scoping Survey

In the fall of 1998, Umetco retained SMI to expand upon the previous investigations to estimate the lateral extent of windblown contamination at the Gas Hills site (SMI 1999b). This windblown scoping survey focused on a 300-acre area located north and slightly east of the site (see Section 3, Figures 3.1 and 3.3). This area was selected for investigation based on the predominant wind direction in the region, which is from the southwest, and its location relative to the primary contaminant source, the AGTI. Due to the steep terrain in this region, the actual area covered by the survey was limited to approximately 150 acres of the 300-acre area of interest. The southern half of this study area, which included soil samples identified with a "B" prefix, coincided with the area of SMI's previous investigation that was ultimately excluded from the background data set due to apparent windblown impacts (see Figure 3.3). However, the northern half of the study area included unaffected regions that had not been characterized previously. Soil sampling results conducted in this area (denoted by an "A" prefix) were therefore used to supplement the northern area background data used herein.

The windblown scoping survey was conducted using an integrated radiation measurement and global positioning system (RMGPS). The RMGPS was designed to simultaneously record external gamma radiation measurements and the coordinates at which the gamma measurements were taken. Gamma survey results are documented in SMI's (1999b) report and in the *Final Status Survey Plan* (Umetco 1999) and are not evaluated here. Rather, this report focuses on the associated soil sampling effort results conducted to verify the gamma measurement results. This verification entailed soil sample collection from 68 locations in the vicinity of the windblown survey and determining the corresponding depth-weighted average (0-15 cm) Ra-226 concentration. Twenty-seven (27) samples were collected in the southern half of the study area, portions of which exhibit apparent windblown contamination impacts. The remaining 41 soil samples were collected in the unaffected northern region; corresponding Ra-226 data were used herein as described in Section 3.2.

The windblown scoping survey report concluded that Ra-226 activity measured within the survey area generally decreased to the north, with sporadic observations of elevated Ra-226 activity (>20 pCi/g) attributable to localized natural mineralization, rather than deposits of 11e.(2) byproduct material (SMI 1999b). In summary, Ra-226 activity in the area north of background sample BKG 73 (see Figures 3.1 and 3.3) was found to be consistent with Ra-226 concentrations in unimpacted soils (SMI 1999b). The hilltops in northern areas exhibited elevated Ra-226

activity attributable to localized uranium mineralization. As demonstrated in previous investigations (SMI 1999a and Umetco 1997), isolated areas of localized mineralization and mineralized outcrops are a common occurrence in all soil groups throughout the site area.

### **2.3 1995-1996 Radiological Investigation Program**

In 1995 and 1996, Umetco conducted a scoping survey of the Gas Hills site and adjacent offsite areas (Umetco 1997). As part of this survey, soil samples were collected from approximately 60 background locations and analyzed for Ra-226, U-nat, Th-230, sulfate (SO<sub>4</sub>) and carbonate (CO<sub>3</sub>). These background samples, shown on Figure 3.1 and Appendix A, Figure A.1, are categorized as follows:

- Samples collected in undisturbed areas located west and east of the site, representative of radiological background conditions prior to mining disturbance – 9 soil sample locations (0-5 cm and 5-15 cm depths) and 8 outcrop locations; and
- Samples collected in disturbed (reclaimed) areas west and east of the site, 13 and 30 (0-15 cm) samples respectively, representative of background conditions for areas that were formerly mined or reclaimed.

These samples encompass adjacent disturbed and undisturbed areas to the west and east of the site that were under-represented in SMI's (1999a) data set. Therefore, corresponding analytical results were used to supplement the background data set for surrounding soils, but were not used to determine background concentrations for the northern cleanup area. As discussed in Section 3.3, outcrop data were excluded from the final background data set because they are not considered representative of surrounding soils. The exclusion of these outcrop data is considered a conservative approach in that it excludes some naturally occurring areas of elevated Ra-226 activity that are attributable to localized mineralization.

### 3.0 DEFINING THE FINAL BACKGROUND DATA SET

The final background data set was derived using the data from the three investigations described in the preceding section – the 1998 background investigation (SMI 1999a), the northernmost subset of the data collected for the subsequent windblown scoping survey (SMI 1999b), and relevant data from the initial surveys conducted by Umetco in 1995 and 1996. Table 3.1 summarizes these investigations and discusses how the corresponding data will be applied in this final background evaluation.

Figure 3.1 shows the background sample locations and corresponding Ra-226 concentrations. In this figure, samples listed in red correspond to locations included in previous background evaluations but excluded from this final data set. To provide a context for evaluating background sample locations relative to previous penetrating radiation survey results and former mining and reclamation practices surrounding the site, Figure 3.2 shows the distribution of Ra-226 equivalents relative to historical mining activities. Figure 3.3 shows the 1998 windblown scoping survey locations. Of these samples, only the northernmost data points, denoted by an "A" prefix, were used in the final background data set.

#### 3.1 Identifying Relevant Data from SMI's 1998 Background Investigation

The following evaluation of SMI's background data set is based primarily on the data presented in the following tables of their March 1999 report:

- Table 4.3 – *Duke Engineering and Services Environmental Laboratory Data;*
- Table 5.5 – *Samples Impacted to at Least 6" and Excluded from Background Data Set;*
- Table 5.6 – *Accepted Background Sample Locations;* and
- Table 6.2 – *Average <sup>226</sup>Ra Activity for each Soil Group.*

Figure 3.1 shows the 1998 background investigation sample locations, corresponding Ra-226 data, and the soil classifications used by SMI. SMI's approach for selecting final background locations (i.e., for removing impacted samples from the data set) was based on identifying potential windblown impacts using the criteria shown in Figure 5.1 of their March 1999 report. Two endpoints were evaluated: (1) vertical Ra-226 concentration trends, and (2) analysis of Ra-226/Th-230 and Ra-226/(U-nat/2) ratios. These endpoints were evaluated using an iterative, quantitative approach.<sup>2</sup> However, one critical (qualitative) factor was ignored – the sample location relative to the Gas Hills site, in particular relative to the above-grade tailings impoundment, the primary source of windblown contamination.

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<sup>2</sup>As shown in Figure 5.1 of SMI's March 1999 report, quantitative limits were established for each of these endpoints—Ra-226 surface to depth ratios and equilibrium (Ra-226/Th-230 and Ra-226/U-nat/2) ratios—and samples were excluded or retained based on those criteria. For example, if a sample exhibited a decreasing Ra-226 concentration with depth (e.g., 0-1" Ra/1-6" Ra > 1.39), the decision to accept or reject that sample was then based on the equilibrium ratios. However, because numerous 0-1" samples were not analyzed for Th-230 and U-nat, there was no basis for inclusion or exclusion of those samples that "failed" the depth trend test. Consequently, many samples were erroneously retained due to lack of isotopic ratio data and, more importantly, failure to consider the location of the sample relative to the AGTI contaminant source.

As a result, significant evaluation and filtering of SMI's data set was conducted before including results in the final background database. This process is described below.

### **3.1.1 Re-Examining the Initial SMI Database**

In re-examining the validity of SMI's background database, three primary factors were considered:

- 1) the sample location relative to known 11e.(2) contaminant sources (e.g., the AGTI);
- 2) the magnitude of the Ra-226 concentration, with results greater than 5 pCi/g warranting closer examination (based on historical background sampling results); and
- 3) vertical Ra-226 concentration trends, whereby results with notably higher surficial concentrations are considered suspect (see discussion below).

These factors were evaluated on a sample-specific basis using a qualitative approach, as no defensible basis for quantitative decision rules could be established. To facilitate review of Ra-226 depth trends, Figures 3.4 through 3.7 plot the vertical Ra-226 distributions for each sample location and identify those samples that were excluded from this background data set. Table 3.2 lists all background samples evaluated in SMI's (1999a) report and documents the rationales for either retaining or excluding those locations from the final background data set. Based on a depth trends examination in Figures 3.4 through 3.7, and considering the factors discussed in Table 3.2, thirty (30) sample locations were identified as being potentially impacted (see Figure 3.1). Corresponding analytical results were therefore excluded from the background data set. Table 3.3 and Appendix B, Table B.1 list the analytical results for retained and excluded samples, respectively. Detailed results, including uncertainties and U-nat supporting data, are provided in SMI's (1999a) report.

#### ***Evaluating Ra-226 Depth Trends***

Previous analytical results and field observations have indicated that windblown contamination at the Umetco Gas Hills Site is typically characterized by a thin surficial (e.g., 0-1") veneer. In these areas, Ra-226 concentrations decrease with depth, and this trend is particularly apparent when comparing results for the 0-1" vs. 1-6" depth interval. Alternatively, locations at which Ra-226 concentrations increase with depth are generally indicative of non-11e.(2) material. These observations form the basis for the vertical Ra-226 concentration trend criterion discussed above.

Based on this criterion, examining Figures 3.4 through 3.7 might lead to the conclusion that some sample locations retained in the data set are affected (e.g., BN 51; see Figure 3.6). However, it is important to acknowledge that decreasing Ra-226 magnitude with depth could be due to a number of other factors, including the presence of shallow ore deposits, natural environmental transport processes (e.g., erosion or translocation of erodible materials containing naturally occurring ore), intrinsic spatial variability, and/or variability due to sampling. These factors are particularly relevant for sample locations in which the depth-specific Ra-226

concentrations span a rather small range (e.g., < 5 pCi/g). Consequently, vertical Ra-226 trends must be evaluated in conjunction with the other factors discussed above – sample location and Ra-226 magnitude. Figure 3.8 shows the generalized distribution of Ra-226 by depth in the retained SMI background soil samples. This figure demonstrates that, overall, Ra-226 distributions exhibited for each depth profile (0-1", 1-6", and 6-12") are similar.

### ***Discussion***

As shown in Figure 3.1, most SMI samples excluded from the final background data set were collected at locations north of the above-grade tailings impoundment near the restricted area boundary, within the predominant wind direction. However, exclusion from the background data set does not necessarily mean that the sample was affected (e.g., BKG N73, BN 36, BN 40, and BN 41). As documented in Table 3.2, a conservative approach was used to determine which samples to retain in the background data set. Additionally, as a general rule (and despite the erroneous inclusion of samples exhibiting apparent windblown impacts), SMI's background sample locations selection was very conservative. With the exception of the aforementioned potentially affected samples, heterogeneous areas with naturally occurring ore and/or mining disturbed areas exhibiting highly variable Ra-226 content were apparently intentionally avoided in SMI's field investigation.

### **3.1.2 Assessing Soil Types and Equilibria**

Several distinctions were made in SMI's background evaluation that were not retained in this evaluation. The first relates to categorizing the data according to soil type, and the second relates to examining Ra-226 equilibria in assessing background locations. These issues are discussed briefly below.

#### ***Examining Ra-226 Distributions by Soil Group***

In their analysis, SMI evaluated whether the background data set was representative of a single background population or multiple background populations (SMI 1999a). Based on that evaluation, SMI concluded that the undisturbed lands in the Gas Hills site vicinity are composed of three distinct soil types: soil groups 1, 2, and 3. This approach – i.e., accounting for sub-populations such as soil type – is consistent with NRC guidance (e.g., NUREG-1501 and NUREG-1505), which recommends that the local variability of background should be assessed in areas with similar physical, chemical, radiological, and biological characteristics. However, further review of the background data set revealed that such distinctions are not necessarily meaningful due to the highly variable physical and geological environment that characterizes the Gas Hills site vicinity. Figure 3.9, which plots Ra-226 distributions according to soil group, demonstrates that the differences in Ra-226 concentrations between soil types are not notable, especially when the sample-specific (scatterplot) results are examined. This finding is particularly true for soil groups 1 and 2, the predominant soil types in the northern area surrounding the Gas Hills site.

Given the findings discussed above, combined with the imprecise boundaries of the soil types shown in Figure 3.1, the value added of these soil type distinctions is probably negligible.

Additionally, scientists working on site have observed that the soil types are not practicably resolvable in the field – i.e., they are not discrete or distinctive. Consequently, although useful from an academic standpoint, the soil type distinctions are probably not useful for the purpose of future final status survey and soil cleanup efforts. Therefore, sub-populations of the background data set based on soil type are not characterized herein.

### ***Assessing Ra-226 to U-nat/2 Ratios***

NRC guidance (1999) recommends the using Ra-226/U-238 ratios in distinguishing between affected and unaffected samples, and this factor weighed heavily in the selection criteria applied in the preceding background evaluation (SMI 1999a; see footnote 2 on page 7). However, although considering isotopic ratios was necessary in the initial data evaluation stages, examining the results reveals that these ratios can not be used as a reliable basis for identifying windblown contaminated soil at the Gas Hills site. Previous site characterizations yielded compelling results (i.e., significant Ra-226/U-238 disequilibria was apparent) when ratios were compared between pure 11e.(2) byproduct material and unaffected samples. However, this type of evaluation does not appear to be useful for the "gray area" situation which characterizes the Gas Hills site vicinity – i.e., where 11e.(2) windblown contamination is intermixed with (unaffected) naturally occurring mine spoil and/or soil containing naturally occurring ore. To demonstrate this finding, Ra-226 to U-nat/2 ratios were plotted for those samples that exhibited clear windblown impacts (Figure 3.10). Comparing these ratios with those obtained for the unaffected background samples yields negligible differences. Consequently, Ra-226 equilibria data were not used to distinguish between affected and unaffected samples in defining this final background data set.

### **3.2 Identifying Relevant Data from the 1998 Windblown Scoping Survey**

Although the initial objective of the windblown scoping survey was not to characterize background conditions, data from the northern half of the survey area are considered representative of background and were therefore used to supplement the previous (1999a) SMI data set. Corresponding results, identified by an "A" prefix, are shown in Figure 3.3 and plotted in Figure 3.11. Forty-one (41) 0-15 cm samples were collected and analyzed for Ra-226. Table 3.4 lists the northern windblown scoping survey sample results that were included in the final background data set. Appendix B, Table B.2 lists the results for samples that were not evaluated herein, which corresponds to the southern half of the windblown scoping survey area.

As shown in Figure 3.3, some samples were collected in areas characterized by localized mineralization and/or mineralized outcrops, contributing to the variability in the background Ra-226 distribution. Additionally, due to the spatial proximity of some data points (reminiscent of colocated samples), several results were averaged to minimize any bias in the northern data set, resulting in a final sample n of 28 (see Table 3.4).

### **3.3 Data Used from the 1995-1996 Radiological Investigation Program**

As defined previously, Umetco's 1995-1996 investigation results (Umetco 1997) were used to supplement the characterization of surrounding soils, but, with the exception of sample B-22,

were not used to define background for the northern cleanup area. Results encompass adjacent disturbed and undisturbed areas to the west and east of the site, areas that were under-represented in SMI's data set. Corresponding analytical results are provided in Tables 3.5 through 3.8. Sample locations are shown in Figure 3.1, along with the SMI background sample locations. Figure 3.12 plots the distribution of Ra-226 in the Umetco (1995-1996) background samples. The Umetco data used in the final background data set are summarized as follows:

- Undisturbed Areas: n = 9 locations, weighted average of 0-5 cm and 5-15 cm results, outcrops excluded (Table 3.5; Table 3.6 identifies undisturbed samples that were excluded from the background data set)
- Disturbed/Reclaimed Areas: n = 43 locations, 13 west and 30 east, 0-15 cm depths (Tables 3.7 and 3.8)

For undisturbed areas, outcrop data were excluded from the background data set because they are not considered representative of surrounding soils (see Table 3.6). As shown in Figure 3.12, the geometric mean Ra-226 concentration in undisturbed areas is about 8 pCi/g.<sup>3</sup> The geometric mean was used as an estimate of central tendency because several outliers are apparent in the undisturbed sample data set. These outliers include samples B-01 and B-04, collected from undisturbed areas west of the site, and sample B-08, collected in an undisturbed area east of the site (Figure 3.12, Table 3.6). Although initial review of these data indicated possible 11e.(2) impacts, further examination reveals that these locations are not impacted. Rather, they correspond to areas characterized by naturally occurring mineralization (Umetco 1997, Umetco 1999). Therefore, samples B-01 and B-04 were retained in the background data set. However, although previous evaluations have demonstrated that the undisturbed B-08 sample location is not affected, associated data were nonetheless excluded due to the extreme magnitude of the radionuclides detected (Table 3.6).

Geometric mean Ra-226 concentrations in adjacent reclaimed areas are 19.3 pCi/g and 4.1 pCi/g for western and eastern areas, respectively (Figure 3.12). These results demonstrate the differences in adjacent reclamation efforts. The higher Ra-226 residual to the west of the site is primarily the result of Pathfinder's reclamation activities, whereas the cleaner residual to the east reflects Umetco's voluntary reclamation efforts performed under the Wyoming Abandoned Mine Lands (AML) program during the later operational period of the mill.

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<sup>3</sup>The data set provided for undisturbed areas represents lands that were not mined as a result of the low uranium content. For example, undisturbed west soil samples were collected from a total area representing approximately 10% of the original surface area (*i.e.*, the remaining 90 percent of the land area west of the site was mined by Pathfinder). Therefore, it is reasonable to assume that the pre-mining "background" Ra-226 concentrations in adjacent offsite soils may have been greater than the current 10 pCi/g average, as mining would have been concentrated on the highly mineralized lands.

## 4.0 DATA MANAGEMENT AND ANALYSIS

Integrating the relevant background samples from the three previous investigations yielded a final data set consisting of 207 background sample locations. The resulting distribution of background radionuclide concentrations was characterized using the methods and approaches documented below.

### 4.1 Data Management

As a preface to the following discussion of analytical/statistical approaches, some reiteration of data management issues identified in the preceding section is warranted. These issues are discussed below.

#### 4.1.1 Data Categorization

The background data set was divided into two groups: 1) a comprehensive grouping representing surrounding soils, and 2) a northern area subset, to be applied to the northern cleanup area. These groups are defined as follows:

- Site-Wide (Surrounding) Soils:  $n = 207$ , including the 127 background samples collected by SMI (Table 3.3), the 28 northernmost windblown scoping survey locations (Table 3.4), 9 samples collected in disturbed areas (Table 3.5), and 43 samples collected in disturbed/reclaimed areas (Tables 3.6 and 3.7).
- Northern Cleanup Area:  $n = 69$ , including the 41 northern area samples listed in Table 3.3 (weighted averages of the 0-1" and 1-6" results), twenty-seven (27) 0-15 cm windblown scoping survey results (Table 3.4) collected in the northernmost areas shown in Figure 3.3, and one undisturbed area sample (B-22; see Table 3.5 and Figure 3.1).

The first site-wide data set includes the combined results of the previous SMI (1999a and 1999b) and Umetco (1997) investigations. The second data set includes northern SMI background and windblown scoping survey data only.

#### 4.1.2 Considering Sample Depth

Although results for individual depth profiles (0-1", 1-6", and 6-12") were evaluated, only the 0-6" results were used to determine the background concentrations recommended herein. This approach is consistent with the criteria specified in NRC regulations (10 CFR 40, Appendix A). These 0-6" data correspond to the weighted averages of the 0-1" and 1-6" results collected by SMI in their 1998 background investigation, the weighted averages of the 0-5 cm and 5-15 cm results obtained for disturbed samples in Umetco's earlier investigation, and the 0-15 cm results obtained for the remaining samples (i.e., SMI's windblown scoping survey results and the results for surrounding reclaimed areas).

## **4.2 Data Analysis Approach**

The data analysis undertaken for this evaluation was extensive, both in the defining the background data set (e.g., see Table 3.2 and Figures 3.4 through 3.12), as well as in deriving site-specific background concentrations for the site-wide and northern cleanup area data sets.

### **4.2.1 Distributional Analysis and Data Transformations**

The statistical approaches undertaken as part of this evaluation included visually examining plotted data, evaluating normality/distributional analysis, and data transformations. These analytical procedures are summarized below.

#### ***Visually Examining Plotted Data***

The first step in the data analysis process was to plot the background Ra-226 concentrations using both maps and statistical graphics (e.g., box plots and scatterplots), and visually examine the results. As discussed in the preceding section and demonstrated in Figures 3.1 through 3.12, this step was critical in the data filtering/distillation process.

#### ***Evaluating Normality/Distributional Analysis and Data Transformations***

Many statistical tests (e.g., t tests) and estimators (e.g., the mean, standard deviation, and confidence limits about the mean, etc.) assume a normal distribution. Given this common normality assumption, evaluating whether variables approximated a normal distribution was undertaken for both the site-wide and northern area background data sets. This was achieved by examining descriptive statistics (e.g., skewness and kurtosis), statistical graphics (e.g., probability plots and frequency histograms), and statistical tests results (e.g., Shapiro Wilk's test and Lillifors test) to identify departures from normality that would need to be corrected (e.g., through a log transformation) prior to conducting any parametric test. A normal distribution can not be assumed for both the site-wide and northern area data sets, as the associated null hypothesis was rejected for the aforementioned tests (see Tables 4.1, 4.3, and 4.5).

#### ***Data Transformations***

Examining both the site-wide and northern area background data using the techniques described above indicated that both data sets are lognormally distributed. Therefore, data were transformed accordingly to allow derivation of more representative estimates of central tendency and/or variation (e.g., use of a geometric mean vs. an arithmetic mean).

### **4.2.2 Discussion**

As acknowledged in the introduction to this document, there is no firm precedence for characterizing background soil concentrations. This finding is particularly true as it relates to determining a single estimator that encapsulates both the central tendency and the variability within the data set, especially for data that are not normally distributed. The data analysis and distillation process conducted to prepare this report was exhaustive. Despite these efforts, there is still a great deal of variability in the background sample results – both spatially (horizontally) and with depth. It is important to reiterate that this variability is due to the highly heterogeneous

environment that characterizes the area surrounding the Gas Hills Site and that precludes determining a single representative background concentration that accounts for all these factors.

### **4.3 Characterizing Background Conditions for Site-Wide (Surrounding) and Northern Area Soils**

The exhibits referenced below are self-explanatory and therefore warrant no accompanying discussion. Resulting findings regarding recommended site- and radionuclide-specific background concentrations are presented in the following section.

Table 4.1 presents summary statistics for the 0-6" site-wide background data set. Table 4.2 presents summary statistics for all radionuclide parameters and depth profiles. Figure 4.1 plots the distribution of 0-6" Ra-226 in all background samples. Figure 4.2 shows a box plot of Ra-226 and identifies outliers for all 0-6" data points.

Table 4.3 presents summary statistics for northern cleanup area background samples for the 0-6" depth profile. Table 4.4 lists summary statistics for all radionuclide parameters and depth profiles for northern area samples. Table 4.5 provides more detailed information regarding the Ra-226 distribution in surficial (0-6"). Figure 4.3 plots the distribution of Ra-226 in 0-6" northern area background samples, showing a histogram and quantile-quantile plots developed for normal, lognormal, and Weibull distributions.

## 5.0 SUMMARY OF PROPOSED BACKGROUND RADIONUCLIDE CONCENTRATIONS

Table 5.1 presents the surficial (0-6") background radionuclide concentrations recommended for future application at the Gas Hills site. Figure 5.1 plots the Ra-226 distributions in background samples by area for the 0-6" soil depth profile. Based on the data analysis presented in the preceding section, representative background levels for radionuclides in soil at the Gas Hills site are as follows:

Area/Purpose	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)	Basis
Site-Wide (Surrounding) Soils	10	10	15	Approximately equal to both the median plus the interquartile range (IQR), and the antilog of the mean plus one standard deviation (s.d.) of the log-transformed data—i.e., the geometric mean plus one s.d. (see Table 4.1 and Table 5.1 summary).
Northern Windblown Cleanup Area	6.1	5.8	7.6	99 <sup>th</sup> upper confidence limit (UCL) on the geometric mean of the northern area background data set

The background values proposed for site-wide (surrounding) soils are considered reasonable, especially given the distribution of Ra-226 in the reclaimed and undisturbed areas immediately adjacent to the site (see Figure 5.1). Also, the data plot provided in Figure 4.1 shows that the 10 pCi/g Ra-226 value falls at a point just above which the slope and density of the distribution changes. The 10 pCi/g value thus adequately accounts for the variability in the background distribution, but does not incorporate the less frequently occurring outlying values.

The 6.1 pCi/g Ra-226 background value corresponds to the 99% UCL on both the geometric mean (GM) and the median of the data set. As shown in Table 4.5, it also closely approximates the arithmetic mean and 95% UCLs on the median and GM – i.e., all the aforementioned estimators yield a Ra-226 background value of 6 pCi/g (when rounded to one significant figure). This value is very conservative (e.g., see Figure 4.3), especially given the variability apparent in the northernmost portion of the sampling area (see Figure 3.3), where Ra-226 concentrations are clearly reflective of naturally occurring ore.

As demonstrated previously, the Gas Hills site is situated in a heterogeneously mineralized area which has been significantly impacted by open pit uranium mining, mine reclamation, and impacted to a lesser extent by uranium processing. Therefore, any determination of background must take into account the presence of elevated naturally occurring radioactive minerals in the vicinity of the site resulting from these activities. These factors have been accounted for conservatively herein.

## 6.0 REFERENCES

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- U. S. Nuclear Regulatory Commission (NRC). 1999. *Standard Review Plan for the Review of a Reclamation Plan for Mill Tailings Sites Under Title II of the Uranium Mill Tailings Radiation Control Act*. NUREG-1620, Draft Report for Comment. January 1999.

## Tables

**Table 3.1. Summary of Investigations Used to Define the Final Background Data Set Gas Hills, Wyoming Site.**

Underlying Investigation	Applicability to the Evaluation	Areas Represented	Sample Depths and Numbers	Comment
<p><b>1998 Background Investigation (SMI 1999a)</b></p> <p><i>Note: SMI's previous definition of the background data set was found to be flawed because data from affected areas collected immediately north of the above-grade tailings impoundment (AGTI) were included in their evaluation.</i></p>	<p>The results of this investigation form the basis for the final background evaluation presented herein. However, because some affected samples were identified, significant evaluation and filtering of SMI's data set was conducted before including results in the final background database (e.g., see Table 3.2 and Figures 3.4 to 3.7).</p>	<p>Areas north of the site (previously uncharacterized), used to determine background concentrations for the windblown cleanup area north of the AGTI (41 sample locations), plus an additional 86 samples collected in surrounding areas to the west, south, and east of the site.</p>	<p>0-1": n=127 for Ra-226; n=9 for Th-230 and U-nat</p> <p>1-6": n=127 for Ra-226, Th-230, and U-nat</p> <p>6-12": n=53 for Ra-226; n=29 for Th-230 and U-nat</p> <p><i>The 6-12" depth was analyzed only for northern samples, denoted by a "BN" prefix.</i></p>	<p>Most of the valid (i.e., unaffected) samples collected as part of SMI's investigation probably lead to an underestimation of true background conditions, because heterogeneous areas with naturally occurring ore, as well as surrounding areas coinciding with previous mining activities, were apparently intentionally avoided.</p>
<p><b>1998 Windblown Scoping Survey (SMI 1999b)</b></p>	<p>Although the objective of this evaluation was not to define background, some data are considered representative of background conditions to the north and were therefore used to supplement the previous (1999a) SMI data set, in particular because they encompass more heterogeneous northern areas.</p>	<p>These data, identified by an "A" prefix, constitute the northernmost samples of the background data set. As shown in Figure 3.3, some samples were collected in areas characterized by localized mineralization and/or mineralized outcrops, contributing to the variability in the background Ra-226 distribution.</p>	<p>Forty-one (41) 0-15 cm "A" samples were collected (see Figure 3.3). However, due to the spatial proximity of some data points (comparable to colocated samples), several results were averaged to minimize any bias in the northern data set (see Table 3.4), resulting in a final sample n of 28.</p>	<p>Although no data are available to evaluate vertical Ra-226 distributions, one can infer that the "A" grid results are unaffected based on their northernmost location (outside of any measurable influence from windblown impacts), as well as the adjacent results obtained for SMI's (1999a) background investigation.</p>
<p><b>1995-1996 Background Investigation (Umetco 1997)</b></p>	<p>These data were used to supplement the characterization of site-wide surrounding soils; only one datum (B-22) was used in the northern database.</p>	<p>Results encompass adjacent disturbed and undisturbed areas to the west and east of the site, areas that were vastly under-represented in SMI's data set.</p>	<p><i>Undisturbed:</i> n = 9 (wtd. avg. of 0-5 cm and 5-15 cm results)</p> <p><i>Disturbed/Reclaimed:</i> n = 43 (13 west and 30 east, 0-15 cm sample depths)</p>	<p>Given the small sample n relative to SMI's data set, these areas are probably under-represented in the characterization of surrounding soils developed herein.</p>

**Table 3.2. Re-Examination of the Validity of Background Sample Locations Used in SMI's March 1999 Background Report, Gas Hills, Wyoming Site.** page 1 of 5

Sample Location <sup>1</sup>	Included in Final Data Set? <sup>2</sup>	Rationale for Inclusion or Exclusion
<b>BKG- Samples<sup>3</sup></b>		
BKG N71	No	Ra-226 vertical distribution indicates probable windblown impacts. Also, the sample is located about 1000 ft northeast of the above grade tailings impoundment (AGTI) contaminant source, within the predominant wind direction (see Figures 3.1 and 3.4).
BKG N72*	Yes	Low Ra-226 concentrations (< 5 pCi/g) and no apparent depth trend.
BKG N73	No	Exclusion may be conservative, given lack of notable Ra-226 magnitude or depth trend. However, review of data for surrounding samples BN 62, 63, and 64 suggests possible windblown impacts in this region (see below).
BKG N74*	Yes	Low Ra-226 concentrations, no vertical trend, and distant location.
BKG N75*	Yes	Low Ra-226 concentrations, no depth trend, and upwind location.
BKG N76	Yes	Initial examination of Ra-226 depth trend and magnitude indicates that this location is potentially impacted. However, this sample is located a significant distance west of the site, outside the influence of AGTI windblown impacts. The Ra-226 trends exhibited in this sample may be indicative of historical mining activities and/or naturally occurring ore.
BKG N77	Yes	See rationale for BKG N76.
BKG N78	Yes	Low Ra-226 concentrations, no notable depth trend, and upwind location.
<b>BN- Samples</b>		
BN 1	No	These data were excluded from the background data set due to Ra-226 magnitude and depth trend and, in particular, the proximity of the sample location to the AGTI (see Figures 3.1 and 3.6).
BN 2	No	This sample was previously excluded from SMI's data set (Figure 3.5). Exclusion was valid given the reasons cited above for sample BN 1.

*Shaded rows denote sample locations excluded from the background data set. Samples followed by an asterisk (\*) were included in the northern area background data set, while remaining samples were used in the site-wide (surrounding area) database only.*

<sup>1</sup> The samples listed above were collected for SMI's previous investigation, as listed in Table 4.3 (all data), Table 5.5 (samples excluded from background data set), and Table 5.6 (accepted background locations) of their March 1999 report. These data were re-evaluated in this report to verify the representativeness of the previously established background data set.

<sup>2</sup> As discussed in Section 3.1, the decision to include or exclude a sample from the background data set was based on the following factors: Ra-226 magnitude (with results greater than 5 pCi/g warranting closer examination), Ra-226 vertical distribution (results with notably higher surficial concentrations suspect), and sample location relative to the above grade tailings impoundment (AGTI), considered the primary windblown 11e.(2) contaminant source. Sample locations are shown in Figure 3.1, in which samples excluded from the background data set are listed in red. To facilitate review of Ra-226 depth trends, Figures 3.4 through 3.7 plot the vertical Ra-226 distributions for each sample location. Table 3.3 and Appendix B, Table B.1 list the corresponding analytical results for retained and excluded samples, respectively.

<sup>3</sup> As documented in SMI's report, BKG- samples were requested by the NRC for inclusion in the background data set. In SMI's report, these samples were referred to interchangeably as BKG-## or BKG N##. The original nomenclature used in SMI's maps and tables is retained in this report.

**Table 3.2. Re-Examination of the Validity of Background Sample Locations Used in SMI's March 1999 Background Report, Gas Hills, Wyoming Site.**

Sample Location	Included in Final Data Set?	Rationale for Inclusion or Exclusion
<b>BN- Samples</b>	(cont.)	
BN 3	No	Ra-226 magnitude, depth trend, and proximity of sample location to AGTI
BN 4	No	See rationale for sample BN 3, Figure 3.1, and Figure 3.6.
BN 5	No	See rationale for preceding BN samples.
BN 6	No	Although the surficial Ra-226 concentration is lower in this sample than in the preceding samples (collected closer to the AGTI), there is still evidence of potential windblown impacts.
BN 7	No	See rationale for sample BN 6.
BN 8*	Yes	Low Ra-226 concentrations, no depth trend, and location outside the predominant area influenced by windblown impacts.
BN 9*	Yes	See rationale for BN 8.
BN 10*	Yes	See rationale for BN 8.
BN 11*	Yes	In this sample, Ra-226 concentrations increase with depth (Figure 3.6). This trend is inconsistent with that observed in those samples clearly affected by 11e.(2)—e.g., samples BN 1 through BN 5. This factor, combined with the sample location, suggests the presence of naturally occurring ore.
BN 12*	Yes	See rationale for BN 11.
BN 13	No	This sample was excluded from the data set primarily due to its location relative to the site and, more importantly, the trends observed for adjacent sample BN 14 (see below). Because the Ra-226 trends observed in this sample may be due to naturally occurring ore, its exclusion from the data set is considered conservative.
BN 14	No	This sample exhibits a Ra-226 concentration and depth trend consistent with windblown impacts. Although not within the predominant wind direction, this location might have been impacted given its proximity to the GHP-1 area. Its exclusion from the data set is considered conservative.
BN 15*	Yes	Low Ra-226 concentrations, no depth trend, and location outside the predominant area influenced by windblown impacts.
BN 16*	Yes	See rationale for BN 15.
BN 17	Yes	Ra-226 concentrations are consistent with depth; location is outside the predominant area influenced by windblown impacts. These results are comparable to nearby sample BN 25.
BN 18*	Yes	This sample exhibits trends similar to those described for nearby sample BKG-76 (see corresponding rationale above).
BN 19	Yes	See explanation for BN 18 and BKG-76.

**Table 3.2. Re-Examination of the Validity of Background Sample Locations Used in SMI's March 1999 Background Report, Gas Hills, Wyoming Site.**

Sample Location	Included in Final Data Set?	Rationale for Inclusion or Exclusion
<b>BN- Samples</b>	<b>(cont.)</b>	
BN 20*	Yes	The fact that Ra-226 concentrations increase with depth and the sample location suggest the presence of naturally occurring ore.
BN 21*	Yes	Low Ra-226 concentrations, no depth trend, and sample location.
BN 22*	Yes	Low Ra-226 concentrations, no apparent depth trend, and sample location.
BN 23*	Yes	Low Ra-226 concentrations, no depth trend, and location outside the predominant area influenced by windblown impacts.
BN 24*	Yes	See rationale for BN 23.
BN 25	Yes	No Ra-226 depth trend and location outside the predominant area influenced by windblown impacts. These results are comparable to nearby sample BN 17.
BN 26	No	This sample was previously excluded from SMI's data set (Figure 3.5). Exclusion was valid given Ra-226 magnitude, depth trend, and proximity of sample location to AGTI within predominant wind direction.
BN 27	No	Sample previously excluded from data set; see BN 26 explanation.
BN 28	No	Sample previously excluded from data set; see BN 26 explanation.
BN 29	No	Sample previously excluded from data set; see BN 26 explanation.
BN 30	No	Ra-226 magnitude, depth trend, and proximity of sample location to AGTI within predominant wind direction (see Figures 3.1 and 3.6).
BN 31	No	See rationale for BN 30.
BN 32	No	See rationale for BN 30.
BN 33	No	See rationale for BN 30.
BN 34	No	See rationale for BN 30.
BN 35	No	This sample was previously excluded from SMI's data set (Figure 3.5). Exclusion was valid given the reasons cited above for samples BN 30 through 34.
BN 36	No	Ra-226 concentrations are lower than those reported for the preceding five samples; also, the depth trend is much less marked. However, given the trends observed for nearby samples, combined with the proximity to the AGTI, this sample was excluded from the data set. Its exclusion is considered conservative (see Figures 3.1 and 3.6).
BN 37	Yes	Low Ra-226 concentrations, no depth trend, and location outside the predominant area influenced by windblown impacts.

**Table 3.2. Re-Examination of the Validity of Background Sample Locations Used in SMI's March 1999 Background Report, Gas Hills, Wyoming Site.**

Sample Location	Included in Final Data Set?	Rationale for Inclusion or Exclusion
<b>BN- Samples</b>	(cont.)	
BN 38	Yes	This sample was previously excluded from the background data set in SMI's report. However, further examination of these results relative to the sample location suggests that, although BN 38 may be impacted, the source is not likely to be the Gas Hills site (see Figures 3.1 and 3.5). Rather, the results may be attributable to previous mining and/or reclamation activities that were conducted east of the site.
BN 39	Yes	See rationale for BN 38, Figure 3.1, and Figure 3.6.
BN 40	No	Despite lack of notable Ra-226 magnitude or depth trend, surrounding samples BN 33, BN 36, and BKG 71 exhibit apparent windblown impacts.
BN 41	No	See rationale for BN 40.
BN 42	Yes	Low Ra-226 concentrations, no notable depth trend, and sample location (see rationales for nearby samples BN 37 and BN 38)
BN 43*	Yes	Low Ra-226 concentrations, no depth trend, and sample location.
BN 44*	Yes	See rationale for BN 43.
BN 45*	Yes	Low Ra-226 concentrations and no depth trend.
BN 46	No	This sample was previously excluded from SMI's data set. Exclusion may be valid based on the Ra-226 depth trend (Figure 3.5). However, given the distance from the AGTI combined with the Ra-226 magnitude (not notable), its exclusion from the database may be conservative.
BN 47*	Yes	Low Ra-226 concentrations and no depth trend (Figure 3.6).
BN 48	No	This sample was previously excluded from SMI's data set. Exclusion was valid given Ra-226 magnitude, depth trend, and the results obtained for surrounding samples BN 28, BN 29, and BN 49 (Figures 3.1 and 3.5).
BN 49	No	Ra-226 magnitude, depth trend, and sample location (see BN 48 explanation).
BN 50*	Yes	Low Ra-226 concentrations, no notable depth trend, and sample location.
BN 51*	Yes	These sample results are anomalous in that Ra-226 concentrations are greater than 10 pCi/g for all depth intervals, a trend not observed in any other sample collected for this investigation (Figure 3.6). Note that the samples exhibiting the most obvious windblown impacts (e.g., BN 1, 2, 3, 30, and 28-33) show a marked reduction in subsurface (1-6" and 6-12") Ra-226 concentrations, usually to about 5 pCi/g. BN 51 is located a significant distance north of the site, in an area containing localized mineralized outcrops as identified in a recent windblown scoping survey (see Figure 2, 3). This sample was retained in the database because it represents natural mineralization. Also, it demonstrates the intrinsic variability in surface Ra-226 activity in Gas Hills background samples.

**Table 3.2. Re-Examination of the Validity of Background Sample Locations Used in SMI's March 1999 Background Report, Gas Hills, Wyoming Site.** page 5 of 5

Sample Location	Included in Final Data Set?	Rationale for Inclusion or Exclusion
<b>BN- Samples</b>	(cont.)	
BN 52*	Yes	Low Ra-226 concentrations, no depth trend, and sample location outside the influence of windblown impacts (Figures 3.1 and 3.6).
BN 53*	Yes	See rationale for BN 52.
BN 54*	Yes	See rationale for BN 52.
BN 55*	Yes	See rationale for BN 52.
BN 56*	Yes	See rationale for BN 52.
BN 58*	Yes	See rationale for BN 57.
BN 59*	Yes	Ra-226 increases with depth; sample location relative to site.
BN 60*	Yes	See rationale for BN 59.
BN 61*	Yes	Low Ra-226 concentrations, no depth trends, and sample location.
BN 62	No	Ra-226 magnitude, depth trend, and sample location relative to AGTI within predominant wind direction.
BN 63	No	See rationale for BN 62.
BN 64	No	See rationale for BN 62.
BN 65 through BN 74*, BN 75	Yes	All remaining BN samples were retained in the background database given low Ra-226 concentrations, no depth trend, and sample location. Supporting data are listed in Table 3.3 and shown graphically in Figures 3.1 and 3.6. With the exception of sample BN 75, all samples were included in the northern area background database.
<b>BS- Samples: Global Conclusion</b>		
All Samples – BS 1 through BS 75	Yes	<p>All samples were retained given the location of the sample relative to the Gas Hills site—i.e., upwind location and/or distance from area potentially influenced by windblown impacts. Most samples exhibit low Ra-226 concentrations and no notable vertical trend. Although a few samples (e.g., BS 7) exhibit elevated Ra-226 concentrations reminiscent of windblown impacts, these results are considered attributable to historical mining activities and/or naturally occurring ore. These sample results were therefore retained in the database.</p> <p><i>Note:</i> Samples BS 17 and BS 20 were not included in SMI's list of accepted background locations, nor were they identified for exclusion (SMI 1999a, Tables 5.6 and 5.5, respectively). They are nonetheless included in this report.</p>

**Table 3.3. SMI Background Investigation Sample Results Included in the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location	Applicable Data Set	Soil Group	Sample Depth	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
BKG N72	Northern, S-W	Group 1	<b>0-6" Wtd. Avg.</b>	<b>1.78</b>	<b>2.57</b>	<b>3.29</b>
			0-1"	3.62	3.86	5.62
			1-6"	1.41	2.31	2.83
			6-12"	2.07	2.19	2.24
BKG N74	Northern, S-W	Group 2	<b>0-6" Wtd. Avg.</b>	<b>4.58</b>	<b>5.35</b>	<b>6.67</b>
			0-1"	4.24	6.16	7.55
			1-6"	4.65	5.19	6.50
			6-12"	6.00	7.07	8.77
BKG N75	Northern, S-W	Group 1	<b>0-6" Wtd. Avg.</b>	<b>3.82</b>	<b>4.20</b>	<b>4.84</b>
			0-1"	3.84	4.27	6.32
			1-6"	3.82	4.18	4.54
			6-12"	3.63	3.60	4.56
BKG N76	Site-Wide Only	Group 2	<b>0-6" Wtd. Avg.</b>	<b>4.82</b>	<b>7.12</b>	<b>6.80</b>
			0-1"	10.19	18.19	12.02
			1-6"	3.75	4.91	5.76
			6-12"	4.37	3.80	4.51
BKG N77	Site-Wide Only	Group 2	<b>0-6" Wtd. Avg.</b>	<b>14.33</b>	<b>19.25</b>	<b>24.93</b>
			0-1"	16.92	22.58	29.91
			1-6"	13.81	18.58	23.94
			6-12"	3.96	5.64	7.02
BKG N78	Site-Wide Only	--	<b>0-6" Wtd. Avg.</b>	<b>3.55</b>	<b>2.80</b>	<b>4.64</b>
			0-1"	5.79	6.93	10.32
			1-6"	3.10	1.97	3.50
			6-12"	4.47	5.39	7.31
BN 8	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>4.63</b>	<b>4.86</b>	<b>5.57</b>
			0-1"	4.93	--	--
			1-6"	4.57	4.86	5.57
			6-12"	4.32	6.93	5.20
BN 9	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>4.84</b>	<b>4.97</b>	<b>5.42</b>
			0-1"	5.07	--	--
			1-6"	4.79	4.97	5.42
			6-12"	3.84	--	--
BN 10	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>4.90</b>	<b>5.59</b>	<b>6.71</b>
			0-1"	4.97	--	--
			1-6"	4.88	5.59	6.71
			6-12"	6.94	7.64	8.49
BN 11	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>5.58</b>	<b>3.80</b>	<b>9.88</b>
			0-1"	4.31	--	--
			1-6"	5.83	3.80	9.88
			6-12"	12.50	--	--

Data Source: SMI 1999a. Sample locations are shown in Figure 3.1.

The 0-6" values, i.e., the weighted averages of the 0-1" and 1-6" results where both samples were analyzed, were used as the basis for the background levels derived herein (see explanation on page 11 of this table).

-- Not analyzed or not reported; S-W denotes Site-Wide data set, used to define characteristics of surrounding soils.

**Table 3.3. SMI Background Investigation Sample Results Included in the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location	Applicable Data Set	Soil Group	Sample Depth	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
BN 12	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>7.18</b>	<b>8.90</b>	<b>12.70</b>
			0-1"	4.85	--	--
			1-6"	7.64	8.90	12.70
			6-12"	8.82	10.34	14.80
BN 15	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>5.55</b>	<b>6.73</b>	<b>6.63</b>
			0-1"	6.36	--	--
			1-6"	5.39	6.73	6.63
			6-12"	5.67	--	--
BN 16	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>2.88</b>	<b>3.65</b>	<b>4.68</b>
			0-1"	2.39	--	--
			1-6"	2.98	3.65	4.68
			6-12"	4.16	4.43	4.86
BN 17	Site-Wide Only	--	<b>0-6" Value</b>	<b>8.07</b>	<b>11.40</b>	<b>12.09</b>
			0-1"	7.59	--	--
			1-6"	8.17	11.40	12.09
			6-12"	8.17	--	--
BN 18	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>6.60</b>	<b>6.99</b>	<b>9.06</b>
			0-1"	10.29	--	--
			1-6"	5.86	6.99	9.06
			6-12"	6.95	6.57	8.83
BN 19	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>6.74</b>	<b>9.74</b>	<b>15.11</b>
			0-1"	9.27	--	--
			1-6"	6.23	9.74	15.11
			6-12"	5.05	--	--
BN 20	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>7.91</b>	<b>8.24</b>	<b>7.59</b>
			0-1"	4.96	--	--
			1-6"	8.50	8.24	7.59
			6-12"	12.93	11.86	11.16
BN 21	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>5.40</b>	<b>7.44</b>	<b>12.09</b>
			0-1"	4.57	--	--
			1-6"	5.57	7.44	12.09
			6-12"	4.76	--	--
BN 22	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>5.62</b>	<b>5.83</b>	<b>5.95</b>
			0-1"	5.67	--	--
			1-6"	5.61	5.83	5.95
			6-12"	2.05	2.10	2.73
BN 23	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>5.83</b>	<b>6.30</b>	<b>7.02</b>
			0-1"	4.83	--	--
			1-6"	6.03	6.30	7.02
			6-12"	4.53	--	--
BN 24	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>5.64</b>	<b>6.22</b>	<b>7.58</b>
			0-1"	3.64	--	--
			1-6"	6.04	6.22	7.58
			6-12"	5.37	5.37	7.37

**Table 3.3. SMI Background Investigation Sample Results Included in the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location	Applicable Data Set	Soil Group	Sample Depth	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
BN 25	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>7.69</b>	<b>7.70</b>	<b>8.35</b>
			0-1"	6.14	--	--
			1-6"	8.00	7.70	8.35
			6-12"	8.22	--	--
BN 37	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>2.65</b>	<b>3.96</b>	<b>4.51</b>
			0-1"	2.96	--	--
			1-6"	2.58	3.96	4.51
			6-12"	1.89	--	--
BN 38	Site-Wide Only	--	<b>0-6" Value</b>	<b>4.62</b>	<b>4.38</b>	<b>7.26</b>
			0-1"	6.99	--	--
			1-6"	4.15	4.38	7.26
			6-12"	2.64	3.37	5.20
BN 39	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>5.83</b>	<b>7.34</b>	<b>8.36</b>
			0-1"	11.65	--	--
			1-6"	4.67	7.34	8.36
			6-12"	3.81	--	--
BN 42	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>2.42</b>	<b>2.82</b>	<b>4.36</b>
			0-1"	4.91	--	--
			1-6"	1.92	2.82	4.36
			6-12"	1.92	3.30	4.74
BN 43	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>2.54</b>	<b>2.59</b>	<b>3.33</b>
			0-1"	2.65	--	--
			1-6"	2.51	2.59	3.33
			6-12"	2.38	--	--
BN 44	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>2.45</b>	<b>3.12</b>	<b>4.43</b>
			0-1"	2.96	--	--
			1-6"	2.35	3.12	4.43
			6-12"	2.04	2.31	4.91
BN 45	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>3.24</b>	<b>3.31</b>	<b>4.51</b>
			0-1"	4.70	--	--
			1-6"	2.95	3.31	4.51
			6-12"	3.33	--	--
BN 47	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>2.98</b>	<b>2.92</b>	<b>5.84</b>
			0-1"	3.62	--	--
			1-6"	2.85	2.92	5.84
			6-12"	3.44	--	--
BN 50	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>4.08</b>	<b>6.18</b>	<b>7.28</b>
			0-1"	3.67	--	--
			1-6"	4.16	6.18	7.28
			6-12"	6.94	7.11	8.06
BN 51	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>12.32</b>	<b>16.35</b>	<b>13.15</b>
			0-1"	16.43	--	--
			1-6"	11.50	16.35	13.15
			6-12"	11.62	--	--

**Table 3.3. SMI Background Investigation Sample Results Included in the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location	Applicable Data Set	Soil Group	Sample Depth	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
BN 52	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>2.45</b>	<b>2.54</b>	<b>3.91</b>
			0-1"	2.22	--	--
			1-6"	2.49	2.54	3.91
			6-12"	2.55	2.94	3.67
BN 53	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>3.81</b>	<b>4.69</b>	<b>8.57</b>
			0-1"	5.01	--	--
			1-6"	3.56	4.69	8.57
			6-12"	3.12	--	--
BN 54	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>4.89</b>	<b>5.97</b>	<b>8.65</b>
			0-1"	5.82	--	--
			1-6"	4.71	5.97	8.65
			6-12"	5.70	6.47	9.24
BN 55	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>4.92</b>	<b>4.96</b>	<b>6.97</b>
			0-1"	4.95	--	--
			1-6"	4.92	4.96	6.97
			6-12"	5.94	--	--
BN 56	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>5.74</b>	<b>6.34</b>	<b>8.63</b>
			0-1"	6.55	--	--
			1-6"	5.58	6.34	8.63
			6-12"	5.25	6.75	9.69
BN 57	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>7.48</b>	<b>10.10</b>	<b>15.13</b>
			0-1"	6.65	--	--
			1-6"	7.65	10.10	15.13
			6-12"	7.80	--	--
BN 58	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>3.93</b>	<b>4.97</b>	<b>7.96</b>
			0-1"	3.05	--	--
			1-6"	4.10	4.97	7.96
			6-12"	6.03	5.76	9.70
BN 59	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>6.69</b>	<b>9.53</b>	<b>11.90</b>
			0-1"	5.35	--	--
			1-6"	6.96	9.53	11.90
			6-12"	8.04	--	--
BN 60	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>8.19</b>	<b>13.13</b>	<b>19.96</b>
			0-1"	7.86	--	--
			1-6"	8.26	13.13	19.96
			6-12"	12.25	16.28	24.65
BN 61	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>3.76</b>	<b>5.73</b>	<b>6.53</b>
			0-1"	5.27	--	--
			1-6"	3.46	5.73	6.53
			6-12"	4.48	--	--
BN 65	Northern, S-W	Group 1	<b>0-6" Wtd. Avg.</b>	<b>2.56</b>	<b>2.91</b>	<b>3.68</b>
			0-1" (See Note 2)	2.96	--	--
			0-1" dup	5.36	5.12	6.80
			1-6"	2.00	2.46	3.06
			6-12"	1.86	1.85	2.55

**Table 3.3. SMI Background Investigation Sample Results Included in the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location	Applicable Data Set	Soil Group	Sample Depth	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
BN 66	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>2.67</b>	<b>2.24</b>	<b>2.39</b>
			0-1"	3.42	--	--
			1-6"	2.52	2.24	2.39
			6-12"	2.04	--	--
BN 67	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>2.78</b>	<b>2.78</b>	<b>3.73</b>
			0-1"	4.18	--	--
			1-6"	2.50	2.78	3.73
			6-12"	2.34	2.74	3.61
BN 68	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>3.16</b>	<b>2.59</b>	<b>3.52</b>
			0-1"	3.65	--	--
			1-6"	3.06	2.59	3.52
			6-12"	2.49	--	--
BN 69	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>2.43</b>	<b>2.11</b>	<b>3.36</b>
			0-1"	3.02	--	--
			1-6"	2.31	2.11	3.36
			6-12"	2.51	1.85	3.32
BN 70	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>2.29</b>	<b>2.47</b>	<b>4.12</b>
			0-1"	3.20	--	--
			1-6"	2.11	2.47	4.12
			6-12"	3.12	--	--
BN 71	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>4.67</b>	<b>5.23</b>	<b>7.63</b>
			0-1"	3.22	--	--
			1-6"	5.15	5.61	8.62
			1-6" dup	4.77	4.84	6.63
			6-12"	4.91	5.20	8.39
BN 72	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>5.35</b>	<b>5.65</b>	<b>8.28</b>
			0-1"	5.33	--	--
			1-6"	5.35	5.65	8.28
			6-12"	5.01	--	--
BN 73	Northern, S-W	Group 1	<b>0-6" Value</b>	<b>2.71</b>	<b>3.25</b>	<b>3.87</b>
			0-1"	2.79	--	--
			1-6"	2.69	3.25	3.87
			6-12"	2.73	3.06	3.80
BN 74	Northern, S-W	Group 2	<b>0-6" Value</b>	<b>4.89</b>	<b>6.50</b>	<b>6.74</b>
			0-1"	5.06	--	--
			1-6"	4.86	6.50	6.74
			6-12"	4.81	--	--
BN 75	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>5.33</b>	<b>6.86</b>	<b>8.95</b>
			0-1"	5.07	--	--
			1-6"	5.38	6.86	8.95
			6-12"	6.88	6.38	7.17
BS 1	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>5.54</b>	<b>7.69</b>	<b>8.23</b>
			0-1"	5.11	--	--
			1-6"	5.62	7.69	8.23

**Table 3.3. SMI Background Investigation Sample Results Included in the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location	Applicable Data Set	Soil Group	Sample Depth	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
BS 2	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>10.98</b>	<b>15.88</b>	<b>16.50</b>
			0-1"	8.86	--	--
			1-6"	11.40	15.88	16.50
BS 3	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>10.09</b>	<b>14.24</b>	<b>16.03</b>
			0-1"	5.70	--	--
			1-6"	10.97	14.24	16.03
BS 4	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>8.17</b>	<b>8.95</b>	<b>10.55</b>
			0-1"	9.09	--	--
			1-6"	7.99	8.95	10.55
BS 5	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>1.91</b>	<b>2.05</b>	<b>2.94</b>
			0-1"	2.10	--	--
			1-6"	1.88	2.05	2.94
BS 6	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>2.80</b>	<b>2.67</b>	<b>4.48</b>
			0-1"	4.97	--	--
			1-6"	2.36	2.67	4.48
BS 7	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>13.72</b>	<b>10.79</b>	<b>13.44</b>
			0-1"	16.43	--	--
			1-6"	13.18	10.79	13.44
BS 8	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>4.61</b>	<b>5.34</b>	<b>6.79</b>
			0-1"	6.33	--	--
			1-6"	4.26	5.34	6.79
BS 9	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>14.20</b>	<b>16.30</b>	<b>13.58</b>
			0-1"	11.69	--	--
			1-6"	14.70	16.30	13.58
BS 10	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>6.48</b>	<b>6.45</b>	<b>6.87</b>
			0-1"	6.60	--	--
			1-6"	6.45	6.45	6.87
BS 11	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>5.00</b>	<b>5.59</b>	<b>7.32</b>
			0-1"	4.47	--	--
			1-6"	5.11	5.59	7.32
BS 12	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>3.71</b>	<b>3.92</b>	<b>5.46</b>
			0-1"	3.07	--	--
			1-6"	3.84	3.92	5.46
BS 13	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>1.75</b>	<b>2.21</b>	<b>2.79</b>
			0-1"	2.13	--	--
			1-6"	1.68	2.21	2.79
BS 14	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>2.58</b>	<b>2.86</b>	<b>3.66</b>
			0-1"	2.25	--	--
			1-6"	2.65	2.86	3.66
BS 15	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>1.74</b>	<b>2.00</b>	<b>2.66</b>
			0-1"	1.49	--	--
			1-6"	1.79	2.00	2.66
BS 16	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>4.98</b>	<b>6.20</b>	<b>7.30</b>
			0-1"	5.15	--	--
			1-6"	4.95	6.20	7.30

**Table 3.3. SMI Background Investigation Sample Results Included in the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location	Applicable Data Set	Soil Group	Sample Depth	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
BS 17	Site-Wide Only	--	<b>0-6" Value</b>	<b>2.08</b>	<b>5.36</b>	<b>3.31</b>
			0-1"	2.79	--	--
			1-6"	1.94	5.36	3.31
BS 18	Site-Wide Only	--	<b>0-6" Value</b>	<b>2.15</b>	<b>3.51</b>	<b>3.03</b>
			0-1"	3.04	--	--
			1-6"	1.97	3.51	3.03
BS 19	Site-Wide Only	--	<b>0-6" Value</b>	<b>3.36</b>	<b>3.13</b>	<b>4.85</b>
			0-1"	6.52	--	--
			1-6"	2.73	3.13	4.85
BS 20	Site-Wide Only	--	<b>0-6" Value</b>	<b>6.97</b>	<b>6.60</b>	<b>29.36</b>
			0-1"	9.92	--	--
			1-6"	6.38	6.60	29.36
BS 21	Site-Wide Only	--	<b>0-6" Value</b>	<b>3.53</b>	<b>3.61</b>	<b>5.86</b>
			0-1"	3.68	--	--
			1-6"	3.50	3.61	5.86
BS 22	Site-Wide Only	--	<b>0-6" Value</b>	<b>2.91</b>	<b>4.71</b>	<b>12.53</b>
			0-1"	3.36	--	--
			1-6"	2.83	4.71	12.53
BS 23	Site-Wide Only	--	<b>0-6" Value</b>	<b>4.02</b>	<b>3.93</b>	<b>5.81</b>
			0-1"	3.51	--	--
			1-6"	4.12	3.93	5.81
BS 24	Site-Wide Only	--	<b>0-6" Value</b>	<b>10.05</b>	<b>22.00</b>	<b>58.00</b>
			0-1"	3.92	--	--
			1-6"	11.28	22.00	58.00
BS 25	Site-Wide Only	--	<b>0-6" Value</b>	<b>4.08</b>	<b>4.13</b>	<b>6.69</b>
			0-1"	4.44	--	--
			1-6"	4.01	4.13	6.69
BS 26	Site-Wide Only	--	<b>0-6" Value</b>	<b>7.90</b>	<b>10.08</b>	<b>11.83</b>
			0-1"	6.62	--	--
			1-6"	8.16	10.08	11.83
BS 27	Site-Wide Only	--	<b>0-6" Value</b>	<b>8.51</b>	<b>11.55</b>	<b>17.84</b>
			0-1"	6.31	--	--
			1-6"	8.95	11.55	17.84
BS 28	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>6.54</b>	<b>6.56</b>	<b>11.96</b>
			0-1"	8.01	--	--
			1-6"	6.25	6.56	11.96
BS 29	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>4.04</b>	<b>3.59</b>	<b>4.62</b>
			0-1"	3.29	--	--
			1-6"	4.19	3.59	4.62
BS 30	Site-Wide Only	--	<b>0-6" Value</b>	<b>17.06</b>	<b>18.06</b>	<b>16.00</b>
			0-1"	10.80	--	--
			1-6"	18.31	18.06	16.00
BS 31	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>5.40</b>	<b>6.28</b>	<b>7.32</b>
			0-1"	4.76	--	--
			1-6"	5.53	6.28	7.32

**Table 3.3. SMI Background Investigation Sample Results Included in the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location	Applicable Data Set	Soil Group	Sample Depth	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
BS 33	Site-Wide Only	--	<b>0-6" Value</b>	<b>1.35</b>	<b>1.24</b>	<b>2.67</b>
			0-1"	1.77	--	--
			1-6"	1.27	1.24	2.67
BS 34	Site-Wide Only	--	<b>0-6" Value</b>	<b>3.45</b>	<b>3.56</b>	<b>5.44</b>
			0-1"	3.08	--	--
			1-6"	3.52	3.56	5.44
BS 35	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>1.36</b>	<b>1.30</b>	<b>2.37</b>
			0-1"	1.76	--	--
			1-6"	1.28	1.30	2.37
BS 36	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>1.48</b>	<b>1.46</b>	<b>2.65</b>
			0-1"	1.81	--	--
			1-6"	1.41	1.46	2.65
BS 37	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>1.51</b>	<b>1.93</b>	<b>2.88</b>
			0-1"	1.70	--	--
			1-6"	1.47	1.93	2.88
BS 38	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>1.49</b>	<b>1.68</b>	<b>2.84</b>
			0-1"	1.57	--	--
			1-6"	1.47	1.68	2.84
BS 39	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>1.95</b>	<b>2.51</b>	<b>3.80</b>
			0-1"	1.74	--	--
			1-6"	2.00	2.51	3.80
BS 40	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>2.03</b>	<b>2.18</b>	<b>2.65</b>
			0-1"	1.92	--	--
			1-6"	2.06	2.18	2.65
BS 41	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>3.23</b>	<b>4.35</b>	<b>6.11</b>
			0-1"	2.26	--	--
			1-6"	3.42	4.35	6.11
BS 42	Site-Wide Only	Group 1	<b>0-6" Wtd. Avg.</b>	<b>2.27</b>	<b>2.35</b>	<b>3.21</b>
			0-1" (See Note 2)	1.32	--	--
			0-1" dup	4.61	5.63	7.59
			1-6"	1.80	1.69	2.34
BS 43	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>1.73</b>	<b>1.99</b>	<b>2.62</b>
			0-1"	2.16	--	--
			1-6"	1.64	1.99	2.62
BS 44	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>4.04</b>	<b>4.40</b>	<b>5.75</b>
			0-1"	3.40	--	--
			1-6"	4.17	4.40	5.75
BS 45	Site-Wide Only	Group 1	<b>0-6" Value</b>	<b>3.19</b>	<b>3.99</b>	<b>5.45</b>
			0-1"	2.18	--	--
			1-6"	3.39	3.99	5.45
BS 46	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>3.95</b>	<b>6.60</b>	<b>11.33</b>
			0-1"	4.68	--	--
			1-6"	3.80	6.60	11.33

**Table 3.3. SMI Background Investigation Sample Results Included in the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location	Applicable Data Set	Soil Group	Sample Depth	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
BS 47	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>5.33</b>	<b>5.07</b>	<b>8.96</b>
			0-1"	3.66	--	--
			1-6"	5.66	5.07	8.96
BS 48	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>2.88</b>	<b>2.29</b>	<b>3.36</b>
			0-1"	1.47	--	--
			1-6"	3.16	2.29	3.36
BS 49	Site-Wide Only	--	<b>0-6" Value</b>	<b>2.98</b>	<b>2.07</b>	<b>2.80</b>
			0-1"	1.76	--	--
			1-6"	3.22	2.07	2.80
BS 50	Site-Wide Only	--	<b>0-6" Value</b>	<b>1.88</b>	<b>1.87</b>	<b>2.52</b>
			0-1"	2.01	--	--
			1-6"	1.85	1.87	2.52
BS 51	Site-Wide Only	--	<b>0-6" Value</b>	<b>2.22</b>	<b>2.58</b>	<b>3.62</b>
			0-1"	2.57	--	--
			1-6"	2.15	2.58	3.62
BS 52	Site-Wide Only	--	<b>0-6" Value</b>	<b>3.02</b>	<b>4.26</b>	<b>4.59</b>
			0-1"	2.19	--	--
			1-6"	3.19	4.26	4.59
BS 53	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>1.72</b>	<b>2.21</b>	<b>3.85</b>
			0-1"	2.29	--	--
			1-6"	1.61	2.21	3.85
BS 54	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>7.51</b>	<b>8.28</b>	<b>11.67</b>
			0-1"	9.93	--	--
			1-6"	8.77	10.52	15.72
			1-6" dup	5.29	6.03	7.61
BS 55	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>7.30</b>	<b>9.36</b>	<b>12.42</b>
			0-1"	8.80	--	--
			1-6"	7.00	9.36	12.42
BS 56	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>10.49</b>	<b>10.50</b>	<b>9.13</b>
			0-1"	6.74	--	--
			1-6"	11.24	10.50	9.13
BS 57	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>18.01</b>	<b>19.95</b>	<b>21.16</b>
			0-1"	14.63	--	--
			1-6"	18.69	19.95	21.16
BS 58	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>8.45</b>	<b>8.71</b>	<b>12.48</b>
			0-1"	8.62	--	--
			1-6"	8.41	8.71	12.48
BS 59	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>6.57</b>	<b>5.06</b>	<b>6.81</b>
			0-1"	5.17	--	--
			1-6"	6.85	5.06	6.81
BS 60	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>2.36</b>	<b>3.04</b>	<b>4.35</b>
			0-1"	3.47	--	--
			1-6"	2.14	3.04	4.35

**Table 3.3. SMI Background Investigation Sample Results Included in the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location	Applicable Data Set	Soil Group	Sample Depth	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
BS 61	Site-Wide Only	Group 2	<b>0-6" Value</b>	<b>4.13</b>	<b>4.40</b>	<b>4.89</b>
			0-1"	3.60	--	--
			1-6"	4.24	4.40	4.89
BS 62	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>3.05</b>	<b>1.77</b>	<b>2.56</b>
			0-1"	2.39	--	--
			1-6"	3.18	1.77	2.56
BS 63	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>1.90</b>	<b>1.65</b>	<b>2.38</b>
			0-1"	1.47	--	--
			1-6"	1.99	1.65	2.38
BS 64	Site-Wide Only	Group 3	<b>0-6" Wtd. Avg.</b>	<b>2.13</b>	<b>1.90</b>	<b>2.77</b>
			0-1" (See Note 2)	1.15	--	--
			0-1" dup	5.97	4.51	6.31
			1-6"	1.37	1.38	2.06
BS 65	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>2.37</b>	<b>1.69</b>	<b>2.32</b>
			0-1"	3.45	--	--
			1-6"	2.15	1.69	2.32
BS 66	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>3.25</b>	<b>3.43</b>	<b>5.11</b>
			0-1"	2.54	--	--
			1-6"	3.39	3.43	5.11
BS 67	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>1.75</b>	<b>2.24</b>	<b>3.54</b>
			0-1"	1.95	--	--
			1-6"	1.71	2.24	3.54
BS 68	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>1.88</b>	<b>2.03</b>	<b>3.16</b>
			0-1"	1.93	--	--
			1-6"	1.87	2.03	3.16
BS 69	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>3.44</b>	<b>3.85</b>	<b>4.41</b>
			0-1"	2.85	--	--
			1-6"	3.56	3.85	4.41
BS 70	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>3.76</b>	<b>4.20</b>	<b>5.14</b>
			0-1"	5.28	--	--
			1-6"	3.46	4.20	5.14
BS 71	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>2.46</b>	<b>2.85</b>	<b>3.68</b>
			0-1"	2.33	--	--
			1-6"	2.48	2.85	3.68
BS 72	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>6.08</b>	<b>2.64</b>	<b>3.14</b>
			0-1"	5.12	--	--
			1-6"	6.27	2.64	3.14
BS 73	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>3.14</b>	<b>3.44</b>	<b>5.06</b>
			0-1"	1.93	--	--
			1-6"	2.08	1.68	2.67
			1-6" dup	4.69	5.21	7.46
BS 74	Site-Wide Only	Group 3	<b>0-6" Value</b>	<b>2.07</b>	<b>1.92</b>	<b>2.82</b>
			0-1"	1.61	--	--
			1-6"	2.16	1.92	2.82

**Table 3.3. SMI Background Investigation Sample Results Included in the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location	Applicable Data Set	Soil Group	Sample Depth	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
BS 75	Site-Wide Only	Group 3	0-6" Value	2.68	2.60	3.43
			0-1"	3.05	--	--
			1-6"	2.60	2.60	3.43

**Note**

1. As indicated previously, the 0-6" values were used as the basis for the background levels derived herein for both the northern cleanup area, as well as for the site-wide (S-W) characterization of surrounding soils. For Ra-226, the 0-6" values are the weighted averages of the 0-1" and 1-6" sample results--i.e., (0-1" datum \* 1/6) + (1-6" datum\*5/6). For Th-230 and U-nat, this same averaging approach was used in cases where both the 0-1" and 1-6" samples were analyzed. However, because the majority of the 0-1" samples were not analyzed for Th-230 and U-nat, the 1-6" datum was used to define the corresponding 0-6" depth profile database value.
2. Soil groups listed above were based on those reported in Table 6.2 (*Average Ra-226 Activity for each Soil Group*) of SMI's March 1999 background report. As indicated above, some samples were not classified as to soil type in SMI's report.
3. Uncertainties are documented in SMI's background report (Tables 4.3, 5.5, and 5.6) and are not reiterated here.
4. Some minor discrepancies may be found when comparing the data listed above with those reported in the tables included in SMI's March 1999 background evaluation. These differences are attributable to one or more of the following data management factors:
  - (a) U-nat values presented by SMI were set equal to U-234 + U-238 (the U-235 component, although analyzed, was excluded from their U-nat derivation). In this report, U-nat represents the sum of U-234, U-235, and U-238. The corresponding U-nat uncertainty is equivalent to the square root of the sum of squares reported for U-234, U-235, and U-238.
  - (b) Analytical results for field duplicate sample analyses are reported above. These results were not listed in SMI's tables, nor was the duplicate process described in any of their documentation. Consequently, these data could have been from collocated samples, rather than from true field duplicates. In general, for this report, duplicate analytical results were averaged. The only exceptions were the 0-1" duplicate pairs for samples BN 65, BS 42, BS 64. For each of these pairs, the first sample was analyzed for Ra-226 only, whereas the duplicate was analyzed for all constituents (Ra-226, Th-230, and U-nat). In this case, the sample with data for all analytes was used, and the other was excluded (i.e., Ra-226 results were not averaged). Note that SMI reported results for the first analysis only, i.e., the sample for which only Ra-226 was analyzed.
  - (c) Data for samples BS 17 and BS 20 were listed in SMI Table 4.3 (laboratory data). However, they were not included in either Table 5.6, which identified SMI's accepted background sample locations, or in Table 5.5, which listed those samples that were excluded from the background data set. These results are listed above, however, as they were included in the final background data set.

**Definitions**

- not analyzed or not reported
- dup duplicate sample
- S-W Site-Wide data set

**Table 3.4. Windblown Scoping Survey Samples Included in the Final Background Data Set: Northernmost (A Grid) Results Only, Gas Hills, Wyoming Site.**

Original Data (0-15 cm Depth)			Data Used in the Background Database		
Sample Prefix	Sample ID	Ra-226 (pCi/g)	Sample Code	Ra-226 (pCi/g)	Basis
A21	A2150179	10.31	A21 E	10.31	original datum
A21	A2185214	5.43	A21 W	5.43	" "
A22	A2274303	4.65	A22	4.65	" "
A23	A2331360	4.28	A23 avg	5.01	average of the two A23 samples
A23	A2359388	5.73			
A26	A2625654	24.74	A26 E avg	36.45	Eastern grid average, used in site-wide data base only. Although not affected, this datum was not used in northern database, as is extreme outlier
A26	A2628657	63.57			
A26	A2629658	46.72			
A26	A2689718	10.77			
A26	A2633662	19.17	A26 W avg	15.98	average of A2633662, A2635664, A2664693, and A2666695, corresponding to western portion of A26 sample/grid area.
A26	A2635664	22.16			
A26	A2664693	13.38			
A26	A2666695	9.19			
A27	A2751780	8.14	A27 W	8.14	original datum
A27	A2760789	10.42	A27 E avg	9.69	average of A2760789 and A2790819, corresponding to eastern A27 area
A27	A2790819	8.96			
A34	A3484515	13.98	A34	13.98	original datum
A36	A3636667	7.60	A36	7.60	" "
A37	A3757788	5.76	A37 avg	6.58	average of the two A37 samples
A37	A3788819	7.39			
A38	A3836867	10.72	A38	10.72	original datum
A43	A4321343	7.88	A43	7.88	" "
A44	A4423445	8.95	A44 avg	9.87	average of the two A44 samples
A44	A4446468	10.79			
A45	A4587609	4.35	A45	4.35	original datum
A46	A4650672	4.17	A46	4.17	" "
A47	A4775797	3.72	A47	3.72	" "
A53	A5365456	10.81	A53	10.81	" "
A55	A5546637	7.19	A55	7.19	" "
A57	A5751842	11.56	A57	11.56	" "
A67	A6731762	4.51	A67	4.71	average of the two A67 samples
A67	A6759790	4.90	A67		
A75	A7581612	6.10	A75	6.10	original datum
A76	A7650681	7.36	A76	7.36	" "
A78	A7816810	4.76	A78	4.76	" "
A82	A8239194	7.39	A82	7.39	" "
A83	A8322353	8.70	A83 E	8.70	" "
A83	A8368399	6.13	A83 W	6.13	" "
A84	A8415446	8.48	A84 avg	10.25	average of the two A84 samples
A84	A8443474	12.01			
A94	A9475497	8.55	A94		datum not used due to location coinciding with other excluded samples -e.g., the B-grid data
n = 41; average = 11.3			Average: 8.9 (n = 28)		

Data Source: SMI 1999b. Corresponding sample locations are shown in Figure 3.3.

Outlined areas denote that the average of the boxed values was used in the database; see right column.

**Table 3.5 Background Sampling Results for Undisturbed Areas Included in the Background Data Set: 1995-1996 Characterization Investigation Gas Hills, Wyoming Site**

Sample ID <sup>/a/</sup>	Sample Location	Sample Type <sup>/a/</sup>	Sample Depth (cm) <sup>/b/</sup>	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
B-01B1	B-01	Soil	0-5	37.0	38.0	8.8
B-01B2	B-01	Soil	5-15	69.0	74.0	23.6
<b>B-01</b>	<b>B-01</b>	<b>Soil</b>	<b>Wtd. Avg.</b>	<b>58.3</b>	<b>62.0</b>	<b>18.7</b>
B-04B1	B-04	Soil	0-5	20.0	19.0	48.1
B-04B2	B-04	Soil	5-15	36.0	38.0	41.7
<b>B-04</b>	<b>B-04</b>	<b>Soil</b>	<b>Wtd. Avg.</b>	<b>30.7</b>	<b>31.7</b>	<b>43.8</b>
B-09B1	B-09	Soil	0-5	13.0	13.0	11.0
B-09B2	B-09	Soil	5-15	23.0	18.0	16.6
<b>B-09</b>	<b>B-09</b>	<b>Soil</b>	<b>Wtd. Avg.</b>	<b>19.7</b>	<b>16.3</b>	<b>14.7</b>
B-13A1	B-13	Soil	0-5	3.6	3.1	6.2
B-13A2	B-13	Soil	5-15	2.0	1.8	3.0
<b>B-13</b>	<b>B-13</b>	<b>Soil</b>	<b>Wtd. Avg.</b>	<b>2.5</b>	<b>2.2</b>	<b>4.1</b>
B-17A1	B-17	Soil	0-5	6.7	8.0	7.6
B-17A2	B-17	Soil	5-15	6.8	4.6	7.3
<b>B-17</b>	<b>B-17</b>	<b>Soil</b>	<b>Wtd. Avg.</b>	<b>6.8</b>	<b>5.7</b>	<b>7.4</b>
B-18A1	B-18	Soil	0-5	2.8	4.4	4.5
B-18A2	B-18	Soil	5-15	4.2	5.6	6.4
<b>B-18</b>	<b>B-18</b>	<b>Soil</b>	<b>Wtd. Avg.</b>	<b>3.7</b>	<b>5.2</b>	<b>5.8</b>
B-19A1	B-19	Soil	0-5	2.8	4.2	3.4
B-19A2	B-19	Soil	5-15	4.8	5.3	5.2
<b>B-19</b>	<b>B-19</b>	<b>Soil</b>	<b>Wtd. Avg.</b>	<b>4.1</b>	<b>4.9</b>	<b>4.6</b>
B-20A1	B-20	Soil	0-5	2.8	2.9	1.8
B-20A2	B-20	Soil	5-15	2.2	2.4	1.4
<b>B-20</b>	<b>B-20</b>	<b>Soil</b>	<b>Wtd. Avg.</b>	<b>2.4</b>	<b>2.6</b>	<b>1.5</b>
B-22A1	B-22	Soil	0-5	5.6	3.7	5.0
B-22A2	B-22	Soil	5-15	3.4	3.0	2.8
<b>B-22 <sup>/c/</sup></b>	<b>B-22</b>	<b>Soil</b>	<b>Wtd. Avg.</b>	<b>4.1</b>	<b>3.2</b>	<b>3.5</b>

Data Source: Umetco 1997. Sample locations are shown on Figure 3.1 and Appendix A, Figure A.1.

**Note:**

<sup>/a/</sup> For locations B-01, B-04, and B-09, data for corresponding outcrop samples are provided in Table 3.6. As indicated in Table 3.6, outcrop data were excluded from the final background data set.

<sup>/b/</sup> Weighted averages representing the 0-15 cm (0-6") depth profile were used to calculate the site-specific background values derived herein. Although 0-5 cm and 5-15 cm data were evaluated, the 0-15 cm (weighted average) data were used consistent with NRC guidance and precedent. n = 9 data points used in the background analysis (see values listed in bold).

<sup>/c/</sup> Of the nine sample locations listed above, only B-22 is included in the background database as a north area sample.

wtd. avg. – weighted average

**Table 3.6 Background Sampling Results for Undisturbed Areas Excluded from the Background Data Set: 1995-1996 Characterization Investigation Gas Hills, Wyoming Site**

Sample ID <sup>/a/</sup>	Sample Location	Sample Type <sup>/a/</sup>	Sample Depth (cm)	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
B-01A1	B-01	Outcrop	NA	5.7	5.2	8.3
B-01A2	B-01	Outcrop	NA	6.1	5.5	6.9
B-02	B-02	Outcrop	NA	6.7	7.1	12.7
B-03	B-03	Outcrop	NA	9.9	7.9	41.8
B-04A	B-04	Outcrop	NA	35.0	27.0	106.0
B-05	B-05	Outcrop	NA	11.0	11.0	22.5
B-06	B-06	Outcrop	NA	94.0	98.0	188
B-07	B-07	Outcrop	NA	8.2	12.0	10.6
B-08A1 <sup>/b/</sup>	B-08	Soil	0-5	605.0	594.0	186.0
B-08A2 <sup>/b/</sup>	B-08	Soil	5-15	500.0	571.0	213.0
B-09A	B-09	Outcrop	NA	6.1	7.4	188.0
B-11	B-11	Outcrop	NA	8.6	7.8	12.9
B-12	B-12	Outcrop	NA	3.2	2.6	6.4
B-21A1 <sup>/c/</sup>	B-21	Soil	0-5	1.6	8.0	9.3
B-21A2 <sup>/c/</sup>	B-21	Soil	5-15	8.3	5.6	5.3

Data Source: Umetco 1997. Sample locations are shown on Figure 3.1 and Appendix A, Figure A.1.

**Note:**

<sup>/a/</sup> For all areas (undisturbed and reclaimed), outcrop data were excluded from the final data set because they are not considered representative of surrounding soils (see following tables).

<sup>/b/</sup> Although previous evaluations have demonstrated that the B-08 sample location has not been impacted by 11e.(2) materials, associated data were nonetheless excluded due to the extreme magnitude of the radionuclides detected.

<sup>/c/</sup> Although not considered affected by tailings materials, location B-21 was excluded from the background database due to its proximity to the tailings impoundment, and to be consistent (from a spatial standpoint) with the exclusion of nearby samples BN1 and BN5 (see Figure 3.1).

**Table 3.7 Background Sampling Results for Reclaimed Areas West of the Gas Hills Site: 1995-1996 Investigation, Gas Hills, Wyoming Site.**

Sample ID	Sample Type	Sample Depth (cm)	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
B-57	Soil	0-15	12.0	13.0	14.0
B-58	Soil	0-15	18.0	25.0	53.0
B-59	Soil	0-15	22.0	--	33.0
B-61	Soil	0-15	38.0	20.0	85.0
B-62	Soil	0-15	37.0	35.0	54.0
B-63	Soil	0-15	20.0	19.0	47.0
B-64	Soil	0-15	31.0	0.6	49.0
B-65	Soil	0-15	5.2	12.0	27.0
B-66	Soil	0-15	18.0	16.0	29.0
B-67	Soil	0-15	19.0	14.0	35.0
B-68	Soil	0-15	22.0	22.0	41.0
B-69	Soil	0-15	14.0	23.0	70.0
B-70	Soil	0-15	23.0	30.0	53.0

*Data Source: Umetco 1997. Sample locations are shown on Figure 3.1 and Appendix A, Figure A.1.*

n = 13 data points used in the background analysis. All samples listed above are considered valid for inclusion in the final background data set.

-- Indicates that the B-59 datum (3.8R pCi/g) was rejected in validating laboratory analytical results.

**Table 3.8 Background Sampling Results for Reclaimed Areas East of the Gas Hills Site: 1995-1996 Investigation, Gas Hills, Wyoming Site.**

Sample ID	Sample Type	Sample Depth (cm)	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)
B-23	Soil	0-15	11.0	12.0	18.0
B-24	Soil	0-15	6.2	6.1	8.8
B-25	Soil	0-15	9.3	9.3	17.0
B-26	Soil	0-15	24.0	14.0	28.0
B-27	Soil	0-15	15.0	14.0	20.0
B-29	Soil	0-15	2.5	3.1	3.4
B-30	Soil	0-15	3.4	3.2	3.9
B-31	Soil	0-15	8.7	7.0	11.0
B-32	Soil	0-15	5.0	4.3	4.3
B-33	Soil	0-15	6.1	6.1	6.8
B-34	Soil	0-15	13.0	13.0	16.0
B-35	Soil	0-15	2.7	2.5	2.7
B-36	Soil	0-15	6.4	7.1	5.5
B-37	Soil	0-15	5.9	5.3	5.0
B-38	Soil	0-15	1.8	2.3	2.4
B-39	Soil	0-15	2.6	2.4	2.5
B-40	Soil	0-15	3.1	3.6	3.4
B-41	Soil	0-15	3.7	3.4	4.3
B-43	Soil	0-15	6.0	5.8	6.4
B-44	Soil	0-15	3.2	2.7	2.8
B-45	Soil	0-15	2.7	2.7	2.9
B-46	Soil	0-15	2.6	2.8	3.4
B-47	Soil	0-15	1.5	1.3	1.6
B-48	Soil	0-15	1.6	1.6	2.4
B-49	Soil	0-15	4.4	4.9	4.2
B-50	Soil	0-15	4.5	5.5	4.5
B-53	Soil	0-15	3.7	2.3	4.7
B-54	Soil	0-15	1.9	1.6	2.2
B-55	Soil	0-15	1.0	1.7	2.2
B-56	Soil	0-15	1.1	1.0	1.3

Data Source: Umetco 1997. Sample locations are shown on Figure 3.1 and Appendix A, Figure A.1.

n = 30 data points used in the background analysis. All samples listed above are considered valid for inclusion in the final background data set.

**Table 4.1. Summary Statistics for Site-Wide Background Data Set: 0-6" Depth Profile, Gas Hills, Wyoming Site.**

**General Descriptive Statistics**

	<u>Valid N</u>	<u>Mean</u>	<u>Geometric Mean (GM)</u>	<u>Confid. +95.000%</u>	<u>Standard Deviation</u>	<u>Variance</u>	<u>Skewness</u>	<u>Kurtosis</u>	<u>mean + s.d.</u>	<u>GM + geo. s.d.</u>
Ra-226, 0-6"	207	6.93	4.99	7.93	7.31	53.37	3.39	15.56	14.23	10.67
Th-230, 0-6"	177	6.89	4.92	7.97	7.28	53.05	3.62	19.91	14.18	10.70
U-nat, 0-6"	179	10.34	6.71	12.24	12.93	167.1	3.10	10.83	23.26	15.65

**Ordinal Descriptive Statistics**

	<u>Minimum</u>	<u>Maximum</u>	<u>Range</u>	<u>10th percentile</u>	<u>25th percentile</u>	<u>50th %ile (median)</u>	<u>75th percentile</u>	<u>90th percentile</u>	<u>Interquartile Range (IQR)</u>	<i>Basis #1</i> <u>Median plus IQR</u>
Ra-226, 0-6"	1.00	58.33	57.33	1.91	2.80	4.71	7.69	14.20	4.89	9.60
Th-230, 0-6"	1.00	62.00	61.00	2.00	2.67	4.71	7.44	15.88	4.77	9.48
U-nat, 0-6"	1.30	85.00	83.70	2.66	3.54	5.81	11.67	21.16	8.13	13.9

**Evaluation of Normality: Ra-226\***

<u>Test for Normality</u>	<u>Statistic</u>	<u>Value</u>	<u>Probability</u>	<u>Conclusion</u>
Kolmogorov-Smirnov (K-S)	D Statistic	0.2186	p < 0.01	Reject hypothesis of normal distribution.
Lilliefors	--	--	p < 0.01	" "
Shapiro-Wilk W Test	W Statistic	0.6631	p < 0.001	" "

*Proposed Values*

<u>Average of Basis 1 &amp; 2</u>
10
10
15

(2 sig. figures)

\*Similar results (p values) were derived for Th-230 and U-nat, thus the normal distribution does not apply to these analytes as well.

**Descriptive Statistics for Log-Transformed Data**

	<u>Valid N</u>	<u>Mean</u>	<u>Standard Deviation</u>	<u>Confid. 95.00%</u>	<u>Confid. 99.00%</u>	<u>Standard Error</u>	<u>Skewness</u>	<u>Kurtosis</u>	<u>geo. mean (GM) + s.d.</u>	<i>Basis #2</i> <u>Detransformed GM + s.d.</u>
log 10 Ra-226, 0-6"	207	1.61	0.76	1.71	1.75	0.05	0.58	0.21	2.37	10.7
log 10 Th-230, 0-6"	177	1.59	0.78	1.71	1.74	0.06	0.53	(0.01)	2.37	10.7
log 10 U-nat, 0-6"	179	1.90	0.85	2.03	2.07	0.06	0.79	0.41	2.75	15.7

The log transformation passed both the K-S and Lilliefors tests of normality ( $p > .2$ ); however, it did not pass the Shapiro-Wilks' test of normality. This could mean that the Shapiro-Wilks' test was too powerful (had too much resolution). Nonetheless, examination of the plotted data shown in Figure 4.1, combined with the K-S/Lilliefors test results and kurtosis values, strongly indicates that these data are lognormally distributed.

**10**: Boxed and shaded values are considered most representative of background conditions in surrounding soils (Ra-226 in bold).

**Table 4.2. Summary Statistics for All Radionuclide Parameters and Depth Profiles: Site-Wide Background Data Set  
Gas Hills, Wyoming Site**

Statistical Parameter	Ra-226 Sample Results				Th-230 Sample Results				U-nat Sample Results			
	0-6"	0-1"	1-6"	6-12"	0-6"	0-1"	1-6"	6-12"	0-6"	0-1"	1-6"	6-12"
Valid N	207	127	136	54	177	9	136	30	179	9	136	30
Mean	6.93	4.90	5.13	5.04	6.89	8.58	5.85	5.38	10.34	10.27	7.68	6.98
Geometric Mean (GM)	4.99	4.15	4.06	4.39	4.92	6.94	4.55	4.62	6.71	8.82	6.02	5.98
Median	4.71	4.31	3.83	4.47	4.71	5.63	4.37	5.28	5.81	7.55	5.78	6.11
Standard Deviation	7.31	3.11	4.48	2.80	7.28	6.85	5.04	3.21	12.93	7.65	7.29	4.47
Variance	53.37	9.69	20.06	7.86	53.05	46.88	25.41	10.30	167.12	58.53	53.13	19.96
Standard Error (of mean)	0.51	0.28	0.38	1.22	0.55	2.28	0.43	2.06	0.97	2.55	0.63	1.23
Skewness	3.39	1.78	3.60	1.26	3.62	1.65	2.91	1.62	3.10	2.61	4.12	2.31
Kurtosis	15.56	3.82	19.62	1.31	19.91	1.31	12.67	3.61	10.83	7.15	22.97	7.74
Minimum	1.00	1.47	1.27	1.86	1.00	3.86	1.24	1.85	1.30	5.62	1.80	2.24
10th percentile	1.91	1.92	1.85	2.05	2.00	3.86	1.99	2.14	2.66	5.62	2.67	2.77
25th percentile	2.80	2.79	2.51	2.73	2.67	4.51	2.62	3.00	3.54	6.32	3.58	3.80
50th percentile	4.71	4.31	3.83	4.47	4.71	5.63	4.37	5.28	5.81	7.55	5.78	6.11
75th percentile	7.69	5.82	6.04	6.03	7.44	6.93	6.67	6.75	11.67	10.32	8.73	8.77
90th percentile	14.20	9.09	8.95	8.22	15.88	22.58	11.40	8.99	21.16	29.91	13.44	10.43
Maximum	58.33	16.92	37.00	12.93	62.00	22.58	38.00	16.28	85.00	29.91	58.00	24.65

**Note:**

Summary statistics for the 0-6" depth profile should not be directly compared to those obtained for other depths because the sample numbers are different. The data comprising the 0-6" data set are defined as follows:

1. *SMI 1999a Background Investigation* - weighted average of the 0-1" and 1-6" samples (where both depths were analyzed, e.g., for Ra-226) or, in the case of most Th-230 and U-nat results, the 1-6" datum was used given the lack of 0-1" sample results (n=127);
2. *SMI 1999b Windblown Scoping Survey* -- Results for the 0-15 cm samples listed in the right hand column of Table 3.4 (n=28);
3. *Umetco 1996 Investigation* -- Weighted average results for the 9 undisturbed area samples (Table 3.5) and 0-15 cm results for the 43 samples collected from reclaimed areas located west and east of the site (Tables 3.7 and 3.8, respectively).

Skewness is a measure of the symmetry of the distribution of values. If the distribution is symmetrical (i.e., normal), then the skewness is equal to zero. Similarly, kurtosis measures the "peakedness" of a distribution. If the distribution follows the standard normal distribution, then the value of the kurtosis is zero.

**Table 4.3. Summary Statistics for Northern Cleanup Area Background Samples: 0-6" Depth Profile, Gas Hills, Wyoming Site.**

**General Descriptive Statistics**

	<u>Valid N</u>	<u>Mean</u>	<u>Geometric Mean</u>	<u>Standard Deviation</u>	<u>Mean + std. dev.</u>	<u>Variance</u>	<u>Confid. +95.000%</u>	<u>Confid. 99.00%</u>	<u>Skewness</u>	<u>Kurtosis</u>
Ra-226, 0-6"	69	5.89	5.24	2.96	8.85	8.78	6.60	6.83	1.18	1.39
Th-230, 0-6"	42	5.38	4.76	2.95	8.34	8.73	6.30	6.61	1.75	4.13
U-nat, 0-6"	42	7.00	6.25	3.63	10.63	13.17	8.14	8.52	1.53	3.00

**Ordinal Descriptive Statistics**

	<u>Minimum</u>	<u>Maximum</u>	<u>Range</u>	<u>10th percentile</u>	<u>25th percentile</u>	<u>50th %ile (median)</u>	<u>75th percentile</u>	<u>90th percentile</u>	<u>Interquartile Range (IQR)</u>	<u>Median plus IQR</u>
Ra-226, 0-6"	1.78	15.98	14.20	2.56	3.82	5.01	7.39	10.31	3.57	8.57
Th-230, 0-6"	2.11	16.35	14.24	2.57	3.12	4.97	6.30	8.90	3.18	8.15
U-nat, 0-6"	2.39	19.96	17.57	3.52	4.12	6.65	8.28	12.09	4.16	10.81

**Evaluation of Normality: Ra-226\***

<u>Test for Normality</u>	<u>Statistic</u>	<u>Value</u>	<u>Probability</u>	<u>Conclusion</u>
Shapiro-Wilks' W Test	W Statistic	0.6953	p < 0.0001	Reject hypothesis of normal distribution.
Lilliefors	--	--	p < 0.01	" "
Kolmogorov-Smirnov (K-S)	D Statistic	0.1726	p < 0.15	(not significant)
D'Agostino's Test	Y statistic	-3.74	p < 0.05	Reject hypothesis of normal distribution.

\*Similar results (p values) were derived for Th-230 and U-nat, thus the normal distribution does not apply to these analytes as well.

**Descriptive Statistics for Log-Transformed Data**

	<u>Valid N</u>	<u>Mean</u>	<u>Confid. +95.000%</u>	<u>Confid. 99.00%</u>	<u>Standard Deviation</u>	<u>Standard Error</u>	<u>Skewness</u>	<u>Kurtosis</u>	<u>De-transformed Conf. Limits</u>	
									<u>95% conf.</u>	<u>99% conf.</u>
ln Ra-226, 0-6"	69	1.66	1.77	1.81	0.49	0.06	0.05	(0.47)	5.89	<b>6.12</b>
ln Th-230, 0-6"	42	1.56	1.71	1.76	0.49	0.08	0.33	(0.29)	5.55	5.84
ln U-nat, 0-6"	42	1.83	1.98	2.03	0.47	0.07	0.27	(0.28)	7.25	7.62

Note: The log transformation passed both the K-S and Lilliefors tests of normality ( $p > .2$ ), as well as the Shapiro-Wilks' test of normality ( $p < 0.6782$ ).

**6.1**: Boxed and shaded values are considered most representative of background conditions in unaffected north area (Ra-226 in bold).

Note: Detransformed values =  $\exp(\ln x)$ . For example,  $\exp(1.66)$ , the mean of the ln Ra-226 distribution, = 5.24 (the geometric mean).

**Table 4.4. Summary Statistics for All Radionuclide Parameters and Depth Profiles: Northern Area Gas Hills, Wyoming Site**

Statistical Parameter	Ra-226 Sample Results				Th-230 Sample Results				U-nat Sample Results			
	0-6"	0-1"	1-6"	6-12"	0-6"	0-1"	1-6"	6-12"	0-6"	0-1"	1-6"	6-12"
Valid N	69	41	42	42	42	4	42	23	42	4	42	23
Mean	5.89	4.74	4.61	5.09	5.38	4.85	5.37	5.51	7.00	6.57	7.00	7.16
Geometric Mean	5.24	4.41	4.17	4.40	4.76	4.77	4.74	4.58	6.25	6.53	6.24	5.90
Median	5.01	4.70	4.68	4.51	4.97	4.70	4.97	5.20	6.65	6.56	6.58	5.20
Standard Deviation	2.96	2.25	2.10	2.97	2.95	1.02	2.96	3.60	3.63	0.81	3.63	5.05
Variance	8.78	5.07	4.40	8.80	8.73	1.04	8.78	12.95	13.17	0.65	13.21	25.46
Standard Error	0.36	0.35	0.32	0.46	0.46	0.51	0.46	0.75	0.56	0.40	0.56	1.05
Skewness	1.18	3.61	1.00	1.34	1.75	0.68	1.74	1.44	1.53	0.08	1.52	2.05
Kurtosis	1.39	18.17	1.50	1.29	4.13	-1.02	4.09	2.44	3.00	-0.18	2.99	5.76
Minimum	1.78	2.22	1.41	1.86	2.11	3.86	2.11	1.85	2.39	5.62	2.39	2.24
10th percentile	2.56	2.96	2.35	2.07	2.57	3.86	2.47	2.10	3.52	5.62	3.36	2.73
25th percentile	3.82	3.62	2.85	2.73	3.12	4.07	3.12	2.74	4.12	5.97	4.43	3.61
50th percentile	5.01	4.70	4.68	4.51	4.97	4.70	4.97	5.20	6.65	6.56	6.58	5.20
75th percentile	7.39	5.27	7.64	6.00	6.30	5.64	8.90	7.07	8.28	7.17	12.09	9.24
90th percentile	10.31	6.36	5.60	8.82	8.90	6.16	6.30	10.34	12.09	7.55	8.28	11.16
Maximum	15.98	16.43	11.50	12.93	16.35	6.16	16.35	16.28	19.96	7.55	19.96	24.65

**Note:**

Summary statistics for the 0-6" depth profile should not be directly compared to those obtained for other depths because the sample numbers are different. It is also important to recognize that the 0-6" Ra-226 data set includes windblown scoping survey samples, which were analyzed for the 0-6 in (0-15 cm) depth profile only. This latter factor accounts for the higher summary statistics that were yielded for 0-6" Ra-226 (vs. the corresponding 0-1" and 1-6" values). The data comprising the 0-6" data set are defined as follows:

1. *SMI 1999a Background Investigation* - weighted average of the 0-1" and 1-6" samples (where both depths were analyzed, e.g., for Ra-226) or, in the case of most Th-230 and U-nat results, the 1-6" datum was used given the lack of 0-1" sample results (n=41); and
2. *SMI 1999b Windblown Scoping Survey* -- Results for the 0-15 cm samples listed in the right hand column of Table 3.4, Ra-226 only (n=27);
3. *Umetco 1996 Investigation* -- Weighted average result for sample B-22 (n=1; see Table 3.5 and Figure 3.1).

**Table 4.5. Summary Statistics for Surficial (0-6") Ra-226 Derived for Final Northern Area Background Data Set, Gas Hills, Wyoming Site**

Summary Statistic	Non-transformed	Log Transformed	Detransformed
	Ra-226	ln Ra-226	exp (ln Ra-226) <sup>/a/</sup>
Valid N (n)	69	69	69
Median	5.0	--	--
Geometric Mean	5.2	--	--
Mean	5.9	1.7	5.2
95% UCL, mean	6.6	1.8	5.9
99% UCL, mean	6.8	1.8	<b>6.1</b>
Std. Dev.	3.0	0.49	1.6
Mean + Std. Dev.	8.9	2.1	8.5
Std. Error	0.4	0.06	1.06
Variance	8.8	0.2	1.27
Minimum	1.8	--	--
Maximum	16.0	--	--
25th %ile	3.8	--	--
75th %ile	7.4	--	--
Interquartile Range	3.6	--	--
Skewness	1.2	0.1	--
Kurtosis	1.4	-0.47	--
<b>Normality Tests <sup>/a/</sup></b>			
Shapiro-Wilk W <sup>/b/</sup>	p < 0.0001*	n.s.	--
K-S	n.s. (p < 0.15)	n.s.	--
Lilliefors	p < 0.01*	n.s.	--
D'Agostino's Test	p < 0.05 (Y = -3.74)*	not sig. (Y = 0.55)	--

Ra-226 units for all relevant statistical parameters are in pCi/g.

<sup>/a/</sup> For normality test results, asterisks denote significant results (i.e., reject null hypothesis of a normal distribution)

<sup>/b/</sup> The Shapiro-Wilk's W test results should be interpreted with caution, as this test was designed for  $n \leq 50$ .

**Definitions**

-- statistic not relevant and/or not calculated

n.s. - not significant, i.e., can not reject null hypothesis of a normal distribution.

K-S - Kolmogorov-Smirnov (normality test)

Std. Dev. - Standard Deviation

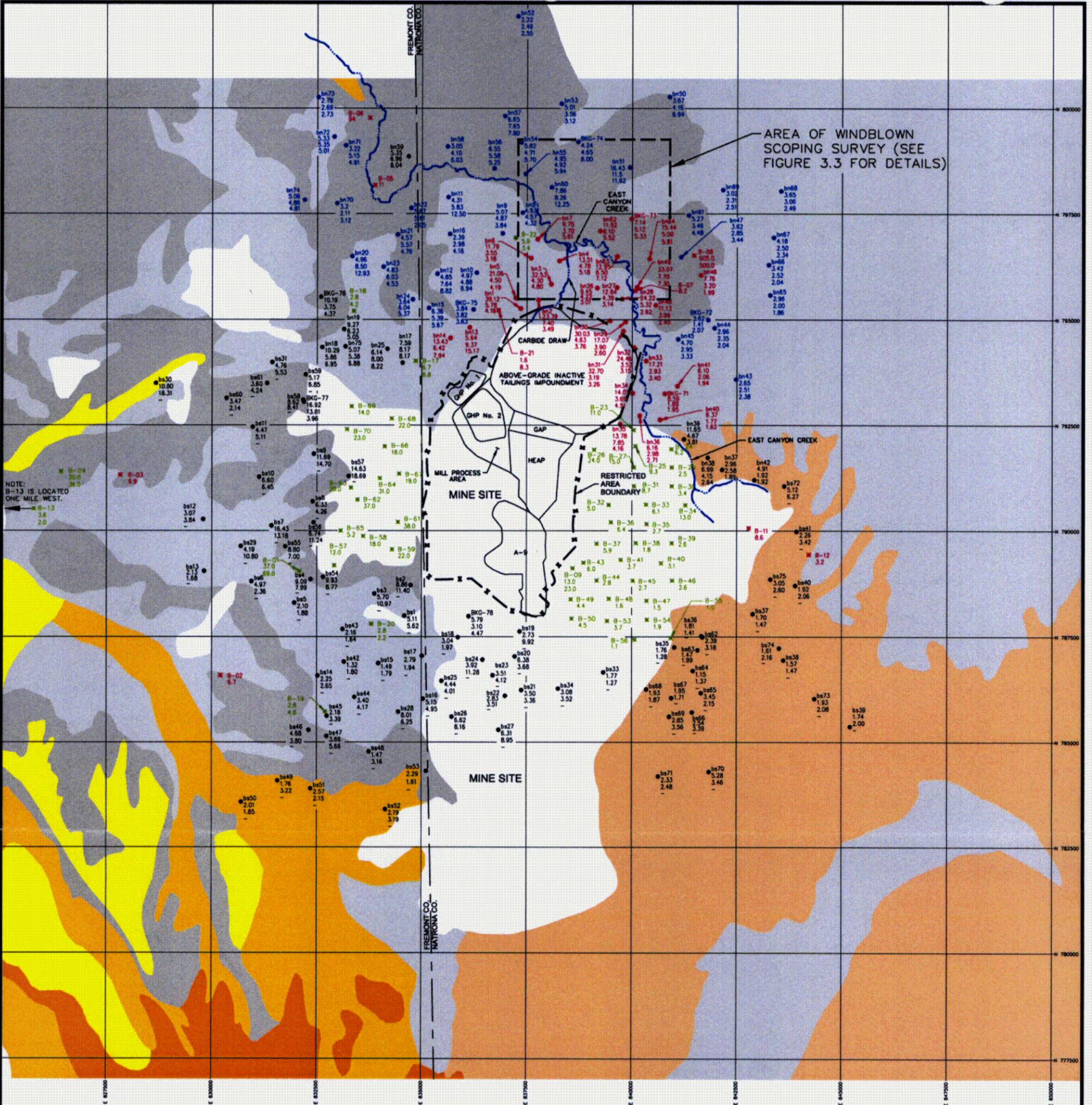
Std. Error - Standard Error

UCL - Upper Confidence Limit

**Table 5.1. Recommended Surficial (0-6") Background Radionuclide Concentrations Gas Hills, Wyoming Site**

Area/Purpose	Ra-226 (pCi/g)	Th-230 (pCi/g)	U-nat (pCi/g)	Statistical Basis	Rationale and Comment
Site-Wide (Surrounding Soils)	10	10	15	Two different estimators, approximately equal, are considered representative of background conditions. The first is the median plus the interquartile range (IQR), assumed to represent a reasonable confidence limit about the median (Ra-226 = 9.9 pCi/g). The second is the antilog of the mean plus one standard deviation (s.d.) of the log-transformed data (Table 4.1)—i.e., the geometric mean plus one s.d. (Ra-226 = 10.7 pCi/g). The average of these two estimators (to 2 significant figures) was used as the final recommended background value.	<p>The proposed values are considered reasonable, especially given the distribution of Ra-226 in the reclaimed and undisturbed areas immediately adjacent to the site (see Figure 5.1), which were under-represented in the final background data set relative to the more homogeneous samples collected during SMI's background investigation.</p> <p>Also, the data plot provided in Figure 4.1 shows that the 10 pCi/g Ra-226 value falls at a point just above which the slope and density of the distribution changes. The 10 pCi/g value thus adequately accounts for the variability in the background distribution, but does not incorporate the less frequently occurring outlying values.</p>
Northern Windblown Cleanup Area	6.1	5.8	7.6	99 <sup>th</sup> upper confidence limit (UCL) on the geometric mean of the northern area background data set (also equivalent to the 99 <sup>th</sup> percent UCL on the median for 0-6" Ra-226)	The 6.1 pCi/g Ra-226 background value is very conservative, especially given the variability apparent in the northernmost portion of the sampling area (see Figure 3.3), where Ra-226 concentrations are clearly reflective of naturally occurring ore (see Figure 4.3).

## Figures



**SOILS LEGEND**

- |   |  |   |   |
|---|--|---|---|
|  | SMI Soil Group 1 - Terraces, Fans, Gently Sloping Hillides, and Plateaus |  | SMI Soil Group 5 - Rock Outcrop, Rubble, and Thin Colluvial Soils |
|  | SMI Soil Group 2 - Gullies, Steep Hills, and Ridges, Entisol order       |  | Other Minor Soil Types  |
|  | SMI Soil Group 3 - Ridges and Steep Hills, Aridisol order                |  | Mine Areas  |
|  | SMI Soil Group 4 - Floodplains   |  | RESTRICTED AREA BOUNDARY  |
|   |  |  | AREA OF WINDBLOWN SCOPING SURVEY (SEE FIGURE 3.3 FOR DETAILS).    |

**LEGEND:**

- BKG-78 SMI 1998 BACKGROUND INVESTIGATION SAMPLE LOCATION
  - 5.79 - Ra226 IN 0-1 INCH SAMPLE (pCi/g)
  - 3.10 - Ra226 IN 1-6 INCH SAMPLE (pCi/g)
  - 4.47 - Ra226 IN 6-12 INCH SAMPLE (pCi/g)
- OR ✕ SAMPLE INCLUDED IN NORTHERN BACKGROUND DATABASE
  - 3.64 - Ra226 IN 0-1 INCH SAMPLE (pCi/g)
  - 6.04 - Ra226 IN 1-6 INCH SAMPLE (pCi/g)
  - 5.37 - Ra226 IN 6-12 INCH SAMPLE (pCi/g)
- OR ✕ SAMPLE EXCLUDED FROM FINAL BACKGROUND DATA SET (SEE TABLES 3.2, 3.5, AND 3.6 FOR SUPPORTING RATIONALES)
- ✕ B-13 UMETCO 1995 - 1996 SAMPLE LOCATION
  - 3.6 - Ra226 IN 0-2 INCH SAMPLE (pCi/g)
  - 2.0 - Ra226 IN 2-6 INCH SAMPLE (pCi/g)\*

\* - WHERE ONLY ONE VALUE IS SHOWN, AND IT IS IN THE 0-2 INCH POSITION, THE VALUE REPRESENTS A SAMPLE DEPTH OF 0-6 INCHES. WITH THE EXCEPTION OF B-08, SAMPLES EXCLUDED FROM THIS DATA SET CORRESPOND TO OUTCROPS.

**NOTE:**

FIGURE ADAPTED FROM DRAWING 4.2 OF SMI 1999 BACKGROUND REPORT.



SCALE: 1" = 2500'

**UMETCO MINERALS CORPORATION**

**BACKGROUND SAMPLE LOCATIONS AND CORRESPONDING Ra-226 CONCENTRATIONS GAS HILLS, WYOMING**

JUNE 2000

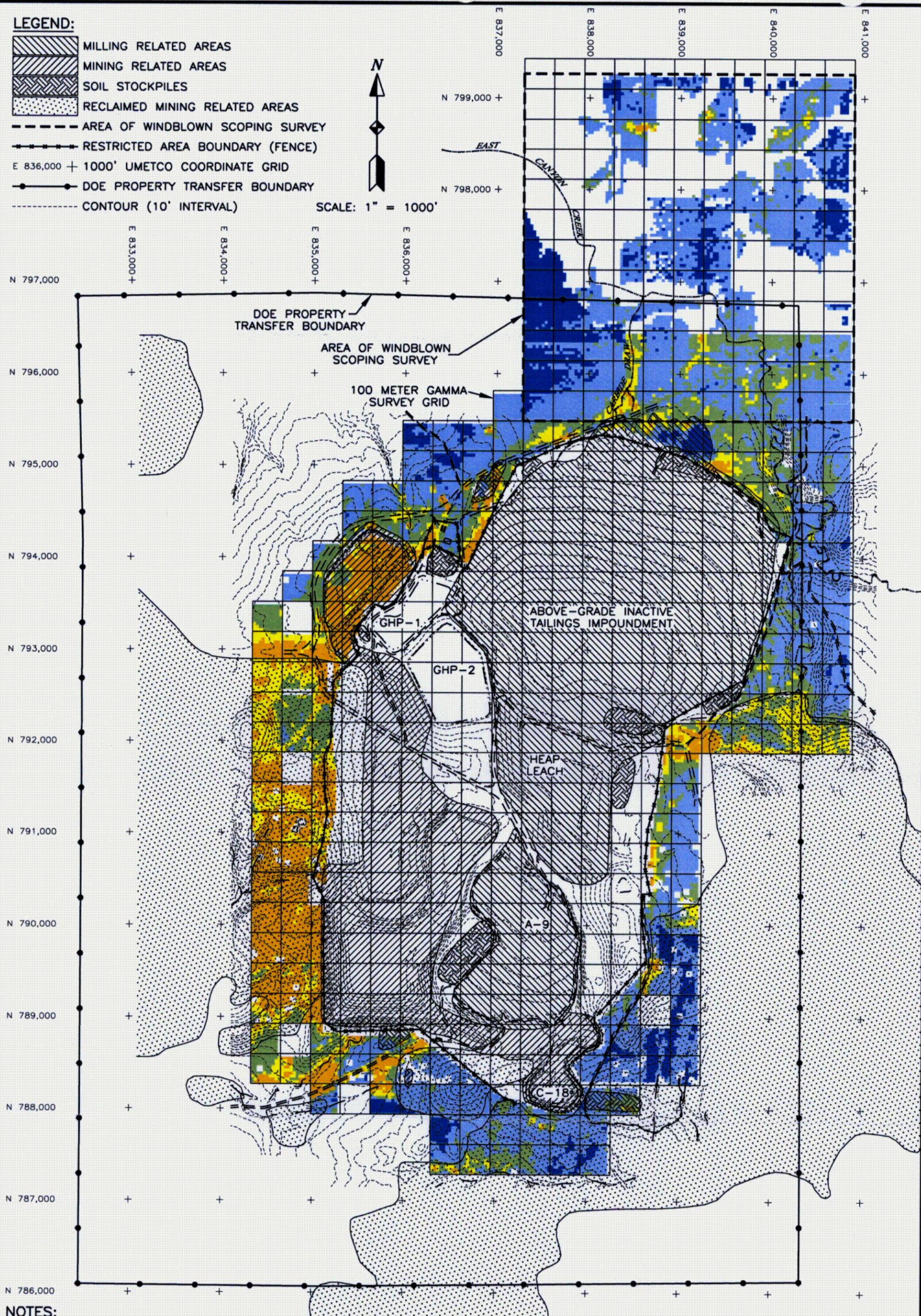
FIGURE 3.1

**LEGEND:**

-  MILLING RELATED AREAS
-  MINING RELATED AREAS
-  SOIL STOCKPILES
-  RECLAIMED MINING RELATED AREAS
-  AREA OF WINDBLOWN SCOPING SURVEY
-  RESTRICTED AREA BOUNDARY (FENCE)
- E 836,000 + 1000' UMETCO COORDINATE GRID
-  DOE PROPERTY TRANSFER BOUNDARY
-  CONTOUR (10' INTERVAL)



SCALE: 1" = 1000'



**NOTES:**

- 1). DATA COLLECTED 7/95 TO 10/95 AND 9/98 TO 12/98.
- 2). ALL DATA FROM GEOGRAPHICAL POSITIONING SYSTEM AND SCINTILLATION MEASUREMENT SURVEYS.
- 3). BECAUSE OTHER TERRESTRIAL RADIONUCLIDES CONTRIBUTE TO THE OBSERVED GAMMA RADIATION LEVELS (e.g., Th-232 DECAY PRODUCTS AND K-40), THE Ra-226 EQUIVALENTS SHOWN HERE ARE EXPECTED TO BE OVERESTIMATED BY APPROXIMATELY 5 TO 6 pCi/g.

**RADIOLOGICAL LEGEND:**

-  > 20 pCie Ra-226/g
-  > 15 ≤ 20 pCie Ra-226/g
-  > 10 ≤ 15 pCie Ra-226/g
-  > 5 ≤ 10 pCie Ra-226/g
-  ≤ 5 pCie Ra-226/g

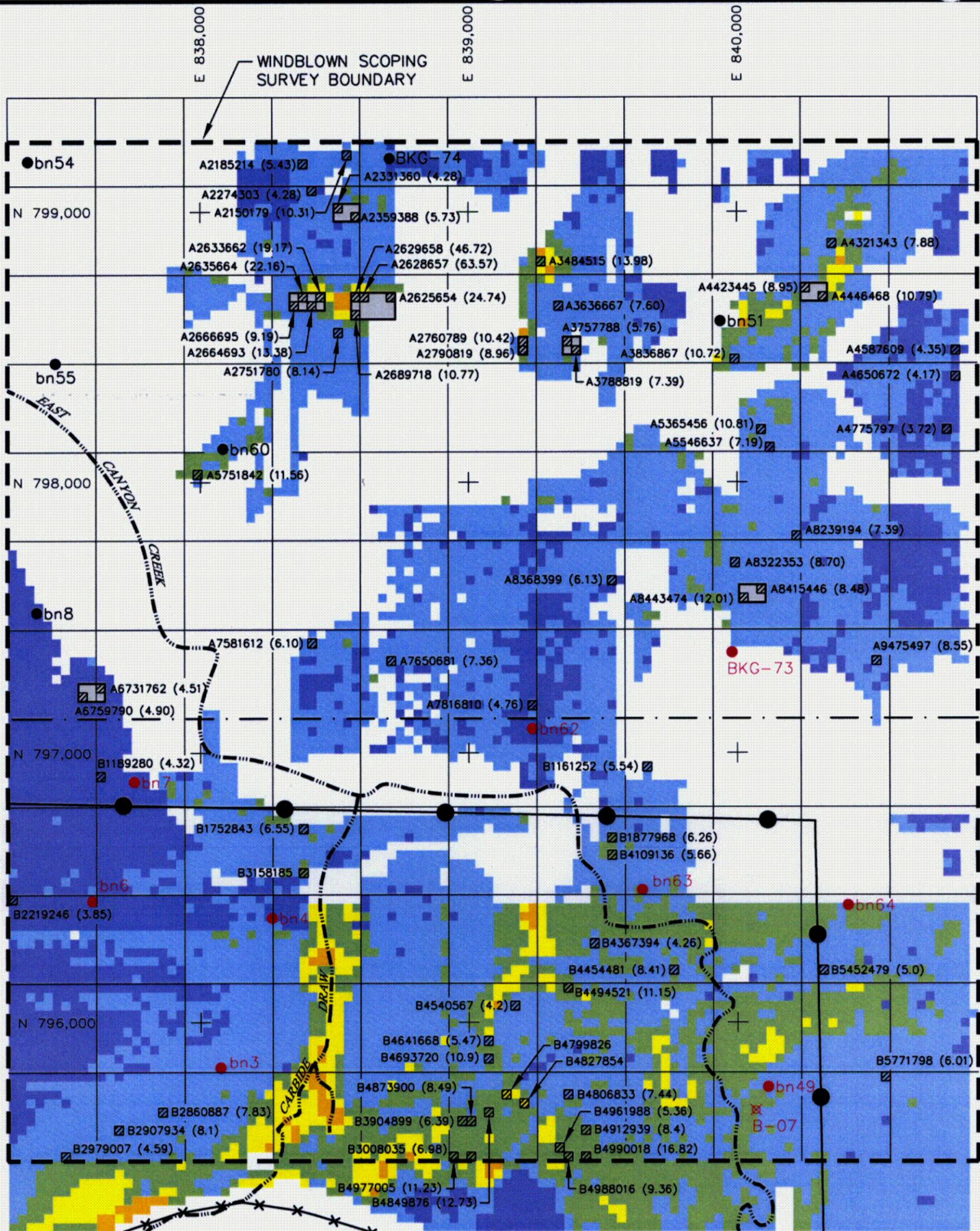
**UMETCO MINERALS CORPORATION**

**DISTRIBUTION OF Ra-226  
EQUIVALENTS RELATIVE TO  
HISTORICAL MINING ACTIVITIES**

GAS HILLS, WYOMING *CO2*

JUNE 2000

FIGURE 3.2



**RADIOLOGICAL LEGEND:**

- > 20 pCie Ra-226/g
- > 15 ≤ 20 pCie Ra-226/g
- > 10 ≤ 15 pCie Ra-226/g
- > 5 ≤ 10 pCie Ra-226/g
- ≤ 5 pCie Ra-226/g

**LEGEND:**

- A3836867 (10.72) - SMI 1998 WINDBLOWN SCOPING SURVEY LOCATION, INCLUDED IN FINAL BACKGROUND DATA SET
- B5771798 (6.01) - SMI 1998 WINDBLOWN SCOPING SURVEY LOCATION, NOT INCLUDED IN FINAL BACKGROUND DATA SET
- bn3 - SMI BACKGROUND INVESTIGATION SAMPLE LOCATION (SEE FIGURE 3.1)
- ⊗ B-07 - UMETCO 1995 - 1996 SAMPLE LOCATION
- OR ⊗ - SAMPLE EXCLUDED FROM FINAL BACKGROUND DATA SET (SEE TABLE 3.2)
- - INDICATES THAT RESULTS WERE AVERAGED FOR USE IN THE BACKGROUND DATA SET
- WINDBLOWN SCOPING SURVEY BOUNDARY
- . - - APPROXIMATE SOUTHERN BOUNDARY OF SCOPING SURVEY AREA INCLUDED IN THE BACKGROUND DATA SET



SCALE: 1" = 400'

UMETCO MINERALS CORPORATION

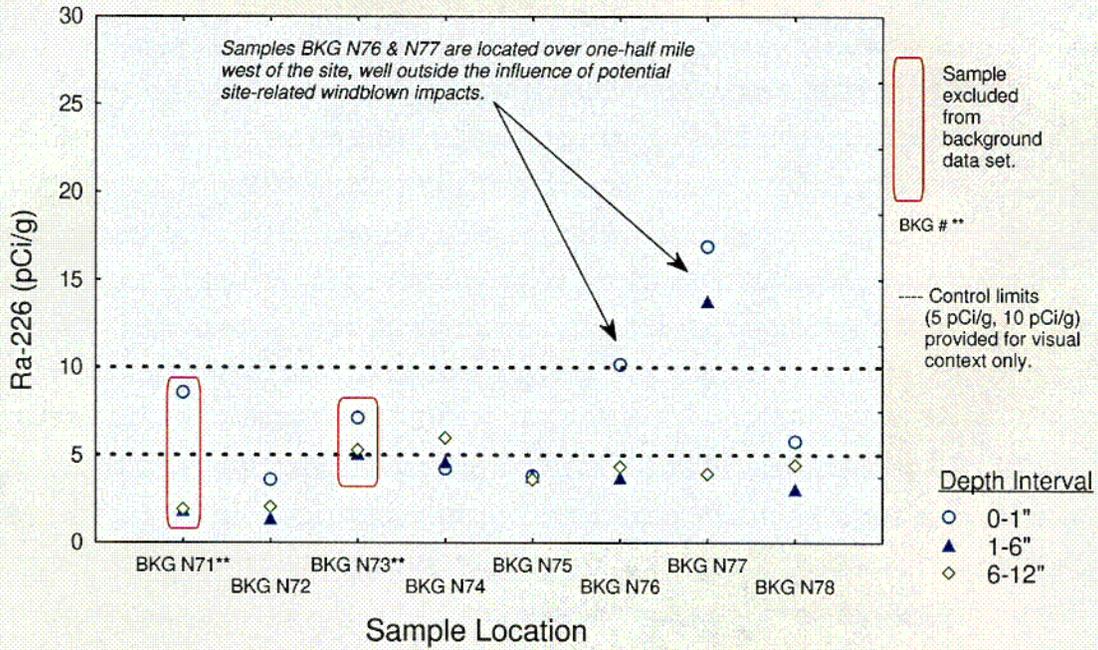
**WINDBLOWN SCOPING SURVEY  
SAMPLE LOCATIONS**

GAS HILLS, WYOMING

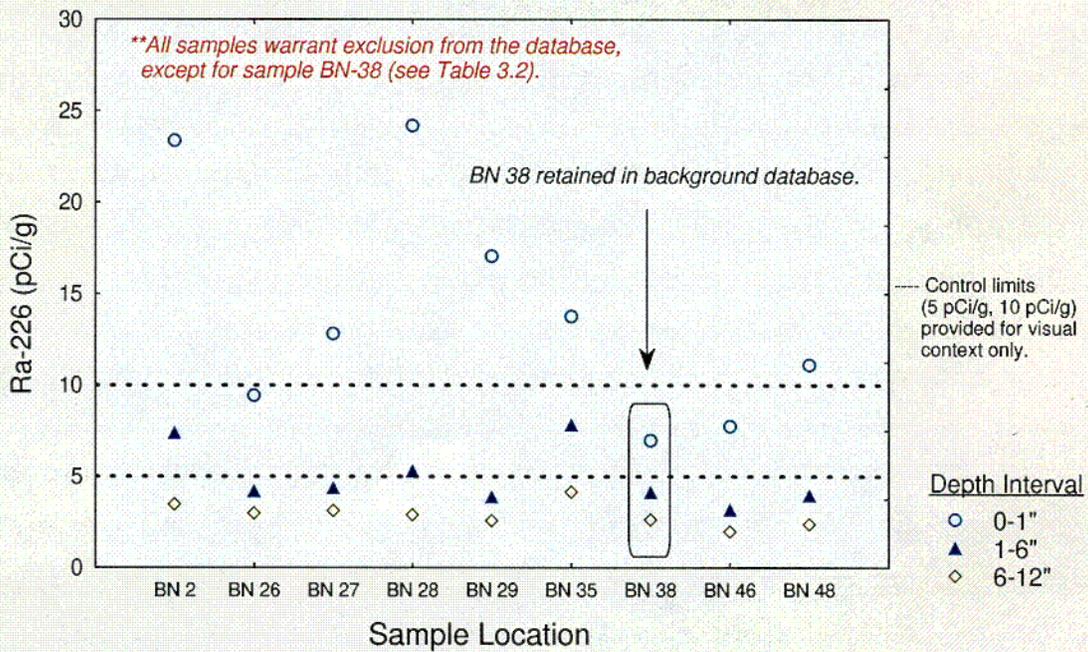
JUNE 2000

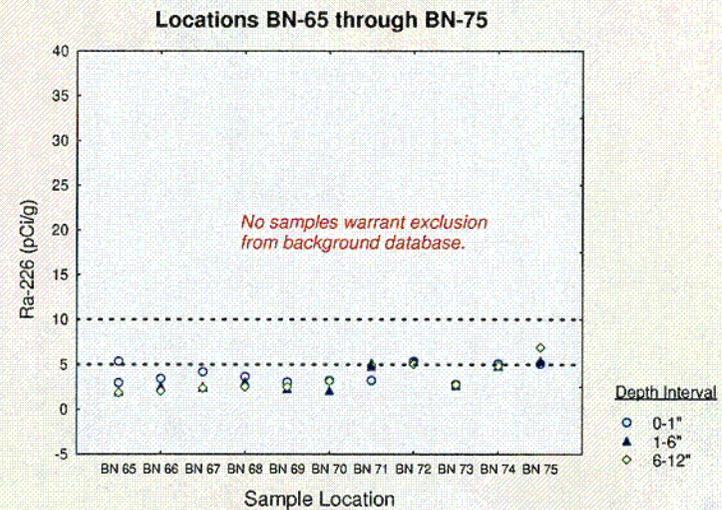
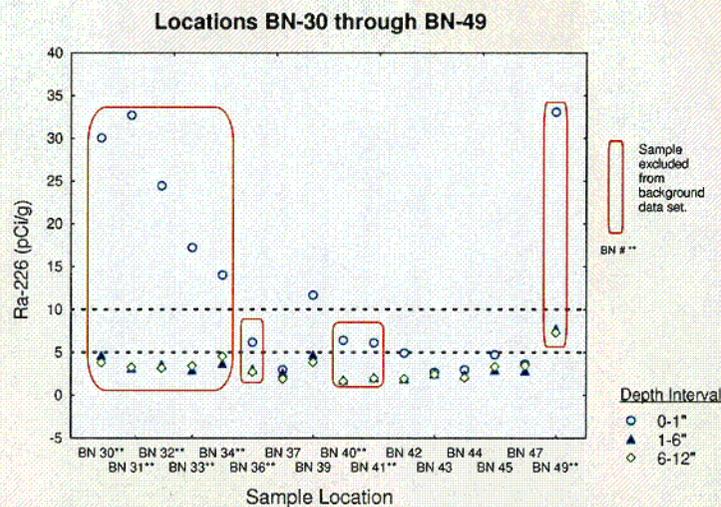
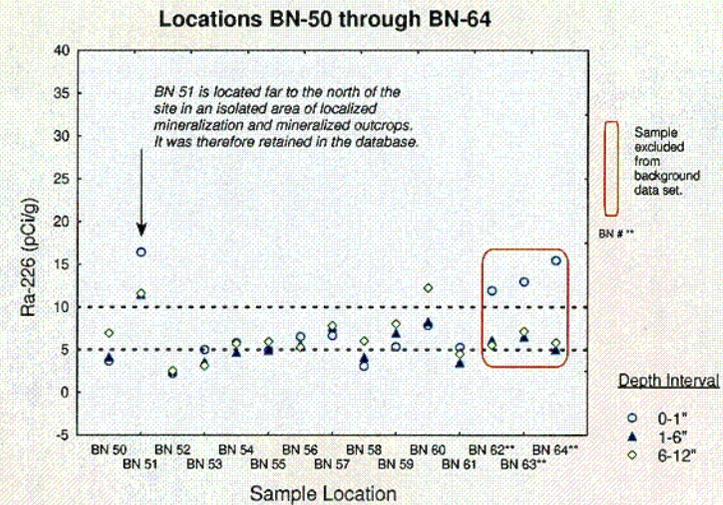
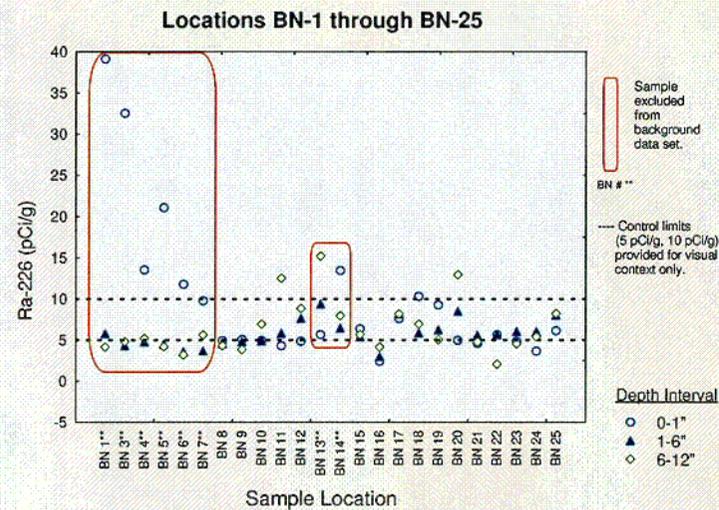
C03  
FIGURE 3.3

**Figure 3.4. Vertical Ra-226 Distributions in NRC Selected Background Samples, Gas Hills, Wyoming Site**



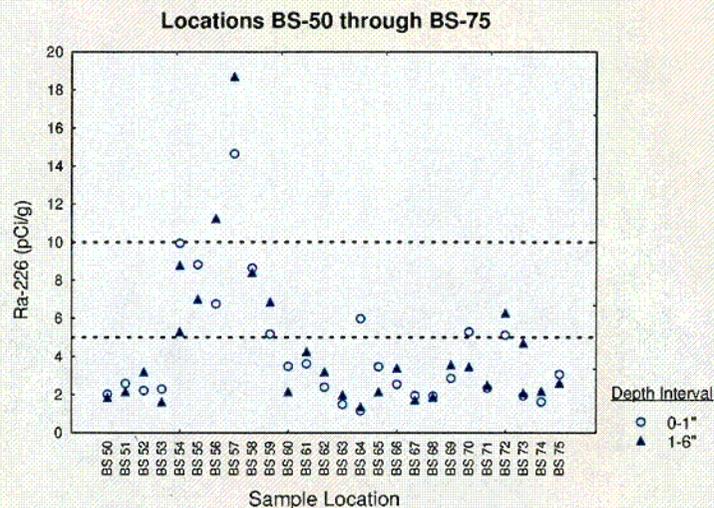
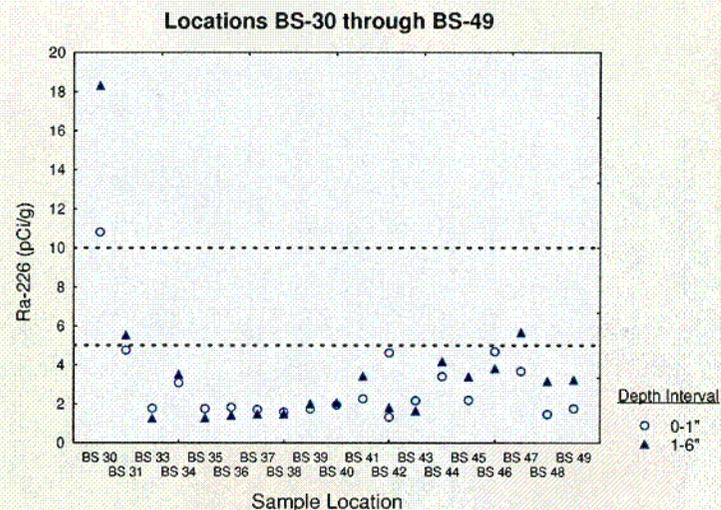
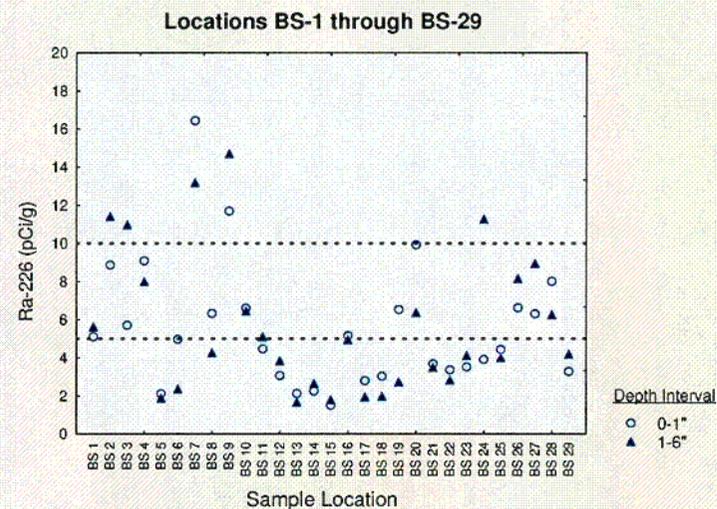
**Figure 3.5. Vertical Ra-226 Distributions in Samples Excluded from SMI's Background Data Set, Gas Hills, Wyoming Site**





**Figure 3.6. Vertical Ra-226 Distributions in Northern (BN-) Background Samples Gas Hills, Wyoming Site**

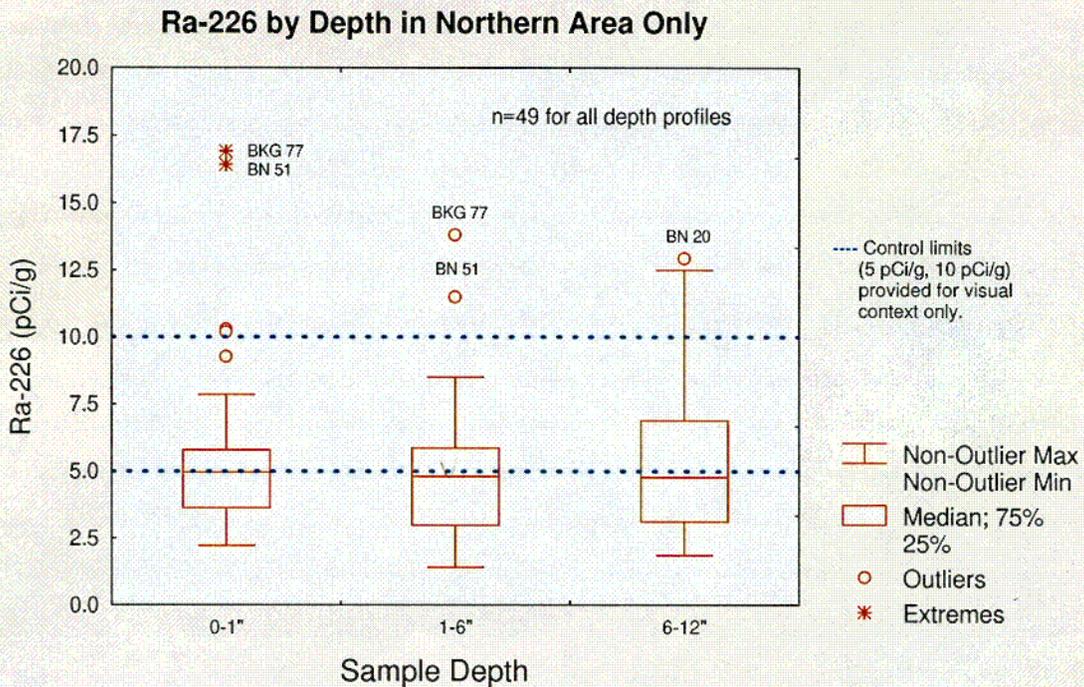
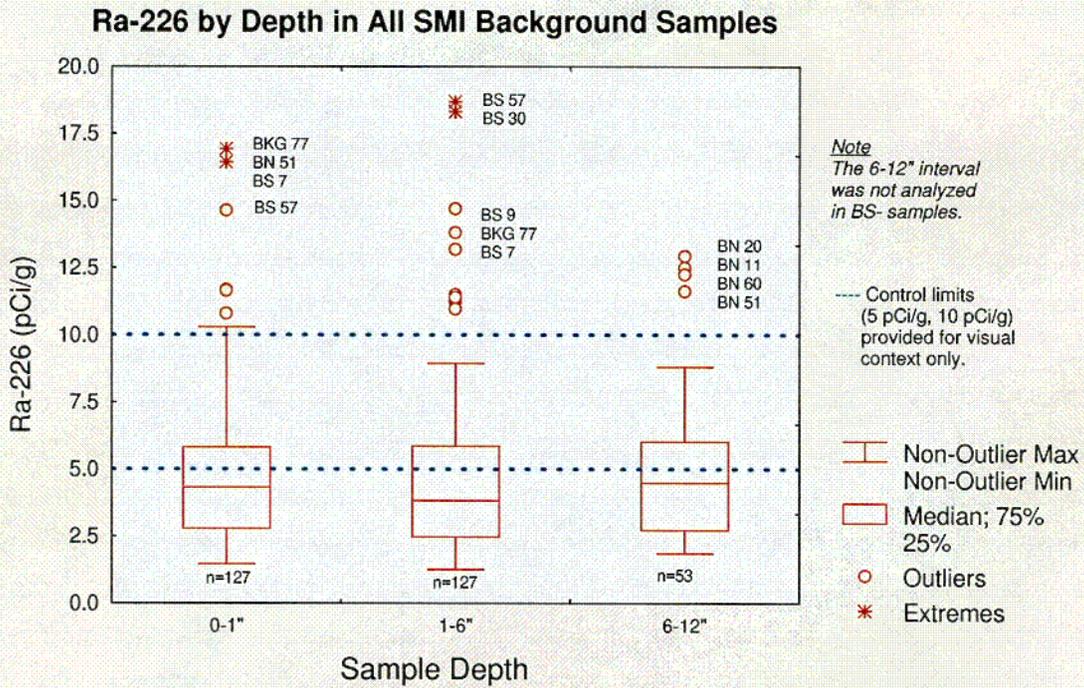
C05



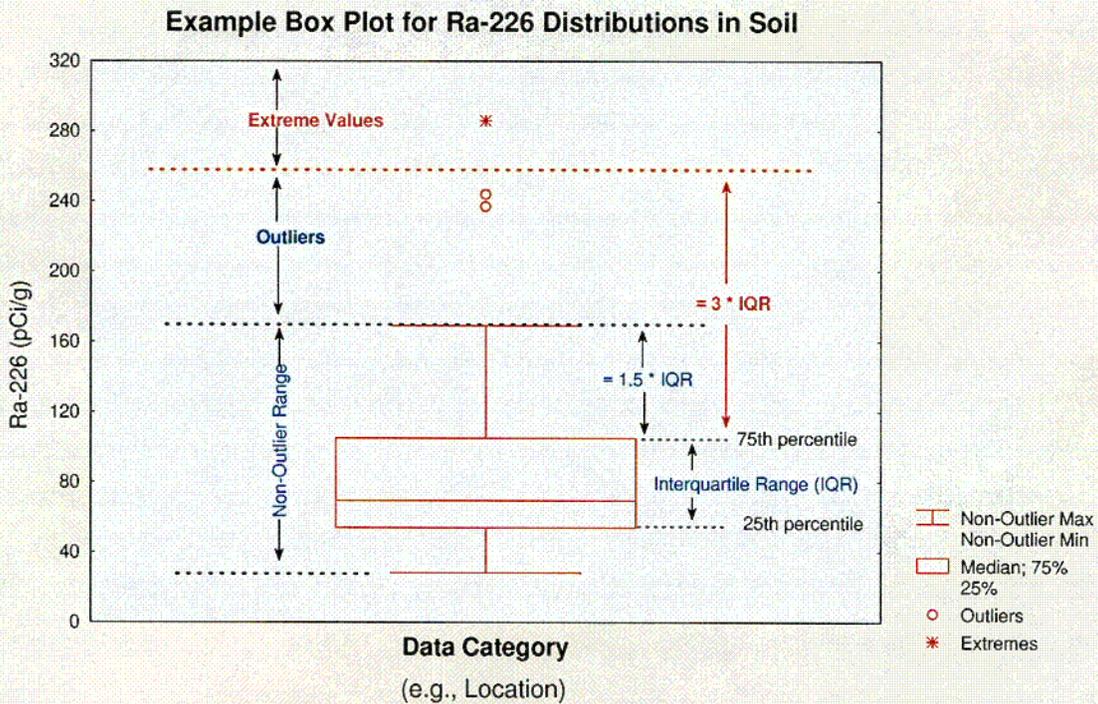
---- Control limits  
(5 pCi/g, 10 pCi/g)  
provided for visual  
context only.

*Note:* As indicated in Table 3.2, all BS-samples were retained in the background data set. Although some samples exhibit trends reminiscent of windblown impacts (e.g., BS 7), these results are considered attributable to historical mining activities and/or naturally occurring ore.

**Figure 3.7. Vertical Ra-226 Distributions in Remaining Surrounding (BS-) Background Samples, Gas Hills, Wyoming Site**



**Figure 3.8. Generalized Distribution of Ra-226 by Depth in SMI Background Soil Samples, Gas Hills, Wyoming Site**



#### Explanation of Terms

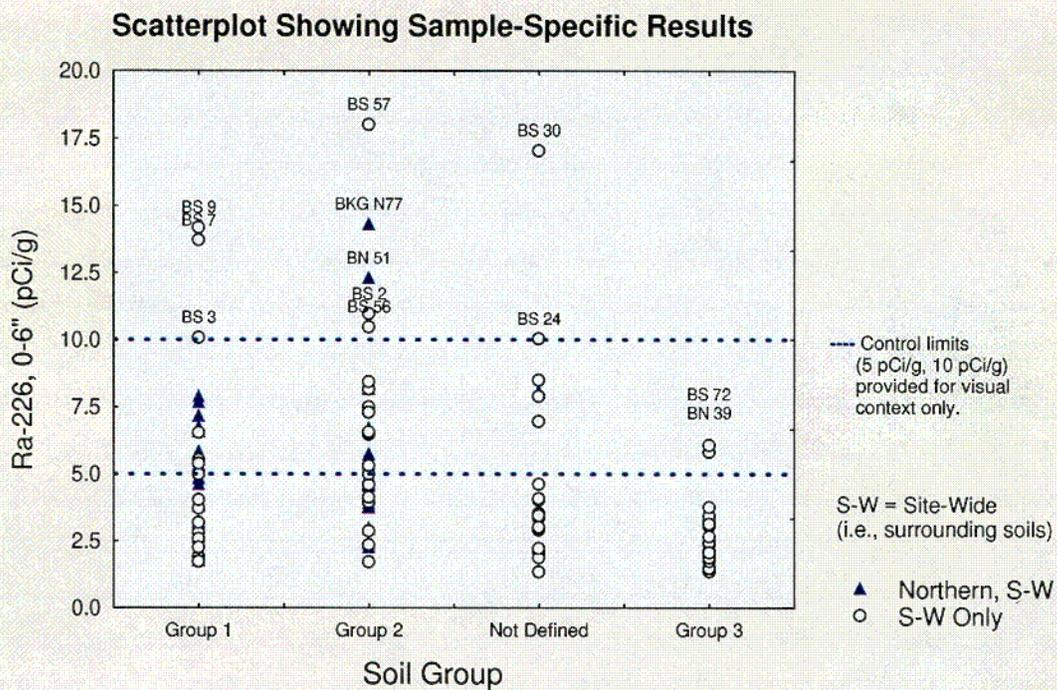
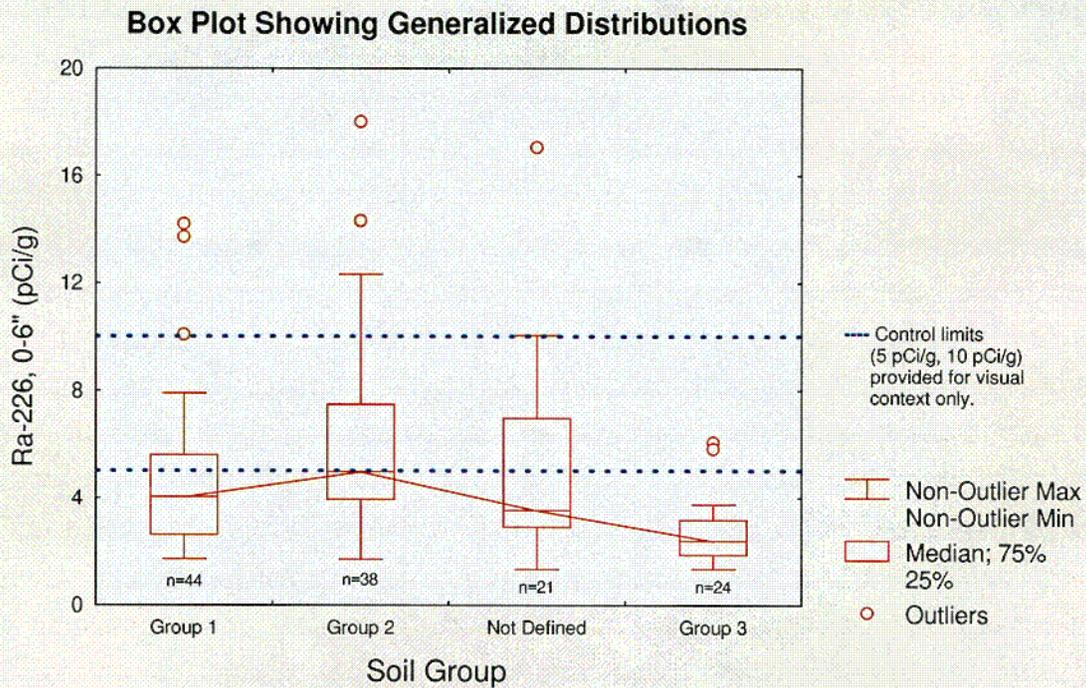
**IQR** = the difference between the upper quartile (75th percentile) value and the lower quartile (25th percentile) value.

**Outliers** are defined as values greater than the 75th percentile value plus  $1.5 * IQR$ .

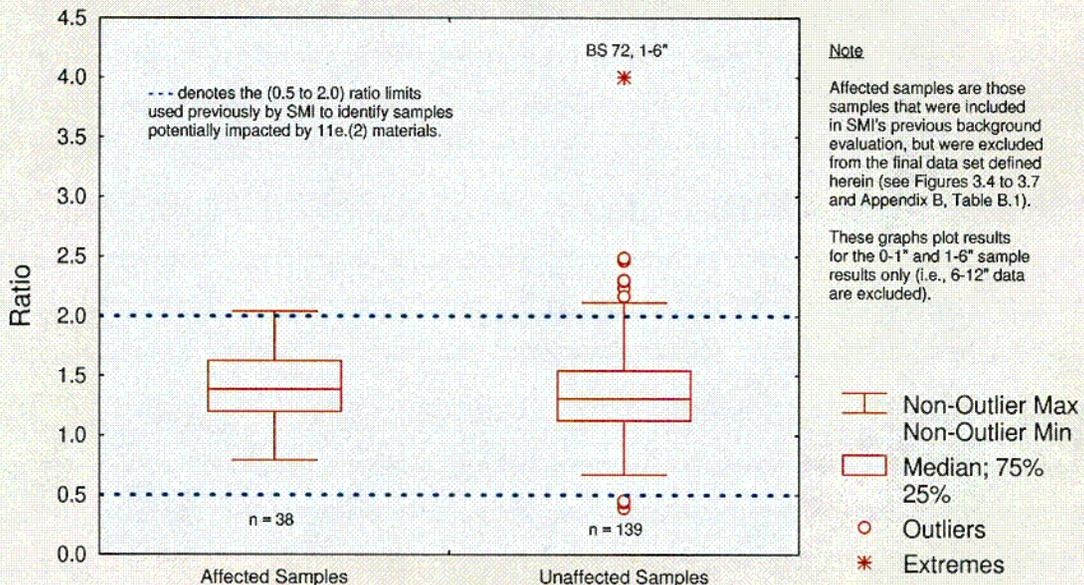
**Extremes** are a subset of outliers, and are defined as values greater than the 75th percentile value plus  $3 * IQR$ .

*The same principle applies to lower bound outliers, using the 25th percentile minus 1.5 or 3 times the IQR as points of departure.*

**Figure 3.8 Addendum.  
Explanation of the Use of Box Plots  
in Examining Statistical Trends**

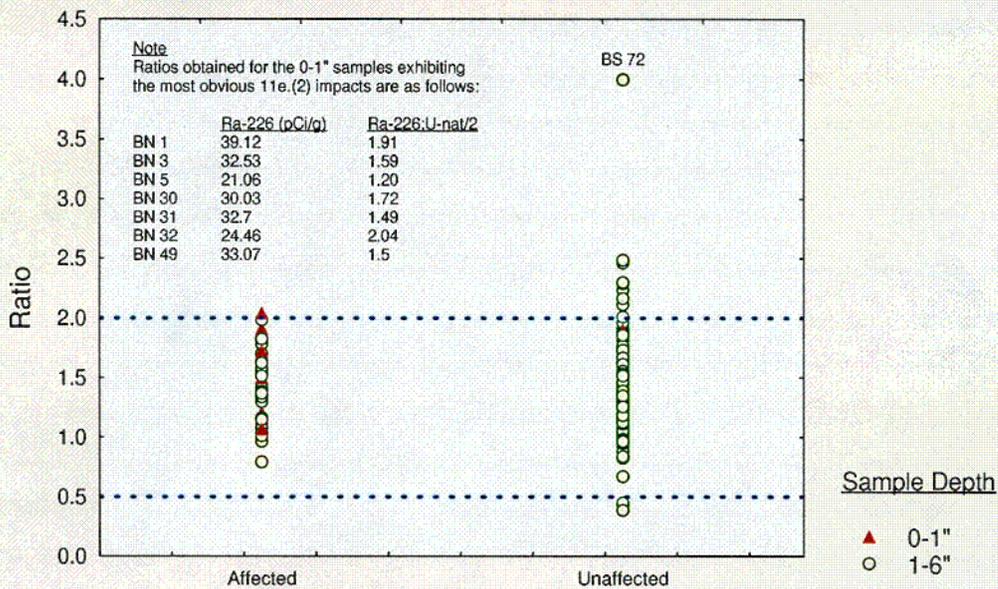


### Ra-226 / (U-nat/2): Generalized Distribution



0-1" and 1-6" Data Set

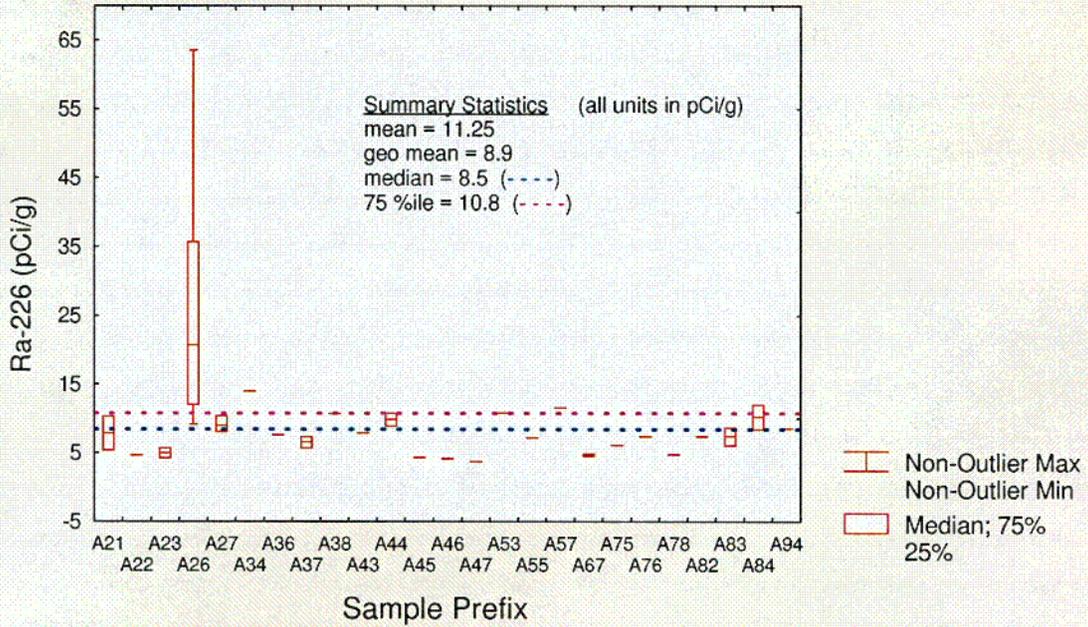
### Ra-226 / (U-nat/2): Sample-Specific Results



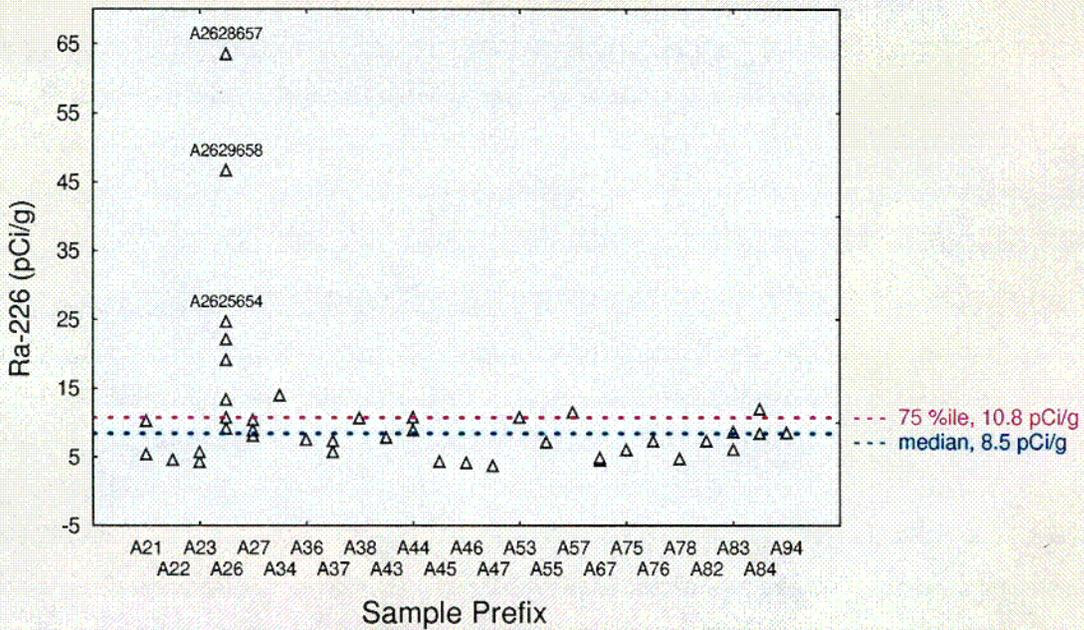
0-1" and 1-6" Data Set

Figure 3.10. Plot of Ra-226 to U-nat/2 Ratios for Affected and Unaffected Samples: SMI 1998 Background Investigation

**Box Plot Showing Generalized Distribution**



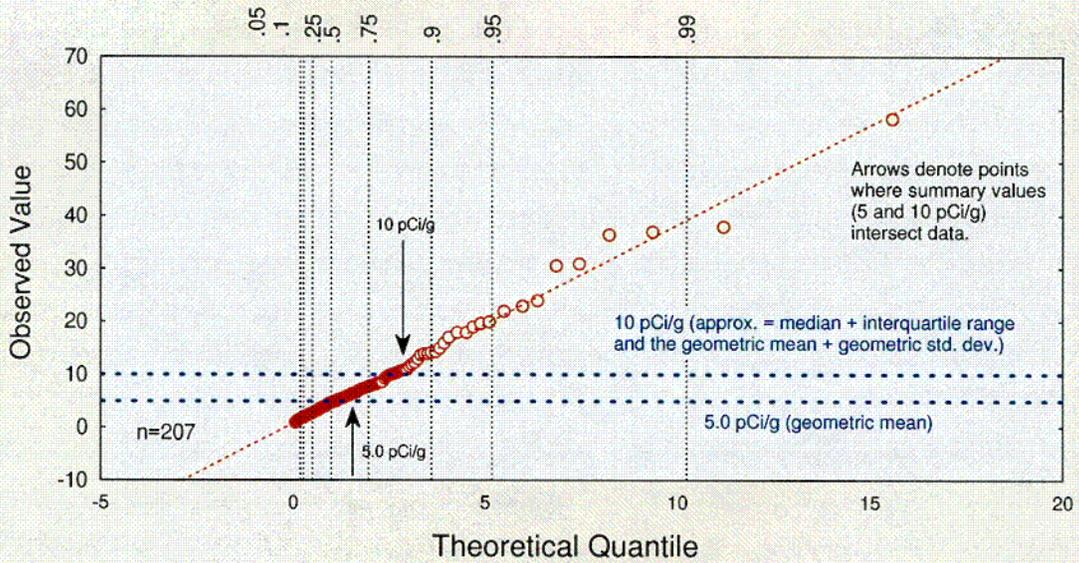
**Scatterplot Showing Sample-Specific Results**



**Figure 3.11. Plot of Northernmost Windblown Scoping Survey Sampling Results, Gas Hills Site**

### Quantile-Quantile Plot of Ra-226, 0-6": All Samples

Distribution: Lognormal;  $y=0.847+3.747*x$



### Histogram Showing Relative Frequencies

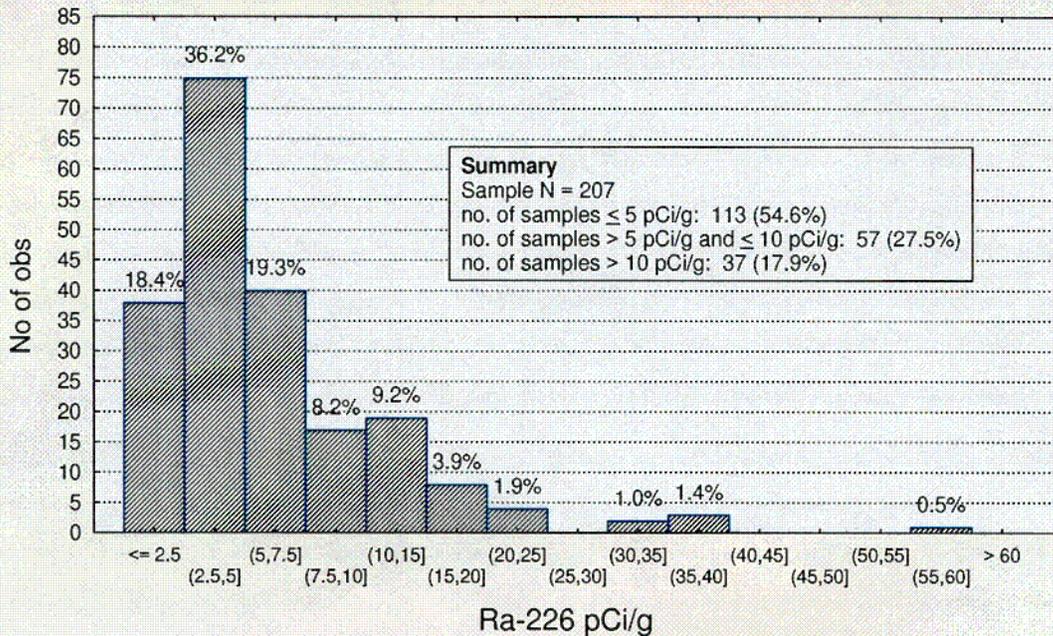
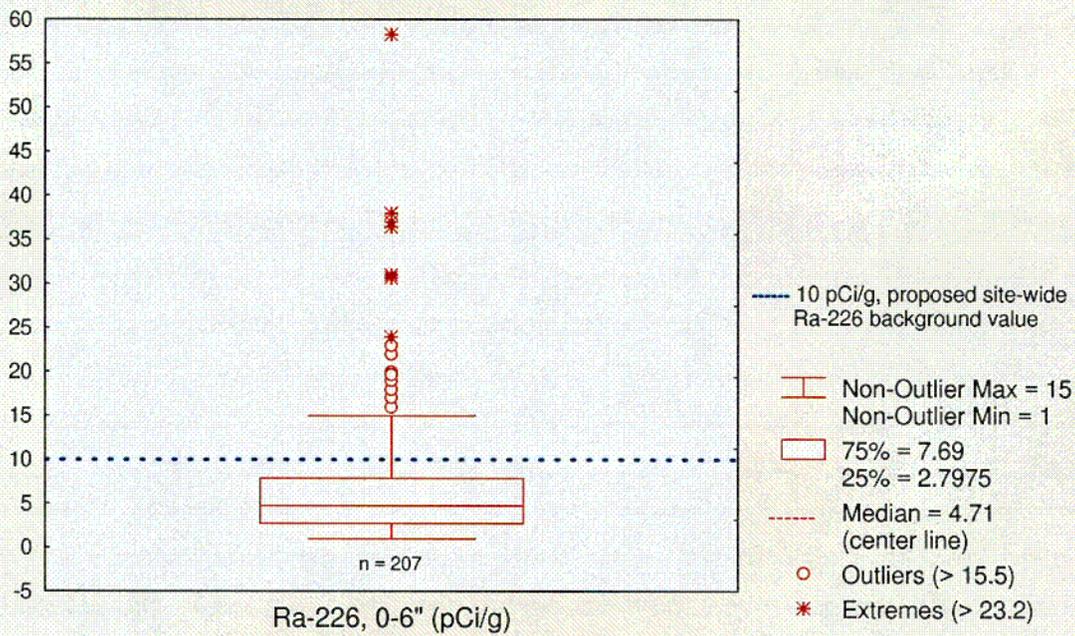


Figure 4.1 Distribution of Ra-226 in 0-6" Background Samples Umetco Minerals Corporation, Gas Hills Site

**Box Plot of Ra-226, 0-6": All Background Data Points**



**Descending Sort of Outlier Data Points, 0-6" Ra-226**

Sample ID	Investigation	Area	Ra-226 (pCi/g)
B-01	Urmetoo '95-'96	Undisturbed	58.3
B-61	Urmetoo '95-'96	Reclaimed West	38.0
B-62	Urmetoo '95-'96	Reclaimed West	37.0
A26W avg	SM 1998 WSS	Northern	36.5
B-64	Urmetoo '95-'96	Reclaimed West	31.0
B-04	Urmetoo '95-'96	Undisturbed	30.7
B-26	Urmetoo '95-'96	Reclaimed East	24.0
B-70	Urmetoo '95-'96	Reclaimed West	23.0
B-59	Urmetoo '95-'96	Reclaimed West	22.0
B-68	Urmetoo '95-'96	Reclaimed West	22.0
B-63	Urmetoo '95-'96	Reclaimed West	20.0
B-09	Urmetoo '95-'96	Undisturbed	19.7
B-67	Urmetoo '95-'96	Reclaimed West	19.0
BS 57	SM 1998 BKG	SM (west)	18.0
B-58	Urmetoo '95-'96	Reclaimed West	18.0
B-66	Urmetoo '95-'96	Reclaimed West	18.0
BS 30	SM 1998 BKG	SM (far west)	17.1
A26E avg	SM 1998 WSS	Northern	16.0

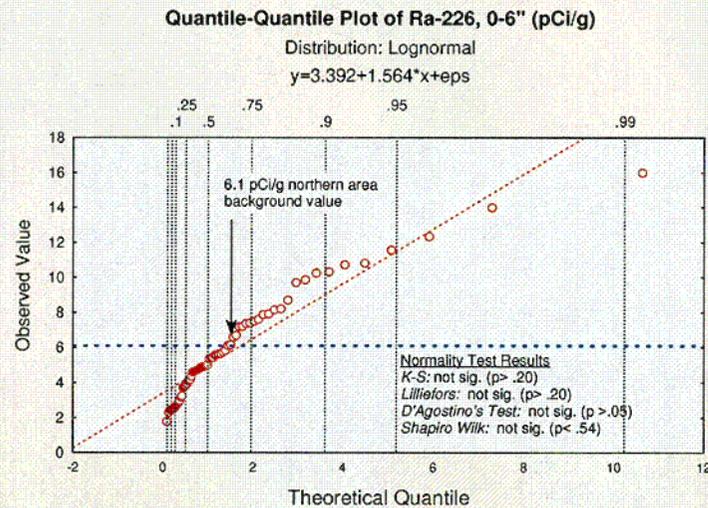
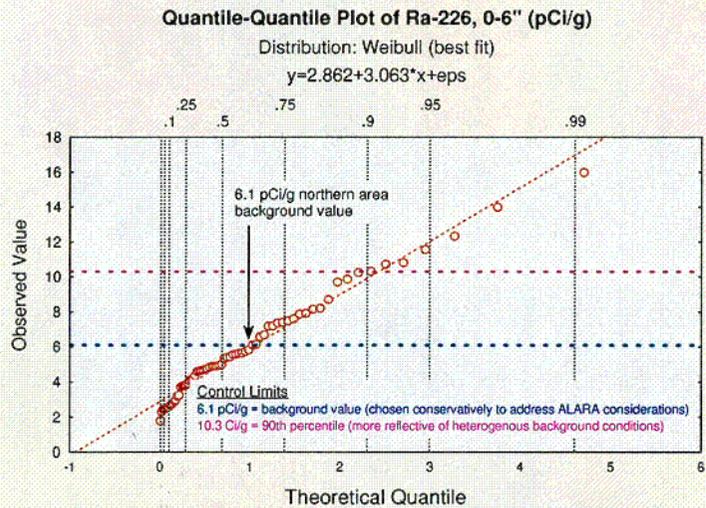
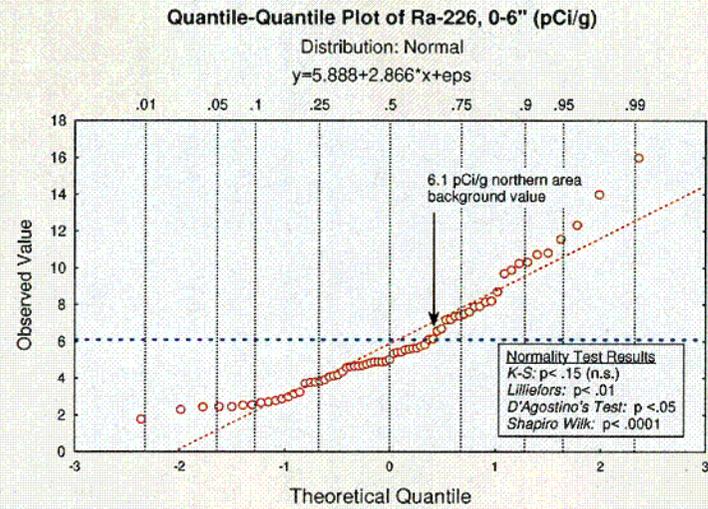
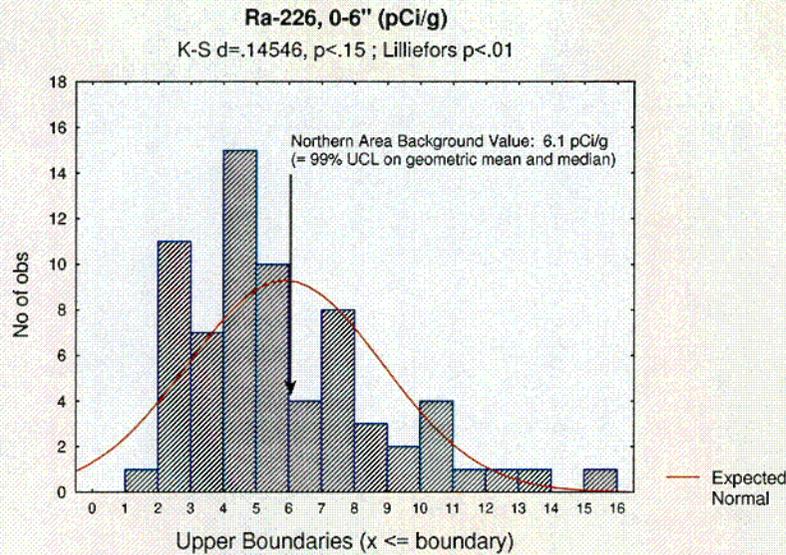
**Note:**

Although clearly outliers, all samples listed here are considered valid for inclusion in the background data set based on the environmental setting and/or information regarding historical (e.g., mining or reclamation) activities (see Figures 3.1 through 3.3).

Non-outlier maximum = 15.0 pCi/g (see plot above), corresponding to reclaimed east sample B-27.

avg = average  
 BKG = Background Investigation  
 WSS = Windblown Scoping Survey

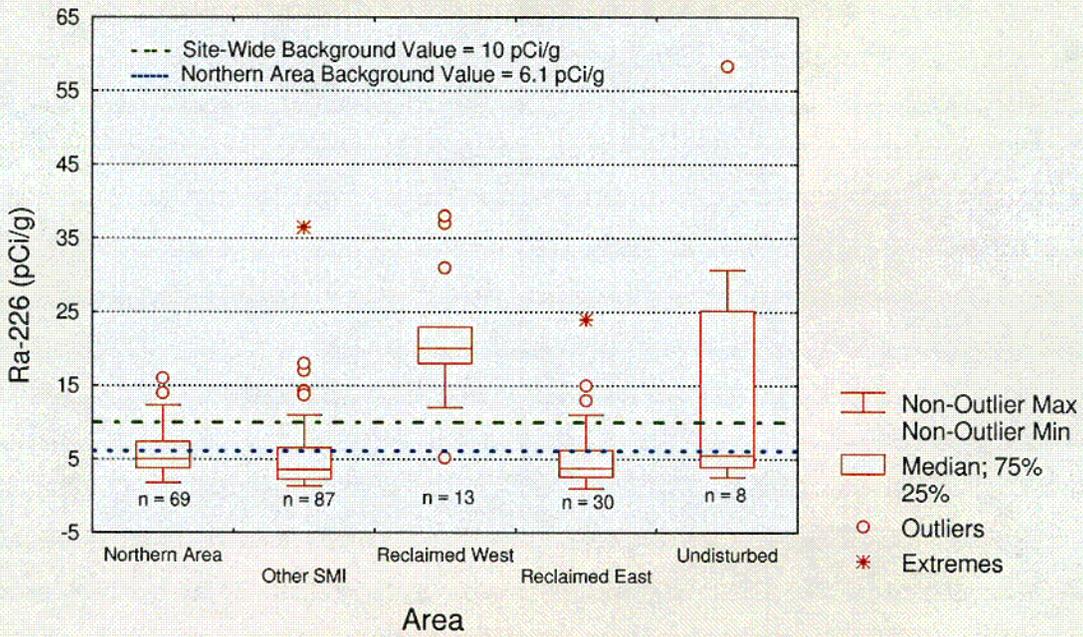
**Figure 4.2. Box Plot of Ra-226 and Identification of Outliers: All 0-6" Data Points, Gas Hills, Wyoming Site**



**Figure 4.3. Distribution of Ra-226 in 0-6" Background Samples:  
Northern Area Data Set, Gas Hills, Wyoming Site**

C14

### Box Plot Showing Generalized Distributions



### Sample-Specific Results

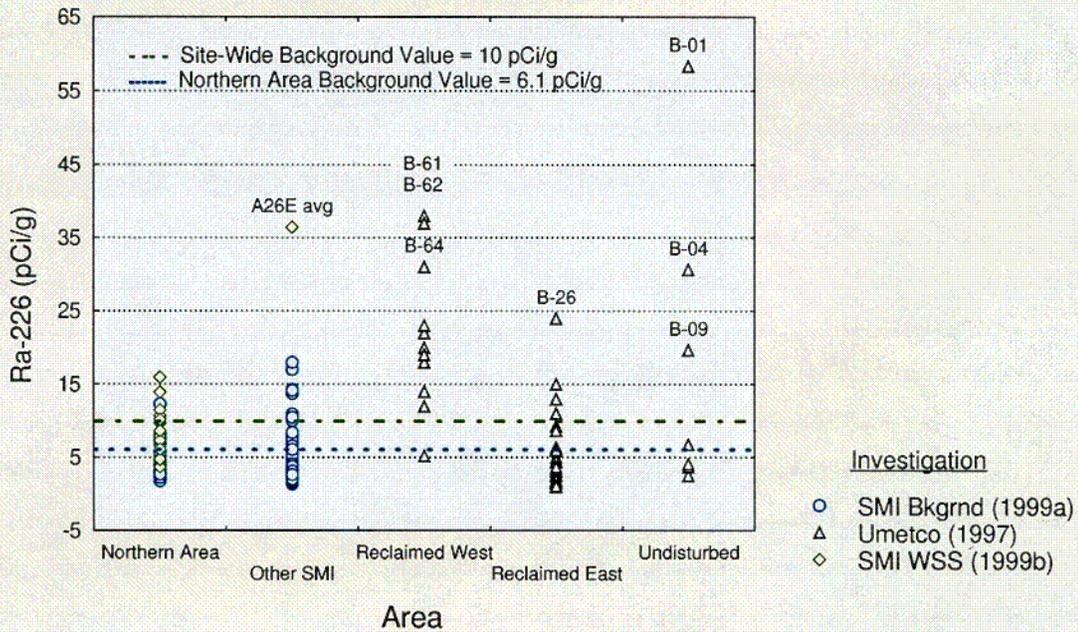


Figure 5.1. Ra-226 Distributions in Background Samples by Area: 0-6" Depth Profile, Gas Hills, Wyoming Site

**Appendix A**

**Determining Background  
Direct Gamma Exposure Rates**

## Appendix A

### Determining Background Direct Gamma Exposure Rates

This appendix presents the data and statistical analyses used to derive the background direct gamma exposure rates to be applied to the repository covers at the Gas Hills, Wyoming site. The data are based on the direct land-based measurements collected during Umetco's previous (1995-1996) investigation (Umetco 1997). Table A.1 lists the background gamma exposure data and summary statistics that form the basis for this evaluation. Figure A.1 shows the corresponding background sampling locations. Figure A.2 shows the distribution of background exposure rates along with results of associated normality tests.

As shown in Table A.1, average (arithmetic mean) one-meter external exposure rates are 30.9  $\mu\text{R/hr}$  measured by ionization (pressurized ionization chamber or PIC) and 33.5  $\mu\text{R/hr}$  measured by scintillation (sodium iodide or NaI). The NaI measurements will be used as the basis for the background direct gamma derived herein, as this endpoint is consistent with the measurement method to be employed in the upcoming Final Status Survey. As shown in Figure A.2, statistical analyses indicate that the NaI data are lognormally distributed. Given these findings, a conservative background direct gamma exposure rate of 30  $\mu\text{R/hr}$ , the geometric mean of the background data set, was derived (see Table A.1 and Figure A.2).

#### References

- Umetco Minerals Corporation. 1997. *Background Land Conditions at the Gas Hills Uranium Project*. Draft Rev. 1. June 30, 1997.
- U. S. Nuclear Regulatory Commission (NRC). 1982. *An Aerial Radiological Survey of the Federal-American Partners, Pathfinder, and Union Carbide Mill Sites and Surrounding Area*. July 1982.

**Table A-1. Background Gamma Exposure Data: 1995-1996 Characterization Investigation  
Gas Hills, Wyoming Site**

Case ID	Sample ID	Sample Type	Phase	PIC (uR/hr)	NaI (uR/hr)
1	B-01A1	Outcrop	I		31
2	B-02	Outcrop	I	22.9	24
3	B-03	Outcrop	I	25.2	28
4	B-04A	Outcrop	I	27.3	31
5	B-04B	Soil	I		32
6	B-05	Outcrop	I		29
7	B-06	Outcrop	I	43.8	58
8	B-07	Outcrop	I	34.9	41
9	B-08A	Soil	I	85.6	97
10	B-09A	Outcrop	I	29.1	32
11	B-11	Outcrop	I	26.1	31
12	B-12	Outcrop	I	20.6	20
13	B-13A	Soil	I	18.6	19
14	B-17	Soil	I		30
15	B-18	Soil	I		24
16	B-19	Soil	I		22
17	B-20	Soil	I		23
18	B-21	Soil	I		29
19	B-22	Soil	I		22
20	B-23	Soil	II	29.5	33
21	B-24	Soil	II	26.7	30
22	B-25	Soil	II	32.2	38
23	B-26	Soil	II	47.4	54
24	B-27	Soil	II	32.8	35
25	B-29	Soil	II	23.3	25
26	B-30	Soil	II	22.3	23
27	B-31	Soil	II	28.2	30
28	B-32	Soil	II	24.2	25
29	B-33	Soil	II	25.7	27
30	B-34	Soil	II	27.3	29
31	B-35	Soil	II	21.3	21
32	B-36	Soil	II	27.3	29
33	B-37	Soil	II	23.7	24
34	B-38	Soil	II	21.2	20
35	B-39	Soil	II	21.3	20
36	B-40	Soil	II	22.4	22
37	B-41	Soil	II	22.5	22
38	B-43	Soil	II	25.2	27
39	B-44	Soil	II	21.1	20
40	B-45	Soil	II	21.3	21
41	B-46	Soil	II	20.4	20
42	B-47	Soil	II	19.0	18

**Table A-1. Background Gamma Exposure Data: 1995-1996 Characterization Investigation**  
**Gas Hills, Wyoming Site** page 2 of 2

Case ID	Sample ID	Sample Type	Phase	PIC (uR/hr)	NaI (uR/hr)
43	B-48	Soil	II	19.4	19
44	B-49	Soil	II	22.7	23
45	B-50	Soil	II	26.6	27
46	B-53	Soil	II	21.7	20
47	B-54	Soil	II	19.9	19
48	B-55	Soil	II	20.0	19
49	B-56	Soil	II	15.5	16
50	B-57	Soil	II	37.3	45
51	B-58	Soil	II	52.2	65
52	B-59	Soil	II	50.4	62
53	B-61	Soil	II	52.7	71
54	B-62	Soil	II	49.5	61
55	B-63	Soil	II	54.6	69
56	B-64	Soil	II	47.8	60
57	B-65	Soil	II	38.6	45
58	B-66	Soil	II	35.6	43
59	B-67	Soil	II	36.5	46
60	B-68	Soil	II	38.0	45
61	B-69	Soil	II	41.7	49
62	B-70	Soil	II	32.4	38

*Note:*

This data set excludes the B-01A2 outcrop datum (NaI, 32.5 uR/hr), as it is considered duplicative of the corresponding equivalent B-01A1 outcrop datum listed above.

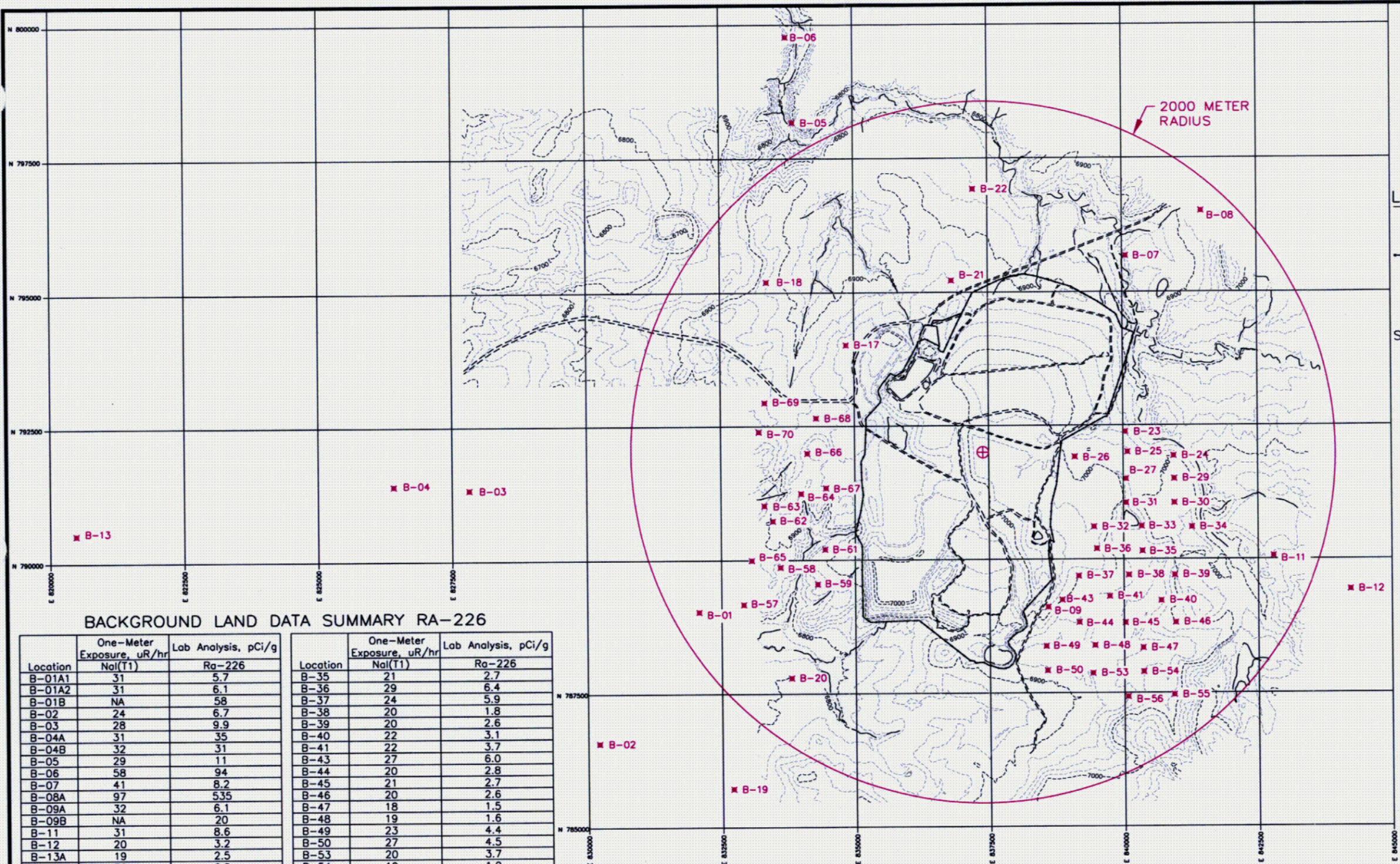
PIC - Pressurized Ionization Chamber (ionization method)

Na I - Sodium iodide (scintillation method)

**Summary Statistics**

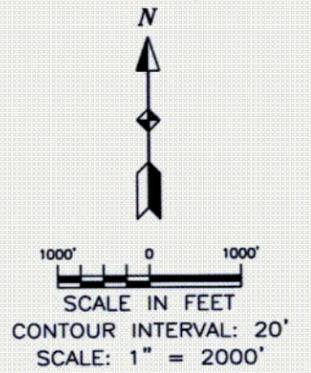
Parameter	Valid N	Mean	Confid.		Minimum	Maximum	Lower	Upper	Std.Dev.
			95.00%	Median			Quartile	Quartile	
PIC	54	30.9	34.3	26.7	15.5	85.6	21.7	36.5	12.8
NaI (uR/hr)	62	33.5	37.7	29.0	16.0	97.0	22.0	41.0	16.4
ln NaI	62	3.4	3.5	3.4	2.8	4.6	3.1	3.7	0.4
exp (ln NaI)	62	<b>30.5</b>	33.9	29.0	16.0	97.0	22.0	41.0	1.5

The 30.5 uR/hr geometric mean NaI value (bolded and outlined above) was chosen to represent the background direct gamma exposure rate for the Gas Hills site. This value was chosen (instead of the arithmetic mean) because a normal distribution could not be assumed (see Figure A.2).



**LEGEND:**  
 ✖ B-02 - SAMPLE LOCATION 1995 SURVEY  
 - - - RESTRICTED AREA BOUNDARY  
 ⊕ - EAST GAS HILLS SITE CENTER

SOURCE: UMETCO 1997a



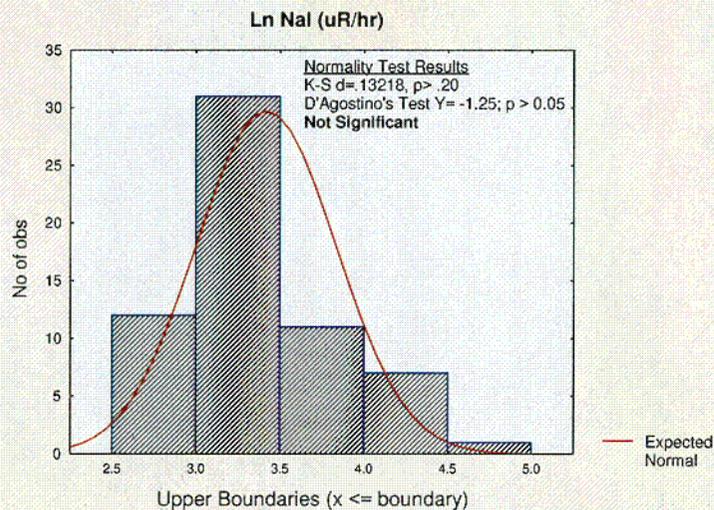
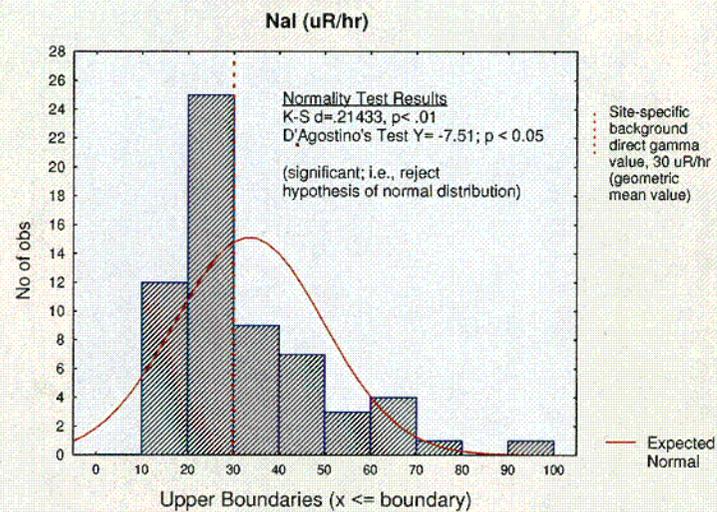
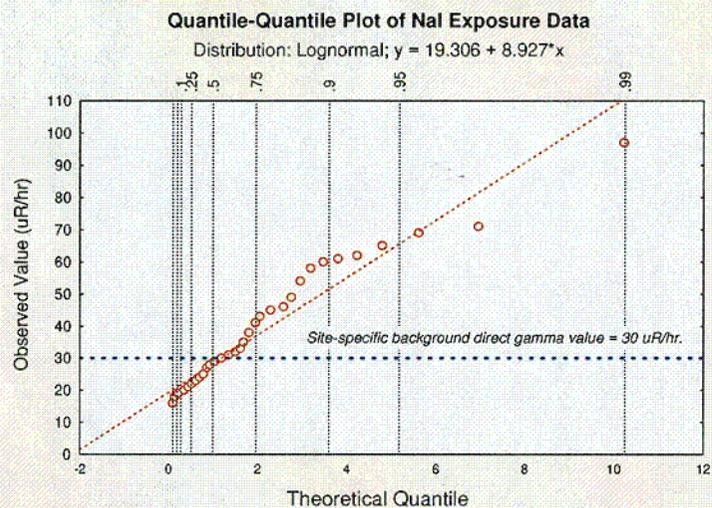
**BACKGROUND LAND DATA SUMMARY RA-226**

Location	One-Meter Exposure, uR/hr		Lab Analysis, pCi/g	
	Nal(T1)	Ra-226	Nal(T1)	Ra-226
B-01A1	31	5.7	B-35	2.7
B-01A2	31	6.1	B-36	6.4
B-01B	NA	58	B-37	5.9
B-02	24	6.7	B-38	1.8
B-03	28	9.9	B-39	2.6
B-04A	31	35	B-40	3.1
B-04B	32	31	B-41	3.7
B-05	29	11	B-43	6.0
B-06	58	94	B-44	2.8
B-07	41	8.2	B-45	2.7
B-08A	97	535	B-46	2.6
B-09A	32	6.1	B-47	1.5
B-09B	NA	20	B-48	1.6
B-11	31	8.6	B-49	4.4
B-12	20	3.2	B-50	4.5
B-13A	19	2.5	B-53	3.7
B-17	30	6.8	B-54	1.9
B-18	24	3.7	B-55	1.0
B-19	22	4.1	B-56	1.1
B-20	23	2.4	B-57	45
B-21	29	6.1	B-58	65
B-22	22	4.1	B-59	62
B-23	33	11	B-61	71
B-24	30	6.2	B-62	61
B-25	38	9.3	B-63	69
B-26	54	24	B-64	60
B-27	35	15	B-65	45
B-29	25	2.5	B-66	43
B-30	23	3.4	B-67	46
B-31	30	8.7	B-68	45
B-32	25	5.0	B-69	49
B-33	27	6.1	B-70	38
B-34	29	13		

NOTE: NA=NOT ASSESSED

**UMETCO MINERALS CORPORATION**  
**BACKGROUND SOIL SAMPLING**  
**LOCATIONS: 1995-1996**  
**RADIOLOGICAL INVESTIGATION**  
 GAS HILLS SITE  
 SEPTEMBER 2000

C16  
 FIGURE A.1



**Figure A.2**  
**Distribution of Background Direct Gamma Exposure Rates**  
**Gas Hills, Wyoming Site**

## **Appendix B**

### **Analytical Results for SMI Samples Excluded from the Background Data Set**

**Appendix Table B.1. SMI Background Sample Results Excluded from the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location <sup>1/1</sup>	Soil Group	Sample Depth	Ra-226 (pCi/g) <sup>1/2</sup>	Th-230 (pCi/g)	U-nat (pCi/g) <sup>1/3</sup>	
BKG N71*	Group 1	0-1"	<b>8.59</b>	10.45	16.1	
		1-6"	1.89	2.64	3.91	
		6-12"	1.95	2.26	3.43	
BKG N73	Group 2	0-1"	<b>7.14</b>	8.20	12.3	
		1-6"	5.12	6.79	12.9	Ra-226:
		6-12"	5.33	6.14	11.9	U-nat/2
BN 1*	Group 1	0-1"	<b>39.12</b>	--	41.0 **	(1.91)
		1-6"	5.78	5.51	8.42	
		6-12"	4.16	--	--	
BN 2*	--	0-1"	<b>23.39</b>	--	--	
		1-6"	7.40	7.75	9.28	
		6-12"	3.49	3.23	4.02	
BN 3*	Group 1	0-1"	<b>32.53</b>	--	41.0 **	(1.59)
		1-6"	4.30	4.94	5.65	
		6-12"	4.80	--	--	
BN 4*	Group 1	0-1"	<b>13.51</b>	--	--	
		1-6"	4.78	5.13	5.28	
		6-12"	5.18	4.94	4.80	
BN 5*	Group 1	0-1"	<b>21.06</b>	--	35.0 **	(1.20)
		1-6"	4.50	4.86	5.05	
		6-12"	4.19	--	--	
BN 6*	Group 1	0-1"	<b>11.79</b>	--	--	
		1-6"	3.55	4.00	4.55	
		6-12"	3.18	3.39	4.08	
BN 7*	Group 1	0-1"	<b>9.75</b>	--	--	
		1-6"	3.70	4.07	5.32	
		6-12"	5.61	--	--	

<sup>1/1</sup> Sample locations followed by an asterisk (\*) are considered to be potentially affected (i.e., contaminated with windblown 11e.(2) material), based on location and/or Ra-226 distributions. The remaining samples are not necessarily affected, but were excluded from the background data set for conservative reasons as documented in text Table 3.2.

<sup>1/2</sup> Values in bold denote the surficial Ra-226 results, the magnitude of which indicated potential windblown impacts for most of the samples listed above.

<sup>1/3</sup> U-nat results followed by asterisks (\*\*) were analyzed at a later date by Umetco's contract laboratory in September 1999. These samples were analyzed to examine the Ra-226:U-nat/2 ratios for affected 0-1" samples (see values in parentheses), given the general lack of U-nat (and Th-230) data for this depth profile (see text Table 3.3).

-- Denotes that soil group was not defined in SMI's report.

**Appendix Table B.1. SMI Background Sample Results Excluded from the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location <sup>1/1</sup>	Soil Group	Sample Depth	Ra-226 (pCi/g) <sup>12/</sup>	Th-230 (pCi/g)	U-nat (pCi/g) <sup>13/</sup>	
BN 13	Group 1	0-1"	5.64	--	--	
		1-6"	9.37	9.36	11.83	
		6-12"	15.17	--	--	
BN 14	Group 1	0-1"	13.43	--	--	
		1-6"	6.42	7.29	9.74	
		6-12"	7.94	7.37	9.80	
BN 26*	--	0-1"	9.45	--	--	
		1-6"	4.22	4.13	4.62	
		6-12"	3.01	2.91	3.66	
BN 27*	--	0-1"	12.84	--	--	
		1-6"	4.39	3.83	4.43	
		6-12"	3.14	--	--	
BN 28*	--	0-1"	24.22	--	--	
		1-6"	5.32	4.99	6.26	
		6-12"	2.92	2.82	3.75	
BN 29*	--	0-1"	17.07	--	--	
		1-6"	3.90	3.53	4.77	Ra-226:
		6-12"	2.60	--	--	U-nat/2
BN 30*	Group 1	0-1"	30.03	--	35.0 **	(1.72)
		1-6"	4.63	5.57	6.72	
		6-12"	3.76	4.47	4.06	
BN 31*	Group 1	0-1"	32.70	--	44.0 **	(1.49)
		1-6"	3.19	3.09	4.52	
		6-12"	3.26	--	--	
BN 32*	Group 1	0-1"	24.46	--	24.0 **	(2.04)
		1-6"	3.52	3.67	5.20	
		6-12"	3.15	3.27	3.98	
BN 33*	Group 1	0-1"	17.21	--	--	
		1-6"	2.93	3.19	5.04	
		6-12"	3.40	--	--	
BN 34*	Group 1	0-1"	14.01	--	--	
		1-6"	3.69	4.41	6.83	
		6-12"	4.51	3.64	4.79	
BN 35*	--	0-1"	13.78	--	--	
		1-6"	7.85	7.39	9.67	
		6-12"	4.16	--	--	

**Appendix Table B.1. SMI Background Sample Results Excluded from the Final Background Data Set, Gas Hills, Wyoming Site.**

Sample Location <sup>1/1</sup>	Soil Group	Sample Depth	Ra-226 (pCi/g) <sup>1/2</sup>	Th-230 (pCi/g)	U-nat (pCi/g) <sup>1/3</sup>
BN 36	Group 1	0-1"	6.16	--	--
		1-6"	2.98	3.44	4.59
		6-12"	2.71	2.88	4.07
BN 40	Group 1	0-1"	6.37	--	--
		1-6"	1.77	2.20	3.42
		6-12"	1.62	1.45	2.30
BN 41	Group 1	0-1"	6.10	--	--
		1-6"	2.06	2.06	3.08
		6-12"	1.94	--	--
BN 46	--	0-1"	7.76	--	--
		1-6"	3.20	2.53	4.63
		6-12"	1.99	2.61	3.55
BN 48*	--	0-1"	11.13	--	--
		1-6"	3.99	4.08	5.77
		6-12"	2.40	2.48	3.27
BN 49*	Group 1	0-1"	33.07	--	44.0 ** (1.50)
		1-6"	7.70	8.88	11.3
		6-12"	7.30	--	--
BN 62*	Group 2	0-1"	11.92	--	--
		1-6"	6.10	6.23	8.07
		6-12"	5.52	6.10	7.58
BN 63*	Group 2	0-1"	12.95	--	--
		1-6"	6.50	8.75	11.3
		6-12"	7.12	--	--
BN 64*	Group 2	0-1"	15.44	--	--
		1-6"	5.00	7.97	9.90
		6-12"	5.81	5.49	8.51

**Appendix Table B.2. SMI Windblown Scoping Survey Results Excluded from the Final Background Data Set, Gas Hills, Wyoming, Site.**

Sample ID	Sample Location	Ra-226 (pCi/g)
A9475497	A94	8.55
B1161252	B11	5.54
B1189280	B11	4.32
B1752843	B17	6.55
B1877968	B18	6.26
B2219246	B22	3.85
B2860887	B28	7.83
B2907934	B29	8.10
B2979007	B29	4.59
B3008035	B30	6.98
B3904899	B39	6.39
B4109136	B41	5.66
B4367394	B43	4.26
B4454481	B44	8.41
B4494521	B44	11.15
B4540567	B45	4.20
B4641668	B46	5.47
B4693720	B46	10.90
B4806833	B48	7.44
B4849876	B48	12.73
B4873900	B48	8.49
B4912939	B49	8.40
B4961988	B49	5.36
B4977005	B49	11.23
B4988016	B49	9.36
B4990018	B49	16.82
B5452479	B54	5.00
B5771798	B57	6.01

*\*This A-grid datum was excluded due to location coinciding with B-grid data, as well as other samples excluded from the background data set.*

Note:

As shown in Figure 3.3 and Table 3.4, only the northernmost windblown scoping survey results (denoted by an "A" prefix) were included in the background data set (see single exception above). The results listed above include all the "B" prefix samples, which were collected in the southern half of the windblown scoping survey area, north of the above-grade tailings impoundment (Figure 3.3).