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Hanford Site Background: Part 2, Soil Background for Radionuclides

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1.0 INTRODUCTION

This report documents the range of radionuclide background activity that occurs in soils and sediments on the Hanford Site and in associated environments. The characterization of background activity in soil and groundwater is an important component in environmental restoration activities, as it can be used to identify contamination, establish cleanup goals, evaluate restoration alternatives, and assess risk and cleanup levels. Background conditions are also useful for establishing pre-operational conditions for new and existing facilities. The sitewide approach has been determined as a technically viable and cost-effective method for evaluating background conditions at the Hanford Site, as opposed to establishing background concentrations at each individual waste unit.

Radionuclides in soil occur as two general types: natural and anthropogenic (see definitions in Section 1.2). These radionuclides are deposited in different positions in the soil column and by different processes, so they must be considered separately when formulating a conceptual model. Conceptual model descriptions for soil radionuclide background at the Hanford Site are outlined in Section 2.0, as well as the data quality objectives that were used in this study.

The data used to evaluate radionuclide background activities in soil were obtained from two sources: (1) sampling and analysis of surface soil associated with monitoring activities, and (2) samples collected and measured specifically for the purpose of establishing the range of natural background activities in the vadose zone. Both types of data are described in greater detail in Section 3.0. The results of the data evaluations are presented in Section 4.0, and interpretation of these results and discussion of the use of sitewide radionuclide background are discussed in Section 5.0.

Many of the tenets upon which this report is based have been thoroughly discussed in previous documents describing other aspects of background at the Hanford Site. These other documents are cited, where relevant, and should be consulted where more detailed information is desired.

1.1 BACKGROUND SOURCES

Radioactivity from natural sources is found everywhere. The dominant source of naturally occurring radioactivity is from the decay of the primordial potassium, uranium, and thorium isotopes and their daughter products, which occur in all rocks and soils. These sources, which include radon, account for approximately 77% (230 mrem/yr) of the average natural background radiation in the United States (300 mrem/yr; NCRP 1987). Exposure to cosmic rays accounts for about 10% (30 mrem/yr) of the average natural background radiation. The remaining 13% (40 mrem/yr) of the average dose is received from internal sources, which are radionuclides naturally present in tissues and bones in the body.

The background concentration and distribution of radionuclides in soils at the Hanford Site is governed by two primary factors. The first factor relates to the abundance of naturally occurring isotopes in the soil and their physical and chemical characteristics. Modifications by human activities also may influence the concentration and distributions of these radionuclides (e.g., radon concentrations in enclosed spaces). The second factor is the abundance of radionuclides in the atmosphere. The predominant source of radioisotopes in the atmosphere is global fallout from aboveground nuclear tests and severe nuclear accidents. Some radionuclides are naturally produced in the atmosphere by cosmic radiation. The concentration and distribution of fallout and cosmogenic radionuclides in soil are influenced primarily by the circulation of the earth's air masses and concomitant rainfall.

These two different types and occurrences of radionuclides require different considerations and treatments for use as background. A discussion of the conceptual models for determination of radiological background is presented in Section 2.0.

1.2 DEFINITIONS

Some of the terms and concepts used in this report have specific meanings in the context of environmental regulations or may not be familiar to the casual reader. Several of these key terms are defined and discussed below.

- Activity is a measure of the transformation rate of a radionuclide in disintegrations per unit time. Typical units of measure are the Becquerel (1 disintegration/sec) and the Curie (3.7×10^{10} disintegrations/sec or 2.2×10^{12} disintegrations/min).

- Anthropogenic radionuclides are radioactive isotopes that are produced or dramatically concentrated by human activities. These radionuclides include all of the anthropogenic radionuclides produced in fission and fusion reactions, as well as naturally occurring radionuclides that have been concentrated during the manufacture of nuclear reactor fuel. Most of the anthropogenic radionuclides important for characterizing background have been produced by aboveground nuclear explosions and nuclear accidents and were subsequently deposited as global fallout by precipitation of atmospheric particles.

- Background radiation refers to the radiation found everywhere in the environment from natural and anthropogenic sources. When applied to environmental cleanup, it refers to the activity of radionuclides in the vicinity of a waste site or potential waste site which are unrelated to releases from that site.

- Dose is a value for estimating the total risk of potential health effects from radiation exposure. It is more precisely termed as effective dose equivalent. Calculations of dose are based on a pathway-specific amount and type of radiation that is adsorbed by body tissue from both internal and external sources. The unit of measure is the rem or Sievert (100 rem).

- Naturally occurring radionuclides occur as a result of natural deposition and accumulation in the soil. Concentrations of these radionuclides are largely dependent on sedimentary, pedogenic, and fluvial processes, but modification of the natural concentrations may be affected by the activities of man.

- Soil, in the context of environmental regulations, refers to inorganic and/or organic material that exists on the earth's surface above bedrock, excluding the atmosphere and bodies of water. The terms "soil" and "sediment" are used interchangeably in this report and refer to unconsolidated materials deposited on the surface of the earth.

- Vadose zone is the unsaturated portion of the soil or rock substrate, above the water table.

2.0 DATA QUALITY OBJECTIVES

This section summarizes the objectives, purposes, and applications of background data and discusses how these data are expected to be used. This aspect of the evaluation focuses on (1) the type of data necessary to evaluate background and (2) the adequacy of these data for their intended uses in terms of the representativeness of the samples and/or data, as well as the completeness, comparability, and quality (e.g., accuracy, precision) of the data types. Conceptual models for evaluating sitewide radionuclide background are presented and discussed to aid in determining the proper types of data to use.

2.1 DATA TYPES AND USES

Information about background levels is used in environmental activities where it is necessary to define contamination and establish cleanup or performance levels. At the Hanford Site, these activities include site characterization for compliance with the *Resource Conservation and Recovery Act* (RCRA); the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA), and other applicable regulations.

Data on background radiation are also used to evaluate the feasibility of corrective measures, treatment, and development of treatment technologies. All of these uses invariably involve the assessment of risk to human health and/or the environment; these assessments are also used in risk management and other cleanup decisions. Risk assessment applications of radiological data include evaluation of potential increased incidence of cancer deaths resulting from external and/or internal radiation dose.

Radiological dose and risk can generally be assessed in two ways: (1) by exposure to individual radionuclides and (2) by exposure to the total measurable radiation present. Measurement of the radionuclide activity is most commonly performed in a fixed laboratory but can also be made with field instruments using high-efficiency, energy-discriminating sensors (e.g., high-purity germanium detectors). Total dose is routinely determined in the field with hand-held instruments and thermoluminescent dosimeters (TLDs). To date, the regulatory agencies have not reached a decision or concurred on the types(s) of radiological soil background data needed or the specific manner in which the data are to be used.

This study evaluates background activities of individual radionuclides that are most often used to calculate dose (most of the existing data is in the form of specific radionuclide activities) (DOE/RL 1995a). There is no accepted suite of radionuclides that are routinely analyzed to evaluate anthropogenic background levels. However, only a limited number of isotopes contribute significantly to risk (EPA 1989), and these have been determined for the Hanford Site (DOE/RL 1994). This list of isotopes includes common and ubiquitous natural radionuclides (e.g., ^{40}K), anthropogenic radionuclides (e.g., ^{137}Cs), and some radionuclides associated with past processes on the Hanford Site. A group of 15 radionuclides (with ^{239}Pu and ^{240}Pu counted as one analyte) has been chosen by the U.S. Department of Energy (DOE) and the regulators as important for background characterization. These are shown in Table 2-1.

The use of field data for measuring dose and risk in remediation has not been adequately addressed in environmental guidance. This data may be useful when expedient, qualitative assessments of risk are required. Background data from TLDs are useful for qualitative and semi-quantitative surveillance and monitoring, but because they are largely independent of radiation energy these data are not comparable to dose equivalent calculations based on isotopic activities. These data cannot, therefore, be effectively used in risk assessment applications that require isotope activities to calculate effective dose equivalents. These applications include computer models for calculating dose and risk contributions from various pathways and procedures as described in *Hanford Site Risk Assessment Methodology* (DOE/RL 1995b).

2.2 CONCEPTUAL MODELS

The background conceptual models presented here provide a basis for understanding the processes and factors that control and influence the distribution of background radiation in the environment. These models focus on the types, sources, spatial distribution, and relative abundances that occur in soil at the Hanford Site.

The conceptual model for radionuclide background concentrations in soil can be described in terms of contributions from naturally occurring and anthropogenic radionuclides. It is important to characterize anthropogenic radionuclide levels (i.e., global fallout not associated with a waste site) in order to allow site-derived contamination to be distinguished from anthropogenic background.

The process by which these radionuclides are deposited in the vadose zone, either as constituents in the soil or as airfall, must be considered by the conceptual model. Radionuclide concentrations in the soil are influenced by a variety of factors and are discussed in detail in the following section. Airfall deposition includes global fallout from anthropogenic and natural sources. Radionuclides that occur naturally in the atmosphere are produced by cosmic rays either by neutron activation (e.g., ^{22}Na) or from spallation processes (e.g., ^{129}I). The abundance of radionuclides in the atmosphere is a function of latitude, time, and climatic conditions (Hardy et al. 1968).

Table 2-1. Suggested Radionuclides for the Evaluation of Sitewide Soil Background.

Radionuclide	Symbol	Half-Life
Potassium-40	^{40}K	**1.28 x 10^{9} yr**
Cobalt-60	^{60}Co	5.3 yr
Strontium-90	^{90}Sr	29.1 yr
Cesium-134	^{134}Cs	2.06 yr
Cesium-137	^{137}Cs	30.2 yr
Europium-152	^{152}Eu	13.5 yr
Radium-226	^{226}Ra	**1600 yr**
Thorium-232	^{232}Th	**1.4 x 10^{10} yr**
Uranium-234	^{234}U	**2.4 x 10^{5} yr**
Uranium-235	^{235}U	**7 x 10^{8} yr**
Uranium-238	^{238}U	**4.5 x 10^{9} yr**
Plutonium-238	^{238}Pu	87.7 yr
Plutonium-239 (combined)	^{239}Pu	2.4 x 10^{4} yr
Plutonium-240 (combined)	^{240}Pu	6537 yr
Americium-241	^{241}Am	433 yr
Gross beta	gross-β	NA

Radionuclides in **bold** are naturally-occurring; others are anthropogenic.
NA = Not Applicable

2.2.1 Natural Background

The naturally occurring radionuclides in Hanford Site soils are associated primarily with basaltic and quartzofeldspathic components, which are the predominant end member compositions in the vadose zone (DOE/RL 1995c). These components are ubiquitous in soils of the Pasco Basin and vary in proportion both laterally and vertically. The dominant natural radionuclides found in these sediments are ^{40}K, ^{232}Th, and ^{238}U and their progeny. These naturally occurring radionuclides may also be concentrated by man. For example, ^{40}K activities would be expected to be higher around agricultural areas where potassium is applied to crops. Both ^{232}Th and ^{238}U are naturally occurring isotopes that were used in Hanford Site operations, so these and their daughters have the potential of being concentrated above natural background around the Hanford Site.

It has been demonstrated (DOE/RL 1995c) that the natural range of soil compositions can be described as a single population because the soils share a common source and depositional process. The naturally occurring radionuclides should behave in a manner similar to the naturally occurring nonradioactive components in the soil, forming a single population for the Hanford Site. The main exception to this conceptual model is ^{222}Rn (radon), which is a gas produced naturally by the decay of ^{226}Ra. This gas accumulates, migrates upward in the soil column, and can collect in poorly ventilated buildings. Radon is the greatest single contributor to radiation dose (about 67 % of the average dose in the United States [NCRP 1987]) from naturally occurring radioactive materials.

The most significant sources of naturally occurring radionuclides are deposited and distributed within the soil column. Some activation and spallation products are produced naturally in the upper atmosphere by interactions with cosmic radiation and fall to the earth's surface either with precipitation or as dry particles. The primary cosmogenic radionuclide products formed in the atmosphere are ^{3}H, ^{7}Be, ^{14}C, and ^{22}Na (NCRP 1987). None of these radionuclides contribute significantly to background dose.

2.2.2 Anthropogenic Background

Exposure to radiation has been influenced during the past century by human practices involving the manufacture and use of radioactive materials. The average adult in the United States absorbs approximately 65 mrem/yr from man-made sources, the largest contribution coming from the medical and dental use of x-rays and gamma rays. Exposure to background radiation in the soil has also increased, mainly from global fallout produced by nuclear weapons testing. With the cessation of most atmospheric testing following adoption of the 1963 Nuclear Test Ban Treaty, most anthropogenic radionuclides decayed away within a few years to levels below detection. The long-lived radionuclides (i.e., half-lives greater than 1 year) that remain from weapons fallout are globally ubiquitous and are referred to here as anthropogenic background.

The conceptual model for anthropogenic radionuclide background differs from that for naturally occurring radionuclides because the sources of anthropogenic isotopes are external, rather than indigenous, to the soil. As a consequence, the species, abundances, distribution in the environment, and geochemical behavior of the anthropogenic radionuclides differ significantly from those of the naturally occurring radionuclides.

Deposition of radionuclides as fallout from the atmosphere is geographically distributed by precipitation and regional wind patterns. These distribution patterns, both vertical and lateral, are not clearly understood, and empirical information is lacking for many of the radionuclides of concern. The geographic distribution of radionuclides is largely controlled by the amount of rainfall a region receives, although "dry precipitation" also occurs on a limited scale by direct deposition from winds. Because of the light rainfall around Hanford, the geographic variability in fallout levels around this region are expected to be relatively small.

Establishing background levels for the anthropogenic radionuclides requires modification of the conceptual model used for nonradioactive and naturally occurring radioactive isotopes, as the isotopes were deposited by different processes. Atmospheric radionuclide deposition from global fallout is generally concentrated in the top few centimeters of undisturbed soil. Distribution of the activity of radionuclides from fallout as a function of soil depth has been measured on the Hanford Site and at several other sites, including sites where atmospheric testing has been conducted. A discussion of these studies can be found in DOE/RL (1994a).

Vertical distribution of ^{90}Sr, ^{137}Cs, and $^{239,240}Pu$ in soil on and away from the Hanford Site has been measured by Price (1991). Results indicate that over 95% of the ^{137}Cs and $^{239,240}Pu$ reside in the top 5 cm of the soil. The ^{90}Sr depth profile differs significantly from the other two isotopes as it gradually decreases in abundance to depths of almost 20 cm, and the interval from 2.5 to 5 cm is likely to contain the highest activities. These are the only known data evaluating anthropogenic radionuclide activity with depth on the Hanford Site; all other monitoring data have been collected from the upper 2.5 cm.

Several factors may contribute to the tendency for fallout-derived radionuclides in this semi-arid region to be restricted to upper parts of the soils where they were deposited. The general lack of transport mechanisms, such as direct recharge from meteoric water, to mobilize the radionuclides downward from the surface soils is one factor. Highly soluble chloride, for example, is restricted to the upper few meters of the soil column in this region due to climatic effects alone. Most radionuclides, however, are expected to be restricted to the uppermost portion of the soil column because they are strongly adsorbed onto the surfaces of soil materials (i.e., have partition coefficients greater than 20 [Ames and Serne 1991]). Isotopes of the more mobile elements (e.g., iodine and ruthenium) can be expected to be more extensively mobilized, but only in areas where the potential for mobilization and transport exists.

2.3 DATA QUALITY OBJECTIVES AND OTHER ISSUES

The type and quality of data used to characterize background are essential considerations in the conceptual models. The different sources for natural and anthropogenic radionuclides make it necessary to collect and treat the two data types differently. As mentioned previously, naturally occurring radioisotopes should be distributed in a manner similar to nonradioactive analytes, which means that the lateral and vertical heterogeneity of the vadose zone at the Hanford Site must be represented. Details of and justification for this approach are included in *Hanford Site Background: Part 1, Soil Background for Nonradioactive Analytes* (DOE/RL 1995c).

The collection, analysis, and/or use of soil for evaluating radionuclide background have been guided by the following considerations.

- Data collected to establish the distribution of natural radionuclide background in soil should come from samples that adequately represent the different soil (sediment) types of the area.

- Data used for background must be from sampling locations that are free from potential contributions from the Hanford Site.

- Background data should have detection limits that are low enough to adequately quantify the analyte with respect to risk-based levels, but these limits should not be set so low that unusual and costly analytical techniques must be employed to meet the limits.

All data used to characterize background should conform to precision, accuracy, representativeness, comparability, and completeness parameters detailed by the U.S. Environmental Protection Agency (EPA 1987). Precision, accuracy, and representativeness are parameters concerned mostly with laboratory analysis where a common measurement method also must be employed, as concentrations can be measured in terms of activity (usually measured in picocuries/gram, pCi/g), or dose rate (typically reported as millirems/year).

2.4 SUMMARY

The conceptual model for radionuclide background concentrations in soil can be described in terms of contributions from naturally occurring and anthropogenic radionuclides. The characterization of anthropogenic radionuclide levels is important in order to distinguish site-derived contamination from anthropogenic radionuclides that were deposited by global fallout.

The conceptual model must be different for natural and anthropogenic radionuclides because they were deposited by two different mechanisms, at different times, and generally have different geochemical characteristics. Naturally occurring radionuclides in the soil should behave identically to nonradioactive analytes, so the conceptual model formulated and confirmed for the latter (DOE/RL 1995c) should hold for both. Anthropogenic radionuclides are deposited exclusively on the surface, and have limited distribution through the top portions of the vadose zone. Anthropogenic radionuclide measurements to define background activities should, therefore, focus on surface samples (DOE/RL 1995a).

The type of data used for characterizing background should correspond to the data used in site remediation activities. If field instruments are used for *in situ* measurements of activity and/or dose, then a means of comparing waste site data to sitewide background data must be made if background is used to assess remediation effectiveness.

3.0 DESCRIPTION OF DATA

The data described and evaluated in this report are of two general types: (1) data from soils collected from the top 2.5 cm of the soil column (surface samples), and (2) data from soils typically collected below the upper 30 cm of the soil column (vadose zone samples). These two types of samples were collected for different purposes and will be discussed separately, although both sample types are suitable for evaluating different aspects of sitewide background. The surface samples are appropriate to determine anthropogenic radionuclide background, and the vadose zone samples are suitable for evaluating natural background activities, as discussed in Section 2.0. A more detailed description of the sampling and analysis of these two types of samples follows.

3.1 SURFACE SAMPLES

The surface samples used to evaluate radionuclide background data compiled and evaluated in this report were collected by the Pacific Northwest National Laboratory (formerly Pacific Northwest Laboratory, PNL) and Washington State Department of Health (DOH) radiation surveillance programs in southeastern Washington. All surface samples were collected from the upper 2.5 cm of soil and consisted of a composite of five round plugs, 10 cm in diameter. The samples were prepared and analyzed by different laboratories, as described in documents from PNL (1992) and DOH (1991).

Soil radionuclide data from PNNL and DOH provide the largest well-documented, quantitative data sets available to evaluate background conditions for surface samples at the Hanford Site (DOE/RL 1995a). Collectively, these two sources provide data on the activities of 25 radionuclides and four other parameters (gross alpha, gross beta, total uranium, and total thorium). These measurements were made on soils collected from over 70 localities within the region. The data used in this report were collected from 1985 to 1992 and are presented and discussed in greater detail in *Hanford Site Background: Evaluation of Existing Soil Radionuclide Data* (DOE/RL 1995a). The surface sampling locations for the soil background data evaluated in this report are shown in Figures 3-1 and 3-2.

The only data evaluated in this report were those from sampling locations considered by DOH and PNNL to be uncontaminated by Hanford operations (DOE/RL 1995a). This data set consists of 149 samples from 39 localities and provides data for 15 radionuclides of concern.

The radionuclides typically measured include the naturally occurring isotopes that contribute significantly to total dose (e.g., ^{40}K), and anthropogenic radionuclides that are ubiquitous in global fallout (e.g., ^{137}Cs) or that could be a contaminant from a monitored facility (e.g., plutonium isotopes). Of the hundreds of radionuclides that could be considered for characterizing background, only a few are of concern when their half-lives, abundances, and threat to human health are evaluated. Perkins and Jenquin (1994) surveyed the types and amounts of radionuclides produced at Hanford and recommended 26 radionuclides for consideration in

Figure 3-1. Sampling Sites for Pacific Northwest Laboratory Soil Monitoring Program (after PNL 1992). Numbers in parentheses correspond to site numbers in Appendix A of DOE/RL 95-55 (DOE/RL 1995a).

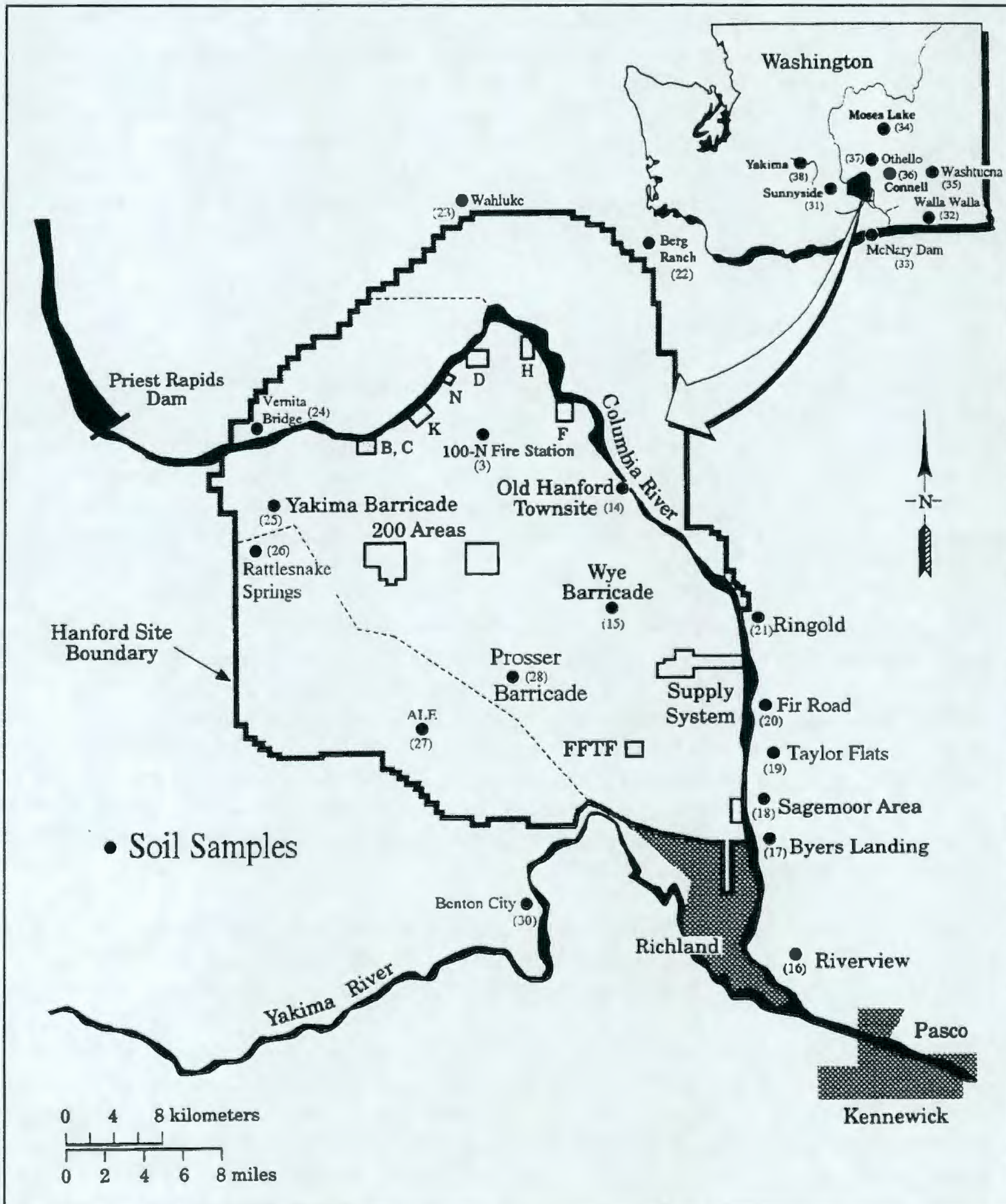
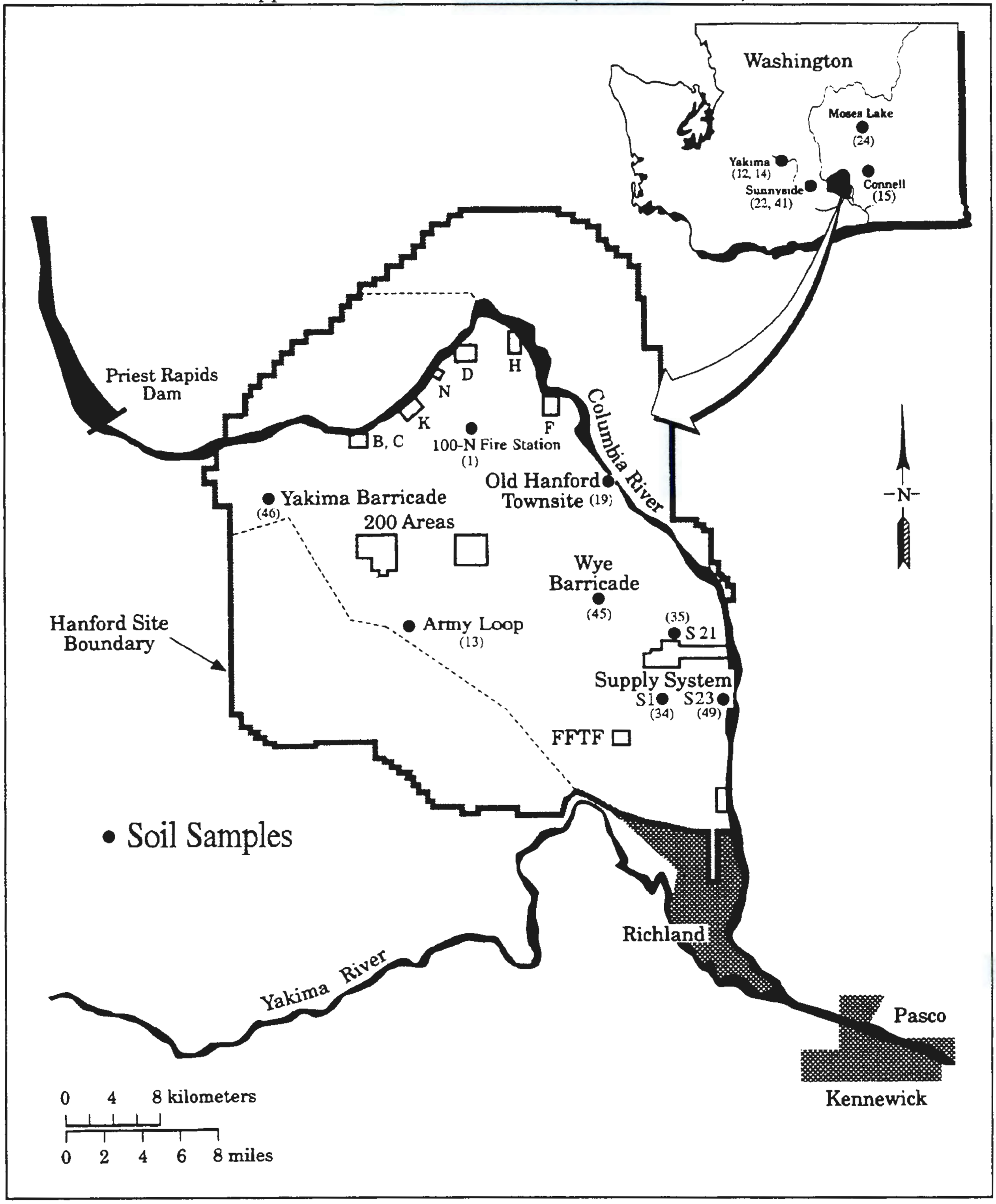


Figure 3-2. Sampling Sites for Washington State Department of Health (after DOH 1991). Numbers in parentheses correspond to site numbers in Appendix A of DOE/RL 95-55 (DOE/RL 1995a).



characterizing background. This list was refined through discussions between the EPA, Washington State Department of Ecology, DOH, and DOE/RL (see Table 2-1).

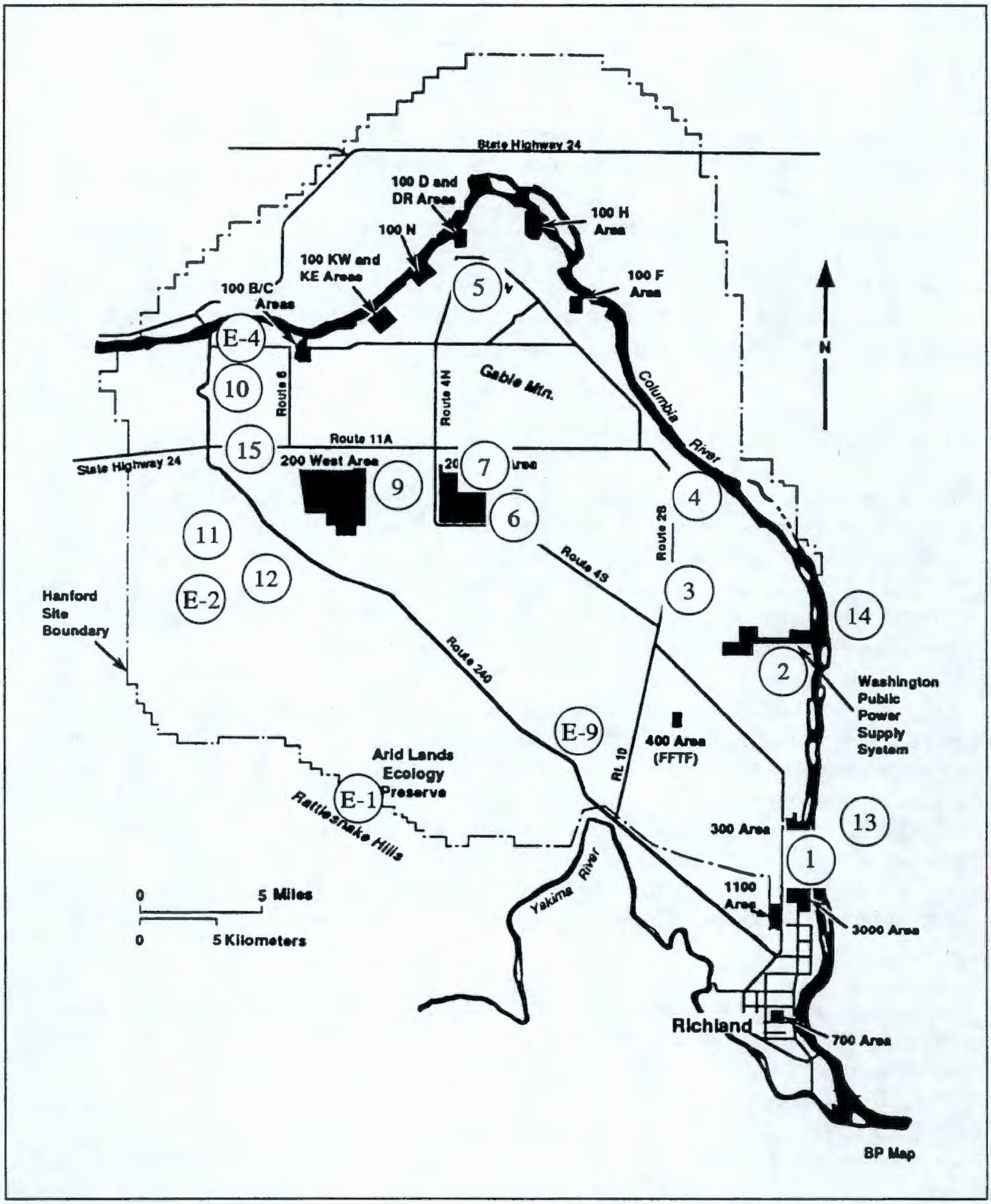
3.2 VADOSE ZONE SAMPLES

The subsurface samples analyzed for natural background radioactivity were collected during a previous study that characterized nonradionuclide background at the Hanford Site (DOE/RL 1995c). Samples from that study were archived at the Hanford Geotechnical Sample Library, at the 2101-M Building in the 200 East Area. A subset of 45 samples from the 105 nonradionuclide background systematic random samples (the background reference sample set) were chosen for analysis using a ranked set sampling procedure. In evaluating the samples for nonradionuclide background, it was shown that basalt dominates the composition of most analytes, so basalt content would be a valid parameter for ranking the samples. Lacking data on modal basalt content for each of the 105 random samples, a factor analysis was performed to correlate specific analyte abundances with samples of known basalt content. The analytes iron (Fe) and cobalt (Co) were found to have strong correlations with basalt content, so the samples were ranked according to the sum of the standardized variables, Z, where:

$$Z=((Fe-(\frac{\overline{X_{Fe}}}{\sigma_{Fe}}))+((Co-(\frac{\overline{X_{Co}}}{\sigma_{Co}}))$$

After ranking, every third sample was chosen for analysis, which resulted in a total of 44 samples. The sample with the largest standardized variable (Z) was then included to bracket the highest and lowest samples in the ranked data (the lowest Z sample was selected in the first 44 samples chosen). Added to these 45 systemic random samples were three ecosystem judgment samples taken from the surface, one sample of Ringold Formation collected from outcrop on the east side of the Columbia River, and one basalt sample used as an internal standard. A total of 50 samples were submitted for analysis of naturally occurring radionuclides. The sample locations are presented in Figure 3-3.

Figure 3-3. Vadose Zone Sampling Sites.



4.0 EVALUATION OF DATA

Evaluation of the surface and vadose zone data considers the quality of the data, the extent to which the data set can be considered a single population, and the identification of any unusual samples that should be suspended from consideration for statistical calculations. Statistical descriptions of the data sets are also presented in this section, along with doses associated with background activities of the naturally occurring radionuclides.

A thorough description of the surface data has been provided in *Hanford Site Background: Evaluation of Existing Soil Radionuclide Data* (DOE/RL 1995a). The vadose zone data are discussed below and tabulated in Appendix A. Also included is a discussion of the extent to which the surface and vadose zone data may be considered together, as part of a single population for naturally occurring radionuclides.

4.1 DATA QUALITY

The vadose zone samples were analyzed by Quanterra, Inc., located in Richland, Washington. The naturally occurring radionuclides listed in Table 2-1 were analyzed. The target detection limits were 1.0 pCi/g for ^{40}K and 0.1 pCi/g for the other five radionuclides (^{226}Ra, ^{232}Th, ^{234}U, ^{235}U, and ^{238}U). Thorium and uranium were analyzed using alpha spectroscopy, and ^{40}K was analyzed using gamma spectroscopy. Samples were counted from 120 to 500 minutes to meet the target detection limits; the analytical values are tabulated in Appendix A.

Total errors were calculated by the laboratory, and include the counting error and other laboratory errors (e.g., weighing errors, dilution errors). Analysis precision and accuracy were evaluated using a minimum of one laboratory control sample, one method blank, and one duplicate per sample batch. The quality control data are contained in Appendix B. All of the data above the detection limit passed the quality control tests. An analysis was considered above detection if the analyzed value was greater than its associated total error. Using this method, only the data for ^{235}U contained samples that were below detection (mean detection limit for ^{235}U is 0.055 pCi/g). Of the 50 samples analyzed for ^{235}U, only 18 were above their associated errors (36%).

Another measure of data quality is data comparability. All of the vadose zone data are considered comparable from an analytical perspective, because they were analyzed in the same laboratory under identical quality control and quality assurance procedures.

The Hanford sitewide soil background data set has been evaluated with respect to its completeness and representativeness (DOE/RL 1995c) and was determined satisfactory. The samples for evaluating naturally occurring radionuclides were chosen from the background data set by a process designed to produce a representative subsample of the larger population (see Section 3.2).

Another approach for evaluating overall data quality is comparing the activities of the parent natural radionuclides to their progeny (when the data are available). If secular equilibrium for appropriate portions of the decay chain is assumed, as would be expected for background samples, parent-progeny activities should be approximately equal and their distributions should be similar. Parent-progeny activities comparisons were made for the thorium and uranium decay chains for the vadose zone samples. Both ^{232}Th and ^{228}Th are compared on the probability plot on Figure 4-1 (Section 4.2.1 contains a description of the parameters presented in the probability plots). The intermediate member of this decay chain, ^{228}Ra, was not plotted because it was not a requested analyte and the reported value was not considered reliable by the laboratory. Both ^{238}U and ^{234}U are plotted in Figure 4-2. The parent and progeny distributions are very similar in each series, with a difference of approximately 5% between the geometric means of the activities within each series.

4.2 DATA DISTRIBUTION AND STATISTICS

The data distribution was evaluated for each of the naturally occurring radionuclides to compute the appropriate statistics. Use of these parameters and other statistical methods that may be applied to the sitewide background data are discussed in Section 5.0.

4.2.1 Distribution of the Data

Background data are a range of values that can be represented by one or more statistical distributions. Data showing a good fit to a distribution can be regarded as representing a single population, thus satisfying one of the data quality objectives for consideration of a sitewide background population (WHC 1991). The distribution analyses reported here are intended to test the hypothesis that the data are of a single population.

All of the background data were used to fit the Weibull and lognormal distributions to the naturally occurring radionuclides ^{40}K, ^{226}Ra, ^{232}Th, ^{234}U, and ^{238}U. None of these analytes had values less than the detection limit or outliers that could be considered anomalies. The data set for ^{235}U consisted of only 36% of the data above detection, and also contained three data points that were considered to be outliers. Cumulative distribution plots for all of the naturally occurring vadose zone analytes are shown in Figures 4-3 through 4-8. Included on these figures are the central tendencies of the data, shown as the geometric mean on the lognormal plots and eta on the Weibull plots. The Weibull distribution uses a t-shift (shown in the upper left of the figure), which must be added to the value given for eta to define the central tendency. Also included on the figures is the best-fit parameter (r^2) and the number of samples (n) comprising the data set.

Both the lognormal and Weibull distributions provide very good fits to the data, with most having an r^2 greater than 0.95. These results are similar to those obtained for nonradionuclides from the sitewide background data set (DOE/RL 1995c), of which these radionuclide samples are a subset. The results indicate that each radionuclide in the vadose zone can be considered a single population which represents the soils at the Hanford Site (Figures 4-3 through 4-8). Radionuclides from the surface samples, obtained from the Pasco Basin and other areas in

Figure 4-1. Lognormal Distribution of ^{232}Th and ^{228}Th From the Vadose Zone Samples.

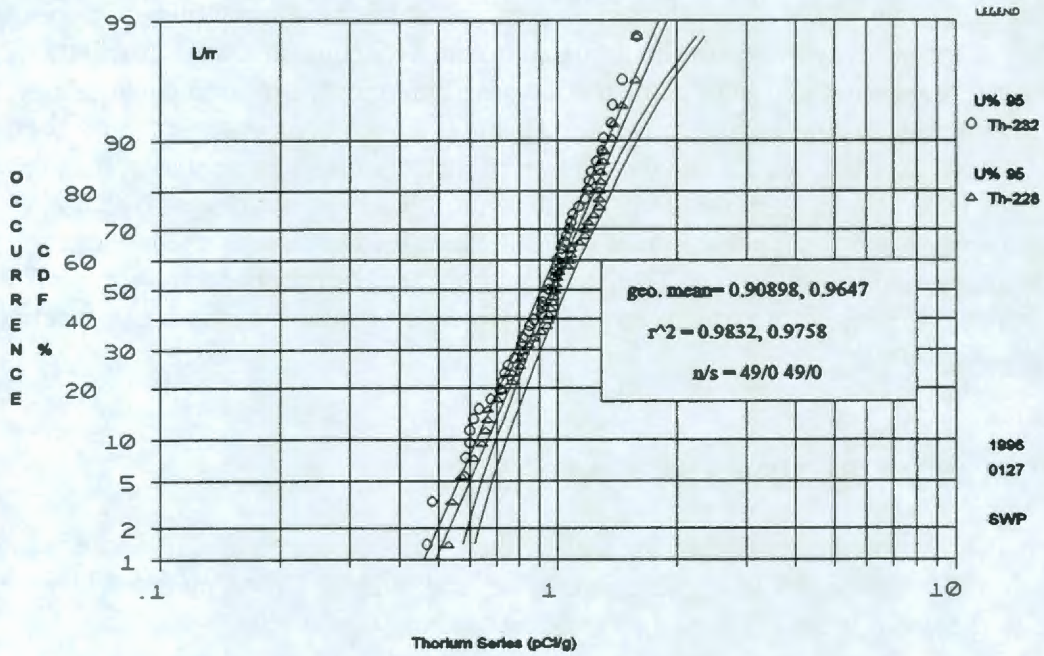


Figure 4-2. Lognormal Distribution of ^{238}U and ^{234}U From the Vadose Zone Samples.

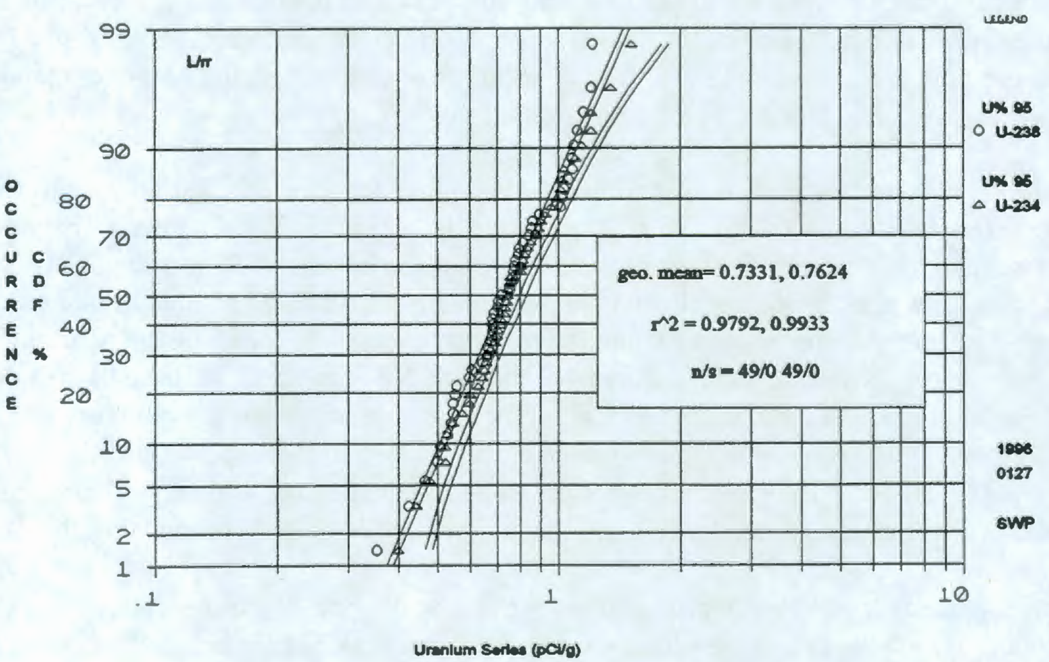
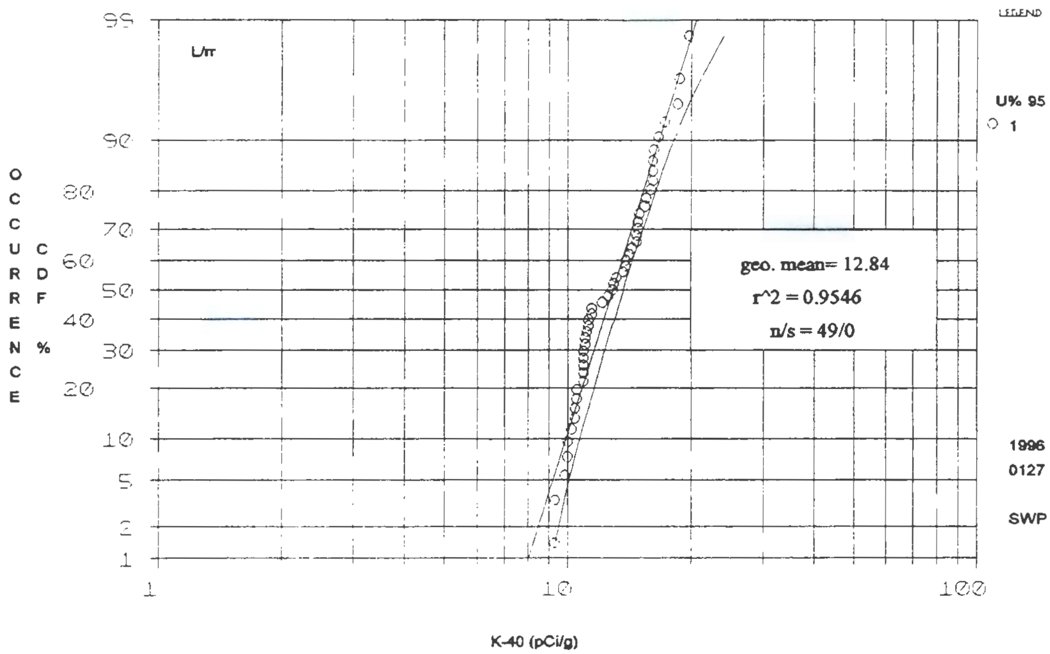


Figure 4-3. Lognormal (top) and Weibull (bottom) Distribution of ^{40}K From the Vadose Zone Samples.



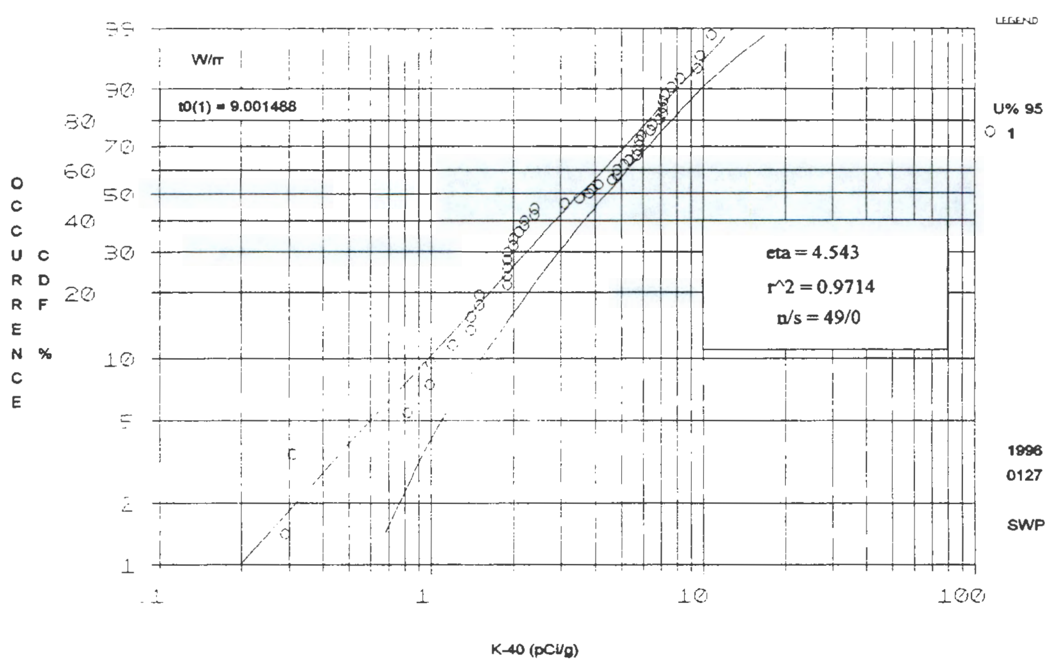
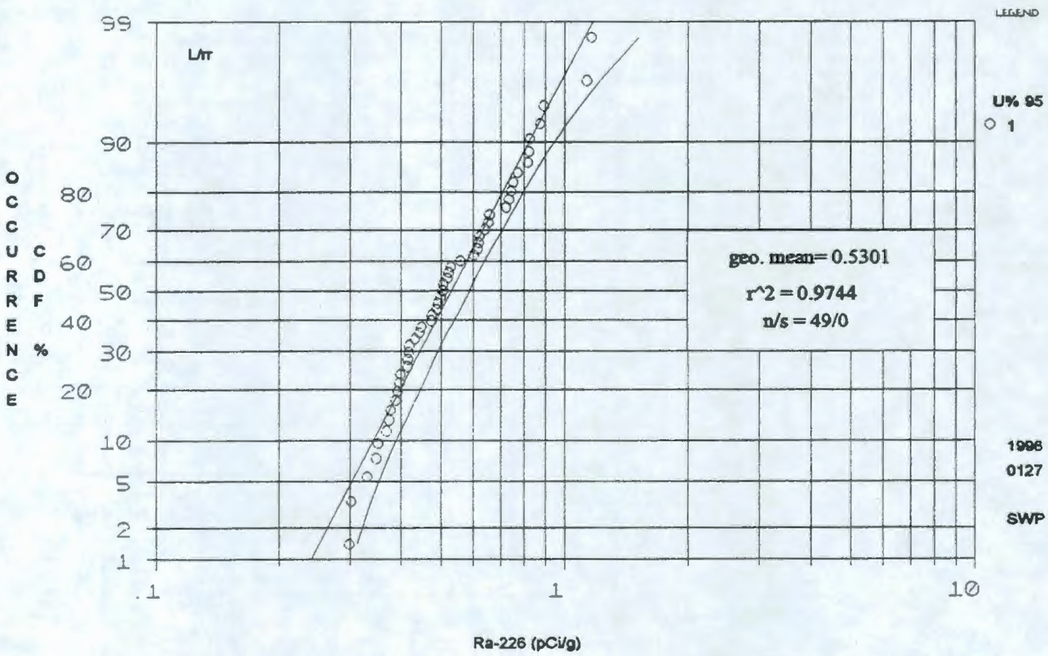


Figure 4-4. Lognormal (top) and Weibull (bottom) Distribution of ^{226}Ra From the Vadose Zone Samples.



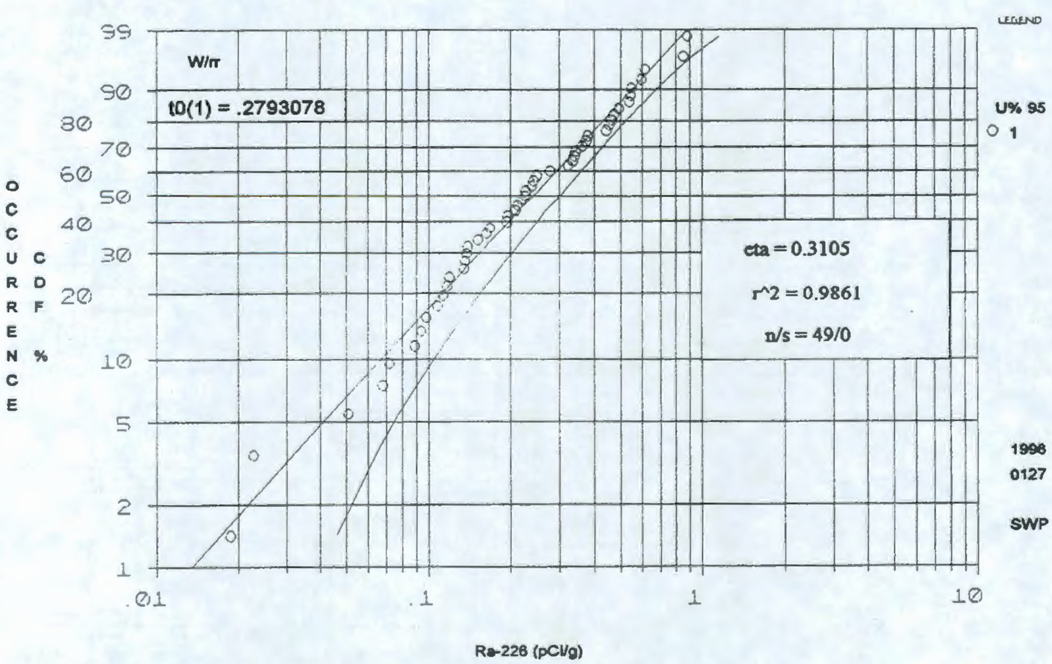
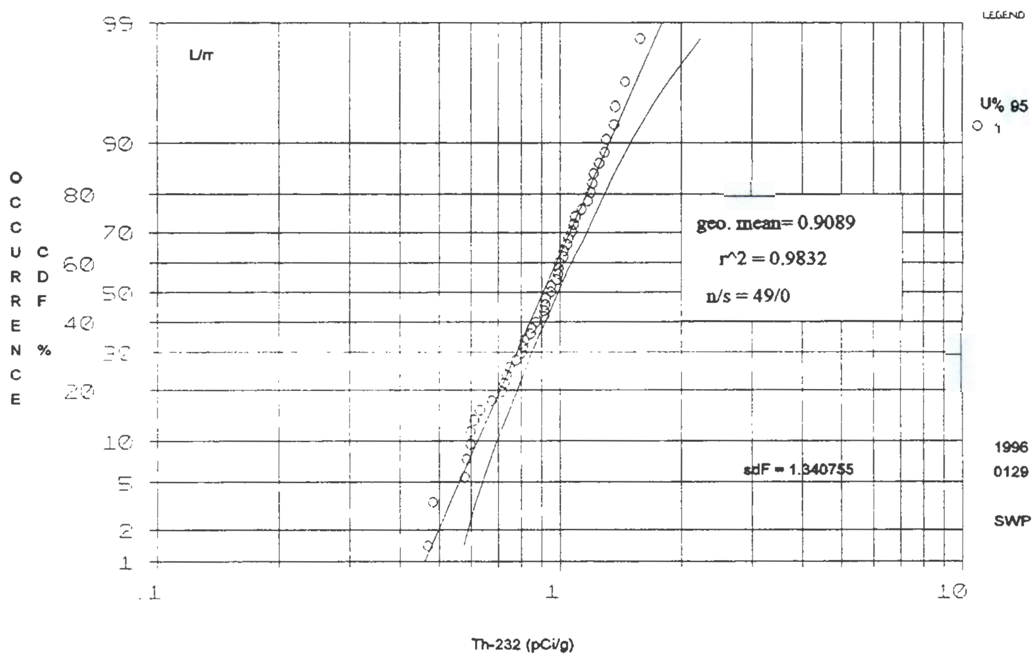


Figure 4-5. Lognormal (top) and Weibull (bottom) Distribution of ^{232}Th From the Vadose Zone Samples.



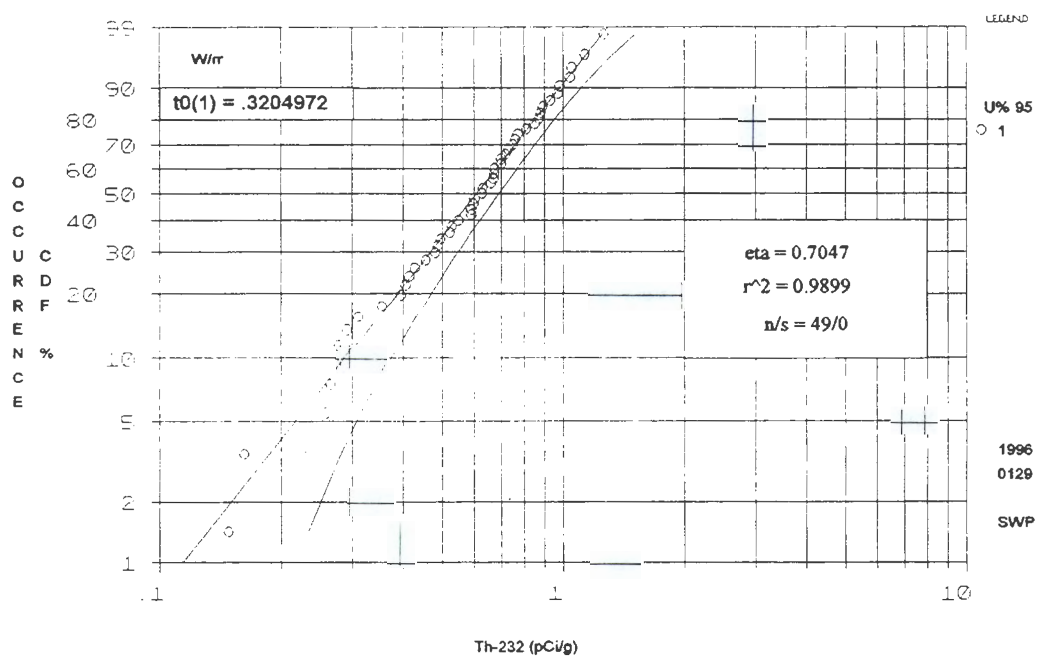


Figure 4-6. Lognormal (top) and Weibull (bottom) Distribution of ^{234}U From the Vadose Zone Samples.

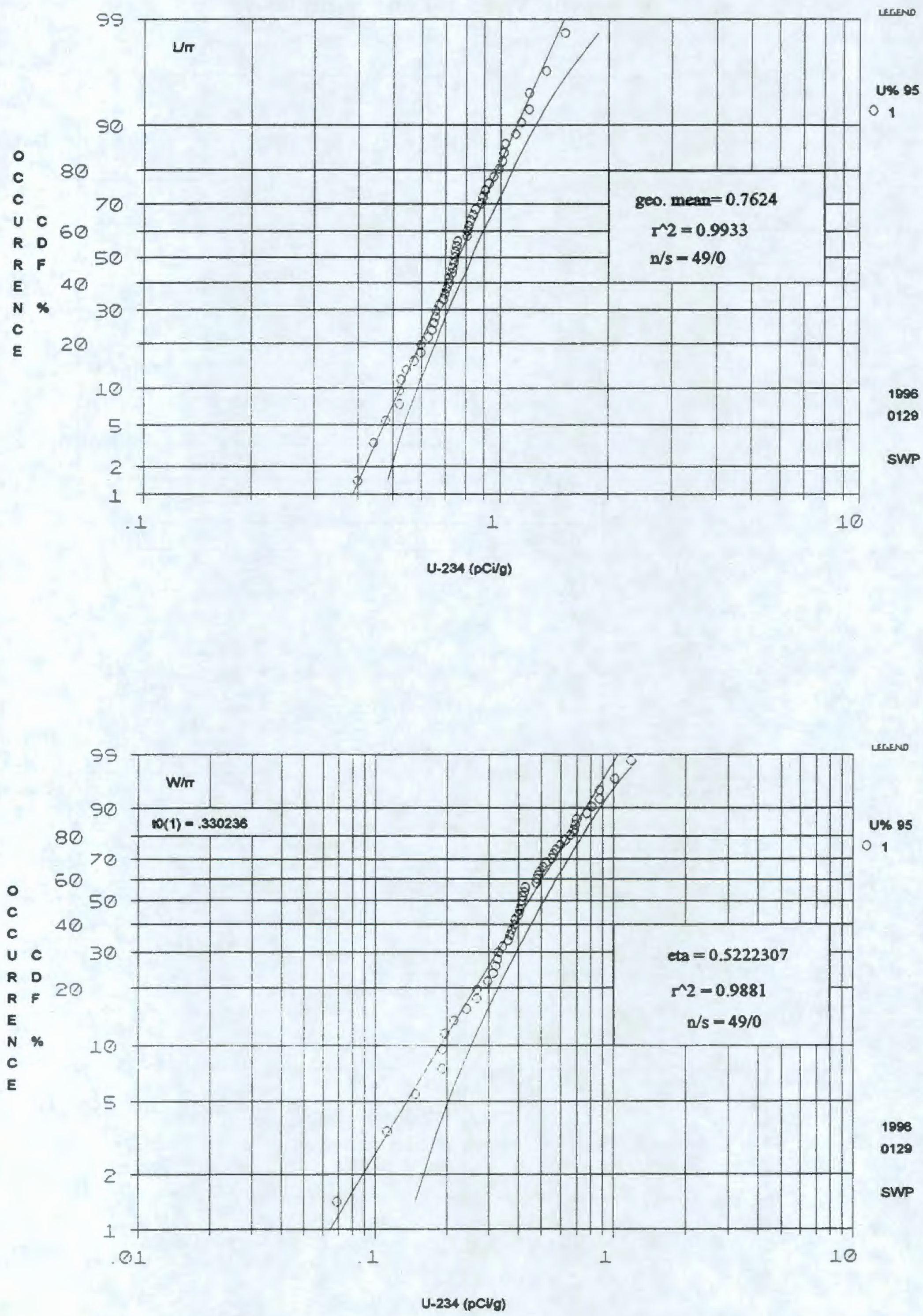
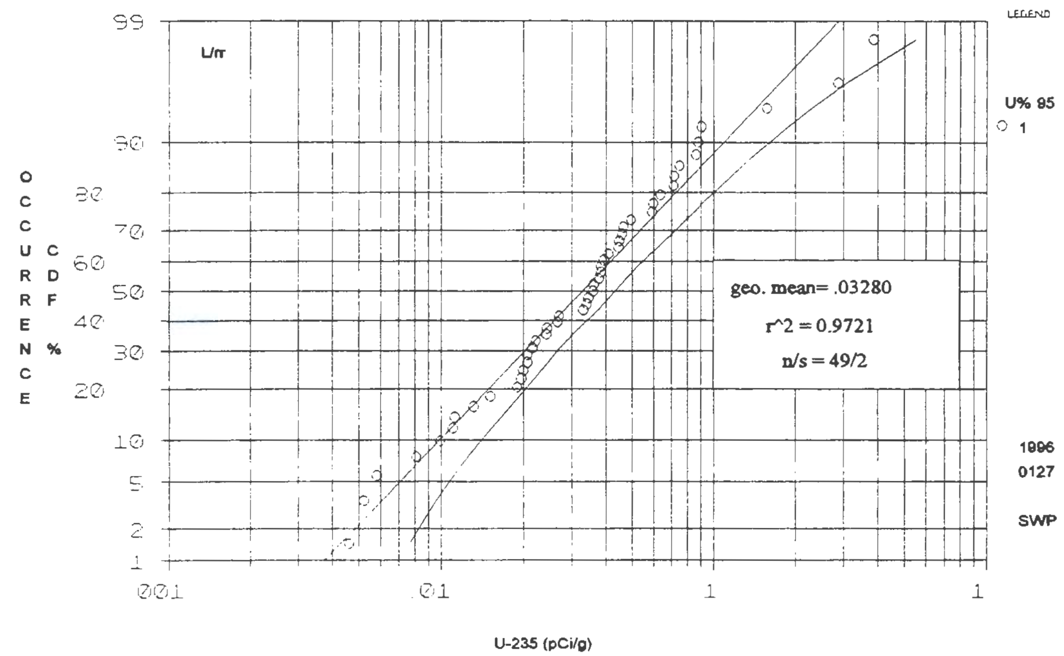


Figure 4-7. Lognormal (top) and Weibull (bottom) Distribution of ^{235}U From the Vadose Zone Samples.



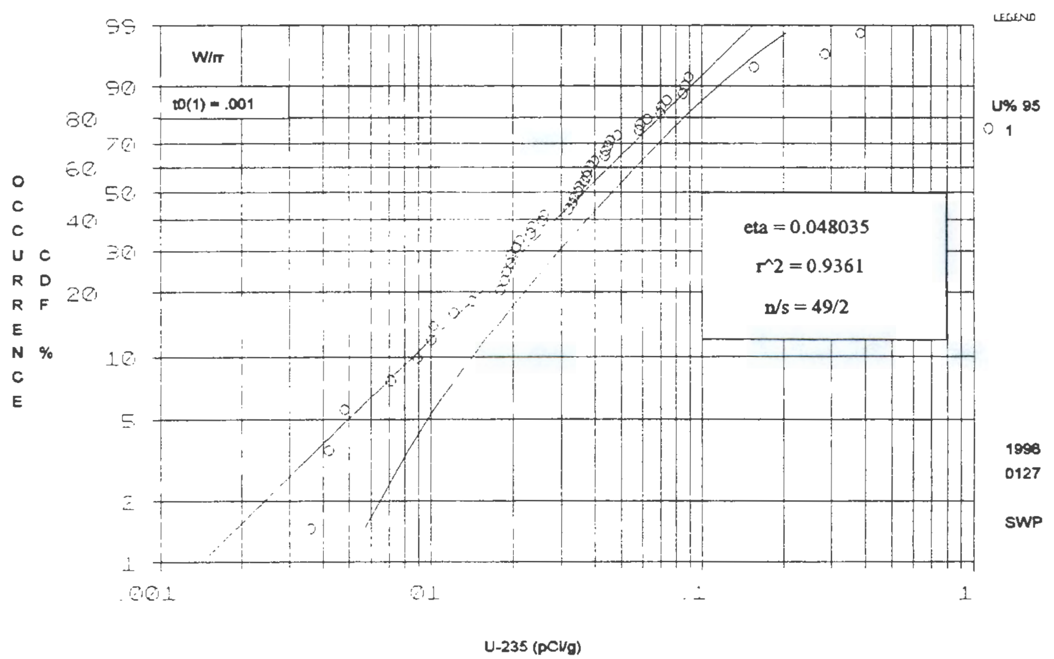
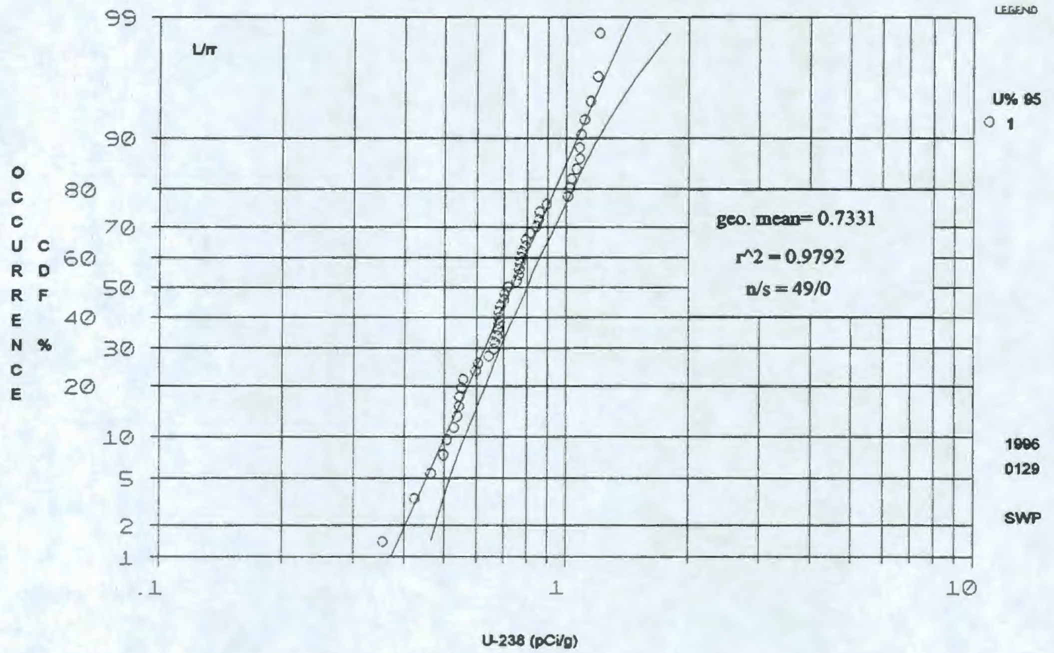
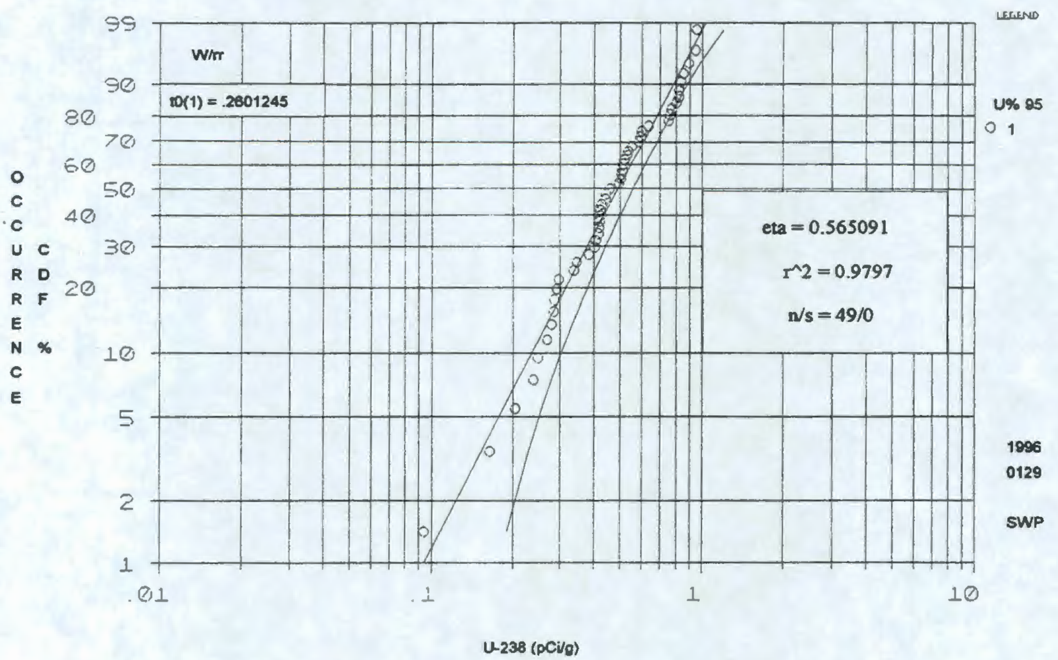


Figure 4-8. Lognormal (top) and Weibull (bottom) Distribution of ^{238}U From the vadose Zone Samples





southeast Washington, show a similarly good fit (DOE/RL 1995a). This evidence indicates that the sitewide background conceptual model is valid for radionuclide constituents in the vadose zone.

4.2.2 Statistics

Summary statistics for lognormal and Weibull distributions are presented in Tables 4-1 and 4-2. These statistics include the best-fit parameter and various percentiles of the data. A comparison of the lognormal and Weibull percentiles indicate an average relative percent difference of less than 5% for the two statistical techniques. The statistical parameters for ^{235}U, which used all of the data including the three outliers, varied the greatest between the lognormal and Weibull percentiles.

4.3 DOSE AND RISK ESTIMATES

Dose and risk associated with the vadose zone data for naturally occurring radionuclides have been estimated using the RESRAD dose modeling program (ANL 1993a), Version 5.61. The calculation of dose and risk from radionuclide data requires assumptions concerning exposure pathways, potential biological damage (i.e., quality factors), and other aspects of exposure for each radionuclide. The doses presented here are based on a residential scenario that includes external exposure; inhalation of fugitive dust; inhalation of radon; ingestion of plants, meat, and milk produced on typical Hanford soil; and ingestion of the soil itself. The parameters used in RESRAD are contained in Table 4-3. The RESRAD dose modeling results are presented here only as an estimate of background dose for a specific scenario, using parameters which cannot be generalized to all waste sites.

The arithmetic means, standard deviations, and upper 95th percent confidence limit of the 95th percentiles (lognormal) for each of the naturally occurring radionuclides were calculated and used to compute doses. These values are presented in Table 4-4. The average total dose for background soils using the residential scenario is 95.0 mrem/yr, with a standard deviation of 28.2 mrem/yr. As a possible upper bound for dose associated with background, values for the 95th upper confidence limit on the 95th percentile yield a dose of 172 mrem/yr.

Total risk calculated by RESRAD for the average activity of background radionuclides is 1.5E-03, with a standard deviation of 4.4E-04, as presented in Table 4-5. Total risk for the upper 95th percent confidence limit of the 95th percentile is 2.7E-03.

The radionuclide that contributes the greatest percentage to average dose (48%) is ^{226}Ra and the daughters produced from it. Most of this dose is from the radon pathway, which is a summation of the ^{226}Ra daughters ^{222}Rn, ^{218}Po, ^{214}Pb, and ^{214}Bi. The average background dose for ^{226}Ra and its daughters is 45.5±16.4 mrem/yr. The radionuclides ^{40}K and ^{232}Th and its progeny also contribute substantially to dose in this residential scenario (28% and 23%, respectively). The ground (external exposure), plant, meat, and milk pathways for ^{40}K sum to 27.0±5.6 mrem/yr for average background activities. Substantial contributions from ^{232}Th and its daughters are from the ground, inhalation, and plant pathways, with a background of 22.0±6.0 mrem/yr.

Table 4-1. Lognormal Statistics for Vadose Zone Samples. UCL is the upper confidence limit. All values in pCi/g.

Analyte	N	% > DL	Minimum	Maximum	Geometric mean	50th percentile	80th percentile	80th percentile UCL	90th percentile	90th percentile UCL	95th percentile	95th percentile UCL
K-40	49	100	9.29	19.70	12.84	12.80	15.23	16.36	16.64	18.14	17.91	20.01
Ra-226	49	100	0.298	1.160	0.530	0.505	0.703	0.795	0.815	0.947	0.921	1.110
Th-232	49	100	0.468	1.580	0.909	0.949	1.158	1.290	1.315	1.500	1.459	1.720
U-234	49	100	0.399	1.510	0.762	0.743	0.969	1.080	1.098	1.250	1.217	1.440
U-235*	17	35	0.00462	0.386	0.0327	0.0328	0.0724	0.0999	0.109	0.161	0.153	0.252
U-238	49	100	0.354	1.210	0.733	0.718	0.933	1.040	1.059	1.200	1.175	1.390

* Uranium-235 statistics were computed using 47 samples: 17 above and 30 below detection limits. Two data were suspended owing to negative values.

Table 4-2. Weibull Statistics for Vadose Zone Samples. UCL is the upper confidence limit. All values in pCi/g.

Analyte	N	% > DL	Minimum	Maximum	Eta	50th percentile	80th percentile	80th percentile UCL	90th percentile	90th percentile UCL	95th percentile	95th percentile UCL
K-40	49	100	9.29	19.7	13.54	12.53	14.28	16.62	17.02	18.86	18.6	21.16
Ra-226	49	100	0.298	1.16	0.590	0.521	0.709	0.801	0.828	0.954	0.936	1.11
Th-232	49	100	0.468	1.58	1.03	0.930	1.17	1.27	1.3	1.43	1.41	1.57
U-234	49	100	0.399	1.51	0.852	0.772	0.978	1.07	1.09	1.21	1.19	1.34
U-235*	17	35	0.00462	0.386	.0490	0.0363	0..0692	0.0859	0.0910	0.115	0.111	0.145
U-238	49	100	0.354	1.21	0.825	0.75	0.94	1.02	1.04	1.14	1.13	1.25

* Uranium-235 statistics were computed using 47 samples: 17 above and 30 below detection limits. Two data were suspended owing to negative values.

Table 4-3. RESRAD Parameters Used to Model Background Dose.
(Parameters not listed use default RESRAD values.)

Parameter	Selected Value	Default	Units	Citation	Rationale
Soil Density	1.6	1.5	g/cm^3	DOE/RL 1994b	
Total Porosity	0.4	0.4			Default[a]
Effective Porosity	0.2	0.2			Default
Hydraulic conductivity	10	10	m/yr		Default
Volumetric water content	0.094	0.05		DOE/RL 1994b	Based on mean 4.7 percent moisture content by weight.
Precipitation rate	0.16	1	m/yr	DOE/RL 1992	Based on 6.3" per year annual rainfall
Irrigation rate	0	2	m/yr		Assumes no irrigation at the site
Evapotranpiration coefficient	0.99	0.5		DOE/RL 1992n	Calculated from evapotranspiration rate of 6.1", precipitation rate of 6.3"
Erosion rate	0.001	0.001	m/yr		Default
Radon vertical mixing dimension	2	2	m		Default
Annual average wind speed	3.3	2	m/s	DOE/RL 1992	Based on 12 km/h. Monthly average wind speeds range from 10 to 16 km/h
Thickness of uncontaminated unsaturated zone	12	12		DOE/RL 1992	Default. Not used for calculations.
Building foundation thickness	0.15	0.15	m		Default
Foundation depth below ground surface	1	1	m		Default
Fraction of time spent indoors on-site	0.5	0.5			Represents half of time spent indoors.
Fraction of time spent outdoors on site	0.5	0.25			Represents half of time spent outdoors.
Area of contaminated zone	1,000,000	10,000	m^2		Background conditions omnipresent.
Cover depth	0	0	m		Cover depth is set at zero, as cover over contamination is not being evaluated.
Mass loading for inhalation	2.00E-04	2.00E-04	g/m^3		Default
Shielding factor for inhalation	0.4	0.4			Default
Depth of roots	0.9	0.9	m		Default
Soil ingestion rate	36.5	36.5	g/yr		Default
Thickness of contaminated zone	2 m	2	m		Default
Seafood consumption rate	Not used				
Fruit, vegetable and grain consumption rate	160	160	kg/yr		Default
Inhalation rate	8400	8400	m^3/yr		Default
Leafy vegetable consumption rate	14	14	kg/yr		Default
Livestock water ingestion rate for beef cattle	50	50	L/d		Default
Livestock water ingestion rate for milk cows	160	160	L/d		Default
Meat and poultry consumption rate63	63	63	kg/yr		Default
Milk consumption rate	92	92	L/yr		Default
Shielding factor for external gamma radiation	0.7	0.7			Default

Notes: [a]Source for default parameters: ANL, 1993b

Table 4-4. Estimates of Dose from Average, Standard Deviation, and Upper 95th Percent Confidence Limit of the 95th Percentile of Background Activities, as Calculated by RESRAD. All values are in mrem/yr.

Dose Estimates from Average Activities									
Analyte	Ground	Inhalation	Radon	Plant	Meat	Milk	Soil	Total	% of Total
K-40	1.16E+01	1.91E-04	0.00E+00	6.36E+00	6.42E+00	2.67E+00	8.89E-03	2.70E+01	28.4
Ra-226	5.33E+00	5.66E-03	3.72E+01	2.60E+00	1.51E-01	1.85E-01	2.72E-02	4.55E+01	47.9
Th-232+D	1.30E+01	2.20E+00	9.83E-01	5.01E+00	2.83E-01	3.35E-01	1.72E-01	2.20E+01	23.2
U-235	3.31E-02	7.43E-03	0.00E+00	3.00E-03	1.98E-04	4.85E-04	5.02E-04	4.48E-02	0.1
U-238+D	8.91E-02	2.24E-01	0.00E+00	9.19E-02	6.06E-03	1.49E-02	1.54E-02	4.41E-01	0.4
Total	30.0	2.44	38.2	14.1	6.86	3.20	0.22	95.0	100
Dose Estimates from Standard Deviation of Activities									
	Ground	Inhalation	Radon	Plant	Meat	Milk	Soil	Total	% of Total
K-40	2.40E+00	3.94E-05	0.00E+00	1.32E+00	1.33E+00	5.53E-01	1.84E-03	5.60E+00	19.9
Ra-226	1.92E+00	2.04E-03	1.34E+01	9.35E-01	5.45E-02	6.68E-02	9.81E-03	1.64E+01	58.2
Th-232+D	3.57E+00	6.07E-01	2.71E-01	1.38E+00	7.78E-02	9.21E-02	4.72E-02	6.04E+00	21.4
U-235	4.36E-02	9.78E-03	0.00E+00	3.95E-03	2.61E-04	6.39E-04	6.61E-04	5.89E-02	0.2
U-238+D	2.52E-02	6.33E-02	0.00E+00	2.60E-02	1.72E-03	4.21E-03	4.35E-03	1.20E-01	0.4
Total	7.95	0.68	13.7	3.66	1.46	0.72	0.064	28.2	100
Dose Estimates from 95th Percentile of Background Activities									
	Ground	Inhalation	Radon	Plant	Meat	Milk	Soil	Total	% of Total
K-40	1.77E+01	2.91E-04	0.00E+00	9.71E+00	9.80E+00	4.08E+00	1.36E-02	4.13E+01	24.0
Ra-226	1.06E+01	1.12E-02	7.37E+01	5.14E+00	3.00E-01	3.67E-01	5.39E-02	9.01E+01	52.3
Th-232+D	2.36E+01	4.01E+00	1.79E+00	9.12E+00	5.15E-01	6.10E-01	3.13E-01	4.00E+01	23.2
U-235	1.62E-01	3.63E-02	0.00E+00	1.44E-02	9.68E-04	2.37E-03	2.46E-03	2.19E-01	0.1
U-238+D	1.62E-01	4.07E-01	0.00E+00	1.67E-01	1.10E-02	2.71E-02	2.80E-02	8.03E-01	0.5
Total	52.2	4.47	75.4	24.1	10.6	5.08	0.41	172	100.0

Th-232+D includes the isotopes ^{232}Th, ^{228}Ra, and ^{228}Th, assumed to be in secular equilibrium.
U-238+D includes the isotopes ^{238}U and ^{234}U. Although ^{226}Ra is a daughter in the uranium series, it was computed separately.

Table 4-5. Estimates of Risk from Average, Standard Deviation, and Upper 95th Percent Confidence Limit of the 95th Percentile of Background Activities, as Calculated by RESRAD.

Risk Estimates From Average Activities									
	Ground	Inhalation	Radon	Plant	Meat	Milk	Soil	Total	% of Total
K-40	2.04E-04	3.46E-09		1.33E-04	1.35E-04	5.59E-05	1.87E-07	5.28E-04	35.9
Ra-226	9.57E-05	5.33E-08	6.69E-04	1.76E-05	1.03E-06	1.26E-06	1.84E-07	7.85E-04	53.4
Th-232+D	1.03E-04	3.89E-06	1.97E-05	2.52E-05	1.44E-06	1.74E-06	5.31E-07	1.56E-04	10.6
U-235	3.55E-07	2.36E-08		1.58E-08	1.05E-09	2.56E-09	2.65E-09	4.00E-07	0.0
U-238+D	1.11E-06	6.98E-07		5.29E-07	3.49E-08	8.56E-08	8.86E-08	2.55E-06	0.2
Total	4.04E-04	4.67E-06	6.89E-04	1.77E-04	1.37E-04	5.90E-05	9.93E-07	1.47E-03	100.0
Risk Estimates From Standard Deviation									
	Ground	Inhalation	Radon	Plant	Meat	Milk	Soil	Total	% of Total
K-40	4.22E-05	6.16E-10		2.76E-05	2.79E-05	1.16E-05	3.86E-08	1.09E-04	25.0
Ra-226	3.45E-05	1.92E-08	2.41E-04	6.33E-06	3.69E-07	4.52E-07	6.64E-08	2.83E-04	64.9
Th-232+D	2.84E-05	1.07E-06	5.43E-06	6.94E-06	3.96E-07	4.79E-07	1.46E-07	4.29E-05	9.8
U-235	4.67E-07	3.10E-08		2.09E-08	1.38E-09	3.37E-09	3.49E-09	5.27E-07	0.1
U-238+D	3.14E-07	1.98E-07		1.50E-07	9.89E-09	2.42E-08	2.51E-08	7.21E-07	0.2
Total	1.06E-04	1.32E-06	2.46E-04	4.11E-05	2.86E-05	1.25E-05	2.80E-07	4.36E-04	100.0
Risk Estimates from 95th Percentile of Background Activities									
	Ground	Inhalation	Radon	Plant	Meat	Milk	Soil	Total	% of Total
K-40	3.11E-04	5.28E-09		2.04E-04	2.06E-04	8.55E-05	2.85E-07	8.06E-04	30.4
Ra-226	1.89E-04	1.05E-07	1.32E-03	3.48E-05	2.03E-06	2.48E-06	3.65E-07	1.55E-03	58.5
Th-232+D	1.88E-04	7.08E-06	3.59E-05	4.59E-05	2.62E-06	3.17E-06	9.66E-07	2.84E-04	10.7
U-235	1.74E-06	1.15E-07		7.75E-08	5.11E-09	1.25E-08	1.30E-08	1.96E-06	0.1
U-238+D	2.02E-06	1.27E-06		9.64E-07	6.36E-08	1.56E-07	1.61E-07	4.64E-06	0.2
Total	6.92E-04	8.58E-06	1.36E-03	2.85E-04	2.10E-04	9.13E-05	1.79E-06	2.65E-03	100.0

Th-232+D includes the isotopes ^{232}Th, ^{228}Ra, and ^{228}Th, assumed to be in secular equilibrium.
U-238+D includes the isotopes ^{238}U and ^{234}U. Although ^{226}Ra is a daughter in the uranium series, it was computed separately.

Risks computed by RESRAD for each individual radionuclide and pathway show that ^{226}Ra contributes the most to risk (53% for average background values), with the majority of the contribution through the radon pathway. The risk contribution by ^{40}K is 36%, and ^{232}Th and its daughters contribute 11%. Background activities of the uranium isotopes do not contribute significantly to dose or risk.

4.4 COMPARISON OF VADOSE ZONE AND SURFACE SAMPLES

The vadose zone samples discussed above were chosen and analyzed specifically to represent naturally occurring radionuclides in the vadose zone. Several anthropogenic radionuclides were determined for these samples, but their use for background purposes is limited because nearly all were collected below the surface. The conceptual model for anthropogenic radionuclides (Section 2.2.2) presents the rationale for using only surface samples to determine background for these radionuclides. The generally low activities of anthropogenic radionuclides in the vadose zone samples compared to the surface samples supports this aspect of the conceptual model: only 4% of the vadose zone samples collected below the surface were above detection for ^{137}Cs, compared to 98% of the surface samples.

It is useful to compare the natural radionuclide data from the vadose zone samples with the surface samples, both to test the conceptual model and to evaluate the possibility of combining the two data sets. The Wilcoxson rank sum test (WRS) was used to evaluate the similarity of these two data sets at the 95% confidence level. The WRS is a nonparametric method of testing two sets of data to determine if one is consistently larger or smaller than another by using all of the data from both sets. Results from these tests are contained in Table 4-6 and conclude that the surface and vadose zone data sets cannot be considered equal for any of the radionuclides tested. On the average, the vadose zone data are larger than the surface data for ^{232}Th, ^{234}U, and ^{238}U and are smaller for ^{40}K and ^{226}Ra. Comparisons between the two data sets for ^{40}K and ^{232}Th are shown graphically in probability plots (Figures 4-9 and 4-10).

4.5 SUMMARY

The vadose zone data satisfy all of the data quality objectives considered for their use as naturally occurring radionuclide background for the Hanford Site. The quality of the data is adequate, and the data have been shown to fit a single distribution, which indicates that they represent a single statistical population. This population can be represented by the lognormal or Weibull distribution; the Weibull distribution shows a slightly better fit for all of the analytes, except for ^{234}U.

Table 4-6. Results of the Nonparametric Wilcoxon Rank Sum Test, Comparing the Vadose Zone and Surface Samples for Naturally Occurring Radionuclides.

	Number of Samples		Mean Activity			
Radionuclide	Surface	Vadose	Surface	Vadose	Z-score*	Comparable?
K-40	140	49	15.4	13.1	4.38	NO
Ra-226	76	49	0.69	0.56	4.39	NO
Th-232	17	49	0.73	0.94	2.76	NO
U-234	43	49	0.65	0.79	3.07	NO
U-238	43	49	0.67	0.76	2.01	NO

* Z-score is compared with the one-tailed cumulative normal distribution, which is 1.645 for a confidence level of 95%. The null hypothesis, Ho: the two data sets have the same mean, is rejected if the Z-score > 1.645.

Figure 4-9. Probability Plot (lognormal) Comparing ^{40}K Activity of Surface and Vadose Zone Samples.

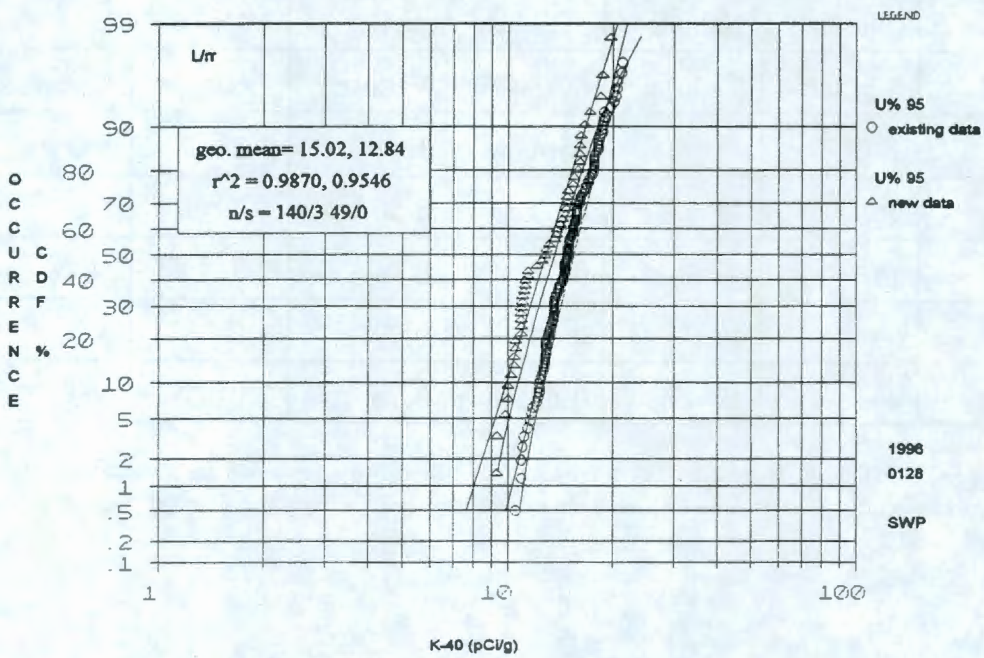
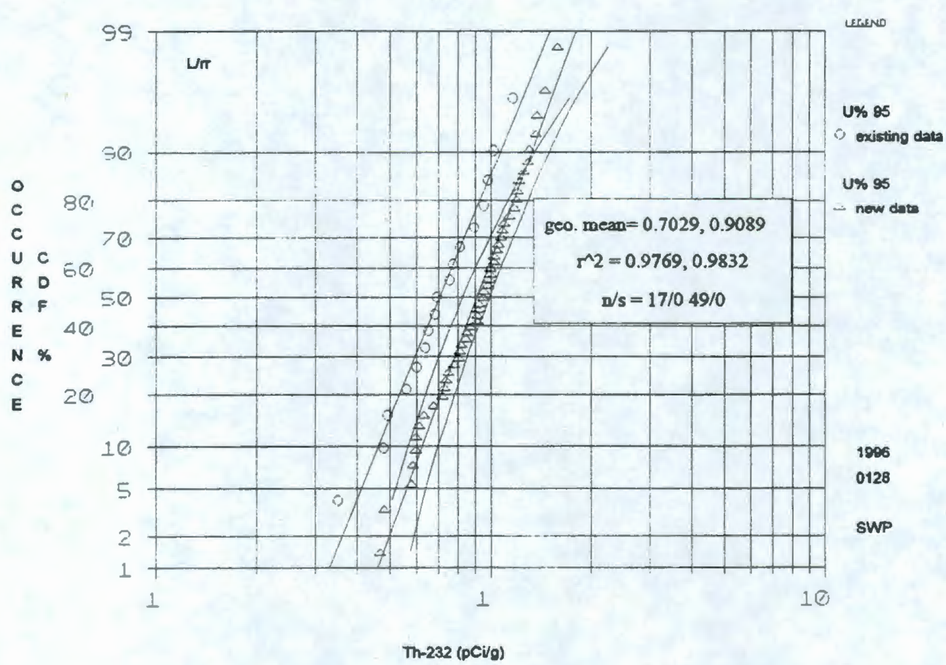


Figure 4-10. Probability Plot (lognormal) Comparing ^{232}Th Activity of Surface and Vadose Zone Samples.



Dose and risk estimates were computed using the RESRAD dose modeling computer code. A residential exposure scenario (excluding ingestion of groundwater and ingestion of fish) was used and resulted in an average background dose of 95 ± 28 mrem/yr. The corresponding risk computed by RESRAD is 1.5E-03$\pm$4.4E-04. The greatest contributor to dose and risk from background radionuclides is from the radon pathway.

The conceptual model for radionuclide background identifies the vadose zone samples as those most appropriate for defining naturally occurring radionuclide background at the Hanford Site. Comparisons of the vadose zone and surface samples show a significant difference between the two types of data, which supports the conceptual model.

5.0 SUMMARY AND CONCLUSIONS

The conceptual model for evaluating radionuclide background distinguishes between the anthropogenic radionuclides deposited on the surface and the naturally occurring radionuclides occurring in the soil. Anthropogenic radionuclides are primarily deposited by global fallout, and their activities have been measured annually by PNNL and DOH. These measurement were performed on surface soils collected from the Hanford Site and from other locations in the Columbia Basin. A previous report evaluated these data to determine anthropogenic background for the Hanford Site and nearby environments with similar depositional characteristics (DOE/RL 1995a). A summary of the results of that study are included in Section 5.1.

This report evaluates background activity for naturally occurring radionuclides in soil collected from the Hanford Site vadose zone. To accomplish this, a subset was chosen from a suite of samples that were collected to determine nonradionuclide background, and the subset was analyzed for naturally occurring radionuclides. This sample set has been shown to be representative of vadose zone compositions for the Hanford Site (DOE/RL 1995c). Section 5.2 summarizes the results of this subset.

5.1 ANTHROPOGENIC RADIONUCLIDES

Background activity for anthropogenic radionuclides was evaluated from surface samples collected from 39 locations throughout the region. The soil sampling locations provide lateral coverage within the region and describe a single population for each analyte (DOE/RL 1995a). These data are therefore consistent with the sitewide approach for defining the distribution of anthropogenic background components and appear to be appropriate for use as sitewide background.

Fifteen radionuclides from the surface samples have been evaluated (DOE/RL 1995a). Of these radionuclides, only the anthropogenic radionuclides (^{90}Sr, ^{137}Cs, and $^{239/240}$Pu) had data of adequate quality (greater than 50% above detection) to yield reliable estimates of background. These data may be adequate to define anthropogenic background, as only ^{137}Cs and ^{90}Sr contribute significantly to dose and risk. A statistical summary of the activity of these radionuclides is included in Table 5-1, along with an estimate of the dose from these and the naturally occurring radionuclides.

5.2 NATURALLY OCCURRING RADIONUCLIDES

The 49 vadose zone samples chosen to represent naturally occurring radionuclide background at Hanford were analyzed primarily for ^{40}K, ^{226}Ra, ^{232}Th, ^{234}U, ^{235}U, and ^{238}U. Other radionuclides were identified by the laboratory, and all of the data are reported in Appendix B.

The samples describe a single population for each radionuclide, which is accurately estimated by lognormal and Weibull distributions. The data quality is good for all naturally occurring analytes, except ^{235}U, which is present in quantities predominantly below the laboratory's detection limit. A statistical summary of the activity of these radionuclides is included in Table 5-1.

5.3 USE OF THE DATA

The data will primarily be used to evaluate contamination, establish cleanup goals, and assess cleanup levels for radionuclides. Background data may be considered as activity levels for individual radionuclides, as a dose associated with specific radionuclides, or as total dose from all background radionuclides. The latter method is identified in draft guidance from the EPA (1994) and Nuclear Regulatory Commission (NRC 1994) as forming the basis for cleanup levels for radioactivity. Using this approach requires modeling background dose using an exposure scenario, which should be congruent with the projected future land use of the site.

The proposed EPA guidance sets cleanup levels at background dose plus 15 mrem/yr (EPA 1994). Average background dose from natural and anthropogenic radionuclides at Hanford (using the residential scenario described in Section 4.3 of this report) is 96.9 mrem/yr (Table 5-1). The variation associated with this dose (1σ) is 29.8 mrem/yr. Thus, natural background variation is greater than the proposed increment above background that is considered for a cleanup level. This could be of concern when a final release criterion measures the total dose at a cleanup site and compares it with average background.

The measurement techniques used for detecting and quantifying radiation at a waste site should be of similar type and quality as the sitewide background data reported here (if comparisons between the two data sets are to be made). If field instruments are used to measure the activities of individual radionuclides, they must be carefully calibrated to approach the accuracy and precision of the background data. If field measurements are used that measure dose directly, factors should be developed relating their dose measurements to modeled dose concentrations based on activity data. If careful consideration is not given to the comparability of the data, decisions regarding the presence or absence of contamination and achievement of cleanup goals could, in some instances, be driven as much by the differences in analytical performance as by any real differences at a waste site.

Table 5-1. Selected Values for the Sitewide Background Data Set. Percentiles are based on the Weibull Distribution. Activities are in pCi/g, doses are in mrem/yr.

Analyte	Minimum	Maximum	Arithmetic Mean	Standard Deviation	50th percentile	90th percentile	90th percentile UCL	95th percentile	95th percentile UCL	Background Dose From Average	Background Dose From 95th UCL	Background Dose From Std. deviation
K-40	9.29	19.7	13.1	2.71	12.84	16.64	18.14	17.91	20.01	27.0	41.3	5.6
Sr-90	0.00661	0.366	0.0806	0.0688	0.0636	0.167	0.205	0.207	0.262	0.49	1.60	0.42
Cs-137	-0.00156	1.64	0.417	0.338	0.323	0.919	1.07	1.16	1.37	1.45	4.76	1.17
Ra-226+D	0.298	1.16	0.561	0.202	0.53	0.815	0.947	0.921	1.11	45.5	90.1	16.4
Th-232+D	0.468	1.58	0.945	0.260	0.909	1.315	1.5	1.459	1.72	22.0	40.0	6.04
U-234	0.399	1.51	0.793	0.233	0.762	1.098	1.25	1.217	1.44	0.18	0.34	0.052
U-235*	0.00462	0.386	0.0515	0.0373	0.0327	0.109	0.161	0.153	0.252	0.045	0.22	0.059
U-238	0.354	1.21	0.763	0.216	0.733	1.059	1.2	1.175	1.39	0.26	0.47	0.073
Pu-239/240	-0.0050	0.0331	0.0094	0.0078	0.0073	0.021	0.025	0.027	0.033	0.014	0.049	0.012
									Totals:	**96.9**	**179**	**29.8**

* Uranium-235 statistics were computed using 47 samples: 17 above and 30 below detection limits. Two data were suspended owing to negative values.
UCL = Upper Confidence Limit

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APPENDIX A

SAMPLE LOCATION INFORMATION AND VADOSE ZONE RADIONUCLIDE DATA

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Table A-1. Sample Locations and HEIS Numbers.

Old HEIS	New HEIS	Site #	Depth (ft)	Old HEIS	New HEIS	Site #	Depth (ft)
B01414	B0C2W8	1	1	B01465	B0C2Y3	10	7
B01429	B0C2X4	2	10	B01468	B0C2Y4	10	1
B01433	B0C2X5	2	1	B014F1	B0C388	11	1
B01B71	B0C396	3	23	B01418	B0C2W9	12	17
B01B78	B0C397	3	2	B01419	B0C2X0	12	14
B01B79	B0C372	3	14	B01420	B0C2X1	12	11
B01458	B0C2Y0	4	4	B01422	B0C2X2	12	5
B014F6	B0C389	5	10	B01425	B0C2X3	12	2
B014G1	B0C390	5	4	B01451	B0C2X9	13	2
B014G2	B0C391	5	1	B01443	B0C2X6	14	6
B01470	B0C2Y5	6	47	B01447	B0C2X7	14	21
B01473	B0C2Y6	6	37	B01448	B0C2X8	14	24
B01480	B0C2Y7	6	37	B014K0	B0C392	15	10
B01482	B0C378	6	34	B014K4	B0C393	15	34
B01484	B0C379	6	28	B014K5	B0C394	15	39
B01487	B0C380	6	19	B014K7	B0C395	15	80
B01489	B0C381	6	13	B0C2W5	B0C2W5	15	115
B01490	B0C382	6	10	B0C2W6	B0C2W6	15	120
B01491	B0C383	6	7	B0C2W7	B0C2W7	15	190
B014C2	B0C385	7	20	B06137	B0C374	E-1	0
B014C3	B0C386	7	17	B0C2W4	B0C2W4	E-2	0
B014C8	B0C387	7	8	B06141	B0C375	E-4	0
B01494	B0C384	9	10	B06146	B0C376	E-9	0
B01462	B0C2Y1	10	13	B01CN1	B0C373	BASALT	0
B01463	B0C2Y2	10	10	B06153	B0C377	RINGOLD	0

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
3	B0C372	Co-60	11/20/91	6/13/94	0.02900	0.02380	0.04270	pCi/g
3	B0C396	Co-60	11/20/91	7/3/94	0.00150	0.02880	0.04890	pCi/g
3	B0C397	Co-60	11/20/91	7/3/94	0.00444	0.02720	0.04650	pCi/g
5	B0C389	Co-60	10/15/91	7/3/94	0.05610	0.02940	0.05490	pCi/g
5	B0C390	Co-60	10/21/91	7/6/94	-0.01700	0.01950	0.03160	pCi/g
5	B0C391	Co-60	10/21/91	7/7/94	0.01470	0.01580	0.02850	pCi/g
6	B0C378	Co-60	10/8/91	6/25/94	0.00310	0.01660	0.02820	pCi/g
6	B0C379	Co-60	10/8/91	6/25/94	-0.00940	0.01740	0.02890	pCi/g
6	B0C380	Co-60	10/8/91	6/30/94	0.00125	0.01560	0.02730	pCi/g
6	B0C381	Co-60	10/8/91	6/30/94	0.01060	0.01500	0.02680	pCi/g
6	B0C382	Co-60	10/8/91	6/24/94	0.01250	0.02120	0.03710	pCi/g
6	B0C383	Co-60	10/8/91	6/30/94	-0.01900	0.01790	0.02840	pCi/g
7	B0C385	Co-60	10/11/91	7/2/94	-0.01400	0.02790	0.04620	pCi/g
7	B0C386	Co-60	10/11/91	7/2/94	-0.00190	0.02540	0.04190	pCi/g
7	B0C387	Co-60	10/11/91	7/2/94	0.02560	0.02610	0.04620	pCi/g
9	B0C384	Co-60	10/9/91	6/28/94	0.02220	0.02720	0.04910	pCi/g
10	B0C2Y2	Co-60	10/3/91	7/9/94	-0.00640	0.10600	0.18900	pCi/g
11	B0C388	Co-60	10/15/91	7/7/94	-0.03000	0.02560	0.03920	pCi/g
15	B0C2W5	Co-60	10/2/90	7/20/94	-0.00150	0.03310	0.05690	pCi/g
15	B0C2W6	Co-60	10/2/90	7/20/94	0.01290	0.03450	0.06280	pCi/g
15	B0C2W7	Co-60	10/9/90	7/20/94	0.01660	0.02680	0.05170	pCi/g
15	B0C392	Co-60	9/30/90	7/6/94	0.00877	0.01690	0.03030	pCi/g
15	B0C393	Co-60	9/17/90	7/7/94	-0.00790	0.02870	0.04670	pCi/g
15	B0C394	Co-60	9/18/90	7/3/94	0.03640	0.04060	0.07460	pCi/g
15	B0C395	Co-60	9/25/90	7/7/94	-0.00570	0.01740	0.02870	pCi/g
E-1	B0C374	Co-60	1/27/92	6/22/94	-0.00470	0.03830	0.06280	pCi/g
E-2	B0C2W4	Co-60	1/27/92	7/19/94	-0.07900	0.10800	0.17900	pCi/g
E-4	B0C375	Co-60	1/27/92	6/22/94	0.00444	0.03410	0.05820	pCi/g
E-9	B0C376	Co-60	1/27/92	6/23/94	-0.03100	0.03540	0.05550	pCi/g
BASALT	B0C373	Co-60	6/12/91	6/23/94	-0.01400	0.02480	0.04050	pCi/g
RINGOLD	B0C377	Co-60	2/4/92	6/23/94	-0.01700	0.02340	0.03760	pCi/g
1	B0C2W8	Cs-137	9/12/91	7/8/94	-0.00130	0.02040	0.03400	pCi/g
2	B0C2X4	Cs-137	9/26/91	7/9/94	-0.03500	0.02020	0.02970	pCi/g
2	B0C2X5	Cs-137	9/26/91	7/9/94	0.05560	0.03690	ND	pCi/g
3	B0C372	Cs-137	11/20/91	6/13/94	0.00334	0.01350	0.02240	pCi/g
3	B0C396	Cs-137	11/20/91	7/3/94	-0.00440	0.01860	0.03010	pCi/g
3	B0C397	Cs-137	11/20/91	7/3/94	-0.00160	0.01780	0.02880	pCi/g
4	B0C2Y0	Cs-137	10/3/91	7/8/94	-0.04900	0.08190	0.12800	pCi/g
5	B0C389	Cs-137	10/15/91	7/3/94	-0.02900	0.02170	0.03400	pCi/g
5	B0C390	Cs-137	10/21/91	7/6/94	-0.00650	0.01370	0.02220	pCi/g
5	B0C391	Cs-137	10/21/91	7/7/94	0.01030	0.01200	0.02030	pCi/g
6	B0C2Y5	Cs-137	10/8/91	7/10/94	-0.01500	0.02210	0.03600	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
6	B0C2Y6	Cs-137	10/8/91	7/10/94	0.00122	0.01890	0.03130	pCi/g
6	B0C2Y7	Cs-137	10/8/91	7/11/94	-0.03100	0.02100	0.03160	pCi/g
6	B0C378	Cs-137	10/8/91	6/25/94	-0.01500	0.01190	0.01880	pCi/g
6	B0C379	Cs-137	10/8/91	6/25/94	0.00159	0.01180	0.01980	pCi/g
6	B0C380	Cs-137	10/8/91	6/30/94	0.00851	0.01180	0.02020	pCi/g
6	B0C381	Cs-137	10/8/91	6/30/94	0.00139	0.01150	0.01900	pCi/g
6	B0C382	Cs-137	10/8/91	6/24/94	-0.01700	0.01580	0.02420	pCi/g
6	B0C383	Cs-137	10/8/91	6/30/94	0.00193	0.01190	0.02030	pCi/g
7	B0C385	Cs-137	10/11/91	7/2/94	0.00418	0.01510	0.02580	pCi/g
7	B0C386	Cs-137	10/11/91	7/2/94	0.00453	0.01600	0.02670	pCi/g
7	B0C387	Cs-137	10/11/91	7/2/94	-0.01600	0.01630	0.02650	pCi/g
9	B0C384	Cs-137	10/9/91	6/28/94	-0.00650	0.01900	0.03140	pCi/g
10	B0C2Y1	Cs-137	10/3/91	7/9/94	0.01270	0.04410	0.07860	pCi/g
10	B0C2Y2	Cs-137	10/3/91	7/9/94	0.03320	0.05060	0.09530	pCi/g
10	B0C2Y3	Cs-137	10/3/91	7/9/94	0.03200	0.04220	0.07870	pCi/g
10	B0C2Y4	Cs-137	10/3/91	7/9/94	-0.06900	0.06160	0.09680	pCi/g
11	B0C388	Cs-137	10/15/91	7/7/94	0.00197	0.01810	0.03020	pCi/g
12	B0C2W9	Cs-137	9/24/91	7/9/94	0.03990	0.02380	0.04600	pCi/g
12	B0C2X0	Cs-137	9/24/91	7/9/94	-0.00410	0.01980	0.03380	pCi/g
12	B0C2X1	Cs-137	9/24/91	7/9/94	-0.01400	0.02160	0.03520	pCi/g
13	B0C2X9	Cs-137	10/1/91	7/8/94	0.04160	0.04830	0.09160	pCi/g
14	B0C2X6	Cs-137	10/1/91	7/8/94	0.02690	0.06910	0.12300	pCi/g
14	B0C2X7	Cs-137	10/1/91	7/9/94	-0.00460	0.02150	0.03670	pCi/g
14	B0C2X8	Cs-137	10/1/91	7/10/94	-0.02700	0.02620	0.04130	pCi/g
15	B0C2W5	Cs-137	10/2/90	7/20/94	0.01350	0.01910	0.03470	pCi/g
15	B0C2W6	Cs-137	10/2/90	7/20/94	0.00394	0.01920	0.03400	pCi/g
15	B0C2W7	Cs-137	10/9/90	7/20/94	-0.01300	0.02040	0.03380	pCi/g
15	B0C392	Cs-137	9/30/90	7/6/94	-0.00830	0.01170	0.01900	pCi/g
15	B0C393	Cs-137	9/17/90	7/7/94	0.01530	0.01640	0.02840	pCi/g
15	B0C394	Cs-137	9/18/90	7/3/94	-0.01100	0.02470	0.03990	pCi/g
15	B0C395	Cs-137	9/25/90	7/7/94	0.00590	0.01060	0.01760	pCi/g
E-1	B0C374	Cs-137	1/27/92	6/22/94	0.45700	0.06780	ND	pCi/g
E-2	B0C2W4	Cs-137	1/27/92	7/19/94	0.31200	0.11200	ND	pCi/g
E-4	B0C375	Cs-137	1/27/92	6/22/94	0.22000	0.04200	ND	pCi/g
E-9	B0C376	Cs-137	1/27/92	6/23/94	0.20000	0.05070	ND	pCi/g
BASALT	B0C373	Cs-137	6/12/91	6/23/94	0.00497	0.01470	0.02520	pCi/g
RINGOLD	B0C377	Cs-137	2/4/92	6/23/94	-0.01400	0.01570	0.02530	pCi/g
1	B0C2W8	Eu-152	9/12/91	7/8/94	0.01940	0.05290	0.09150	pCi/g
2	B0C2X4	Eu-152	9/26/91	7/9/94	-0.00390	0.05150	0.08380	pCi/g
2	B0C2X5	Eu-152	9/26/91	7/9/94	-0.01900	0.05430	0.09090	pCi/g
3	B0C372	Eu-152	11/20/91	6/13/94	-0.03700	0.09000	0.14800	pCi/g
3	B0C396	Eu-152	11/20/91	7/3/94	0.01160	0.05050	0.08420	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
3	B0C397	Eu-152	11/20/91	7/3/94	0.01110	0.04180	0.07040	pCi/g
5	B0C389	Eu-152	10/15/91	7/3/94	0.05750	0.05180	0.08960	pCi/g
5	B0C390	Eu-152	10/21/91	7/6/94	-0.01600	0.03440	0.05670	pCi/g
5	B0C391	Eu-152	10/21/91	7/7/94	-0.03000	0.03250	0.05140	pCi/g
6	B0C2Y5	Eu-152	10/8/91	7/10/94	0.04740	0.05370	0.09730	pCi/g
6	B0C2Y6	Eu-152	10/8/91	7/10/94	0.02770	0.05030	0.08820	pCi/g
6	B0C2Y7	Eu-152	10/8/91	7/11/94	-0.01100	0.05690	0.09150	pCi/g
6	B0C378	Eu-152	10/8/91	6/25/94	0.07970	0.05800	0.10800	pCi/g
6	B0C379	Eu-152	10/8/91	6/25/94	-0.02400	0.07110	0.11600	pCi/g
6	B0C380	Eu-152	10/8/91	6/30/94	0.09540	0.06490	0.12100	pCi/g
6	B0C381	Eu-152	10/8/91	6/30/94	0.09530	0.05820	0.11300	pCi/g
6	B0C382	Eu-152	10/8/91	6/24/94	0.00552	0.08650	0.14900	pCi/g
6	B0C383	Eu-152	10/8/91	6/30/94	0.12200	0.06170	0.11800	pCi/g
7	B0C385	Eu-152	10/11/91	7/2/94	-0.02100	0.04540	0.07090	pCi/g
7	B0C386	Eu-152	10/11/91	7/2/94	0.00638	0.04000	0.06730	pCi/g
7	B0C387	Eu-152	10/11/91	7/2/94	-0.03800	0.04140	0.06570	pCi/g
9	B0C384	Eu-152	10/9/91	6/28/94	0.10600	0.10500	0.18900	pCi/g
10	B0C2Y1	Eu-152	10/3/91	7/9/94	-0.00450	0.10200	0.18000	pCi/g
11	B0C388	Eu-152	10/15/91	7/7/94	-0.02900	0.04640	0.07620	pCi/g
12	B0C2W9	Eu-152	9/24/91	7/9/94	0.03730	0.06710	0.11900	pCi/g
12	B0C2X0	Eu-152	9/24/91	7/9/94	-0.04000	0.05410	0.08560	pCi/g
12	B0C2X1	Eu-152	9/24/91	7/9/94	-0.01400	0.06130	0.09740	pCi/g
13	B0C2X9	Eu-152	10/1/91	7/8/94	-0.09900	0.13300	0.21200	pCi/g
14	B0C2X6	Eu-152	10/1/91	7/8/94	-0.04300	0.15800	0.26700	pCi/g
14	B0C2X7	Eu-152	10/1/91	7/9/94	-0.03000	0.05940	0.09510	pCi/g
14	B0C2X8	Eu-152	10/1/91	7/10/94	-0.03400	0.07050	0.11800	pCi/g
15	B0C2W5	Eu-152	10/2/90	7/20/94	0.02870	0.05740	0.09690	pCi/g
15	B0C2W6	Eu-152	10/2/90	7/20/94	0.00352	0.05920	0.09610	pCi/g
15	B0C2W7	Eu-152	10/9/90	7/20/94	0.01960	0.04890	0.08470	pCi/g
15	B0C392	Eu-152	9/30/90	7/6/94	-0.02600	0.03250	0.05170	pCi/g
15	B0C393	Eu-152	9/17/90	7/7/94	-0.01400	0.04640	0.07660	pCi/g
15	B0C394	Eu-152	9/18/90	7/3/94	-0.00690	0.06070	0.10100	pCi/g
15	B0C395	Eu-152	9/25/90	7/7/94	-0.01800	0.02940	0.04700	pCi/g
E-1	B0C374	Eu-152	1/27/92	6/22/94	-0.03500	0.16400	0.27500	pCi/g
E-2	B0C2W4	Eu-152	1/27/92	7/19/94	-0.17000	0.19300	0.30000	pCi/g
E-4	B0C375	Eu-152	1/27/92	6/22/94	0.15400	0.12800	0.23300	pCi/g
E-9	B0C376	Eu-152	1/27/92	6/23/94	0.03020	0.13200	0.22800	pCi/g
BASALT	B0C373	Eu-152	6/12/91	6/23/94	0.03450	0.08810	0.15500	pCi/g
RINGOLD	B0C377	Eu-152	2/4/92	6/23/94	0.19600	0.08350	0.16100	pCi/g
1	B0C2W8	Eu-154	9/12/91	7/8/94	-0.03400	0.08610	0.14700	pCi/g
2	B0C2X4	Eu-154	9/26/91	7/9/94	-0.02600	0.07560	0.12400	pCi/g
2	B0C2X5	Eu-154	9/26/91	7/9/94	-0.03400	0.07740	0.13200	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
3	B0C372	Eu-154	11/20/91	6/13/94	0.01540	0.06390	0.10700	pCi/g
3	B0C396	Eu-154	11/20/91	7/3/94	-0.07400	0.08380	0.13100	pCi/g
3	B0C397	Eu-154	11/20/91	7/3/94	-0.04300	0.07010	0.11200	pCi/g
5	B0C389	Eu-154	10/15/91	7/3/94	0.13400	0.08130	0.14600	pCi/g
5	B0C390	Eu-154	10/21/91	7/6/94	0.04640	0.04940	0.08930	pCi/g
5	B0C391	Eu-154	10/21/91	7/7/94	0.01010	0.04740	0.07950	pCi/g
6	B0C2Y5	Eu-154	10/8/91	7/10/94	-0.05100	0.08650	0.14400	pCi/g
6	B0C2Y6	Eu-154	10/8/91	7/10/94	0.01790	0.06800	0.11900	pCi/g
6	B0C2Y7	Eu-154	10/8/91	7/11/94	0.05800	0.08700	0.15800	pCi/g
6	B0C378	Eu-154	10/8/91	6/25/94	-0.03200	0.04880	0.07740	pCi/g
6	B0C379	Eu-154	10/8/91	6/25/94	-0.01700	0.04620	0.07770	pCi/g
6	B0C380	Eu-154	10/8/91	6/30/94	-0.03000	0.04680	0.07630	pCi/g
6	B0C381	Eu-154	10/8/91	6/30/94	-0.03700	0.04360	0.06990	pCi/g
6	B0C382	Eu-154	10/8/91	6/24/94	-0.04000	0.06160	0.10200	pCi/g
6	B0C383	Eu-154	10/8/91	6/30/94	-0.00780	0.04310	0.07250	pCi/g
7	B0C385	Eu-154	10/11/91	7/2/94	0.01030	0.06780	0.11600	pCi/g
7	B0C386	Eu-154	10/11/91	7/2/94	0.00702	0.06150	0.10700	pCi/g
7	B0C387	Eu-154	10/11/91	7/2/94	0.00000	0.06700	0.11600	pCi/g
9	B0C384	Eu-154	10/9/91	6/28/94	0.00000	0.07260	0.12300	pCi/g
10	B0C2Y1	Eu-154	10/3/91	7/9/94	-0.01900	0.14500	0.26600	pCi/g
11	B0C388	Eu-154	10/15/91	7/7/94	-0.00030	0.06920	0.11500	pCi/g
12	B0C2W9	Eu-154	9/24/91	7/9/94	0.02290	0.10700	0.19200	pCi/g
12	B0C2X0	Eu-154	9/24/91	7/9/94	0.02290	0.07260	0.13200	pCi/g
12	B0C2X1	Eu-154	9/24/91	7/9/94	0.03280	0.08050	0.14300	pCi/g
13	B0C2X9	Eu-154	10/1/91	7/8/94	0.04470	0.16600	0.32500	pCi/g
14	B0C2X6	Eu-154	10/1/91	7/8/94	-0.20000	0.24200	0.37600	pCi/g
14	B0C2X7	Eu-154	10/1/91	7/9/94	-0.02700	0.07760	0.13300	pCi/g
14	B0C2X8	Eu-154	10/1/91	7/10/94	0.05220	0.09690	0.17500	pCi/g
15	B0C2W5	Eu-154	10/2/90	7/20/94	0.10500	0.08490	0.16100	pCi/g
15	B0C2W6	Eu-154	10/2/90	7/20/94	-0.06800	0.08830	0.14400	pCi/g
15	B0C2W7	Eu-154	10/9/90	7/20/94	-0.00970	0.08890	0.15400	pCi/g
15	B0C392	Eu-154	9/30/90	7/6/94	0.00628	0.05090	0.08650	pCi/g
15	B0C393	Eu-154	9/17/90	7/7/94	-0.15000	0.06820	0.09720	pCi/g
15	B0C394	Eu-154	9/18/90	7/3/94	0.07080	0.09890	0.17600	pCi/g
15	B0C395	Eu-154	9/25/90	7/7/94	0.03040	0.04680	0.07860	pCi/g
E-1	B0C374	Eu-154	1/27/92	6/22/94	-0.05100	0.10100	0.16900	pCi/g
E-2	B0C2W4	Eu-154	1/27/92	7/19/94	0.37900	0.25300	0.53900	pCi/g
E-4	B0C375	Eu-154	1/27/92	6/22/94	0.02090	0.08530	0.14400	pCi/g
E-9	B0C376	Eu-154	1/27/92	6/23/94	-0.02700	0.09410	0.15000	pCi/g
BASALT	B0C373	Eu-154	6/12/91	6/23/94	0.11900	0.06210	0.11300	pCi/g
RINGOLD	B0C377	Eu-154	2/4/92	6/23/94	0.05460	0.05330	0.09500	pCi/g
1	B0C2W8	Eu-155	9/12/91	7/8/94	0.07300	0.07000	0.12200	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
2	B0C2X4	Eu-155	9/26/91	7/9/94	-0.03500	0.07380	0.11500	pCi/g
2	B0C2X5	Eu-155	9/26/91	7/9/94	0.01870	0.07730	0.12200	pCi/g
3	B0C372	Eu-155	11/20/91	6/13/94	0.03010	0.03550	0.06050	pCi/g
3	B0C396	Eu-155	11/20/91	7/3/94	0.09110	0.04750	0.08200	pCi/g
3	B0C397	Eu-155	11/20/91	7/3/94	0.05570	0.04340	0.07040	pCi/g
5	B0C389	Eu-155	10/15/91	7/3/94	0.11100	0.06020	0.10300	pCi/g
5	B0C390	Eu-155	10/21/91	7/6/94	0.06470	0.05020	0.08640	pCi/g
5	B0C391	Eu-155	10/21/91	7/7/94	0.02490	0.03980	0.06690	pCi/g
6	B0C2Y5	Eu-155	10/8/91	7/10/94	0.05700	0.07680	0.13400	pCi/g
6	B0C2Y6	Eu-155	10/8/91	7/10/94	0.06650	0.06320	0.10600	pCi/g
6	B0C2Y7	Eu-155	10/8/91	7/11/94	0.01740	0.07060	0.12200	pCi/g
6	B0C378	Eu-155	10/8/91	6/25/94	0.09010	0.04400	0.07080	pCi/g
6	B0C379	Eu-155	10/8/91	6/25/94	0.07280	0.04820	0.07650	pCi/g
6	B0C380	Eu-155	10/8/91	6/30/94	0.05470	0.04720	0.07380	pCi/g
6	B0C381	Eu-155	10/8/91	6/30/94	0.05180	0.03750	0.06390	pCi/g
6	B0C382	Eu-155	10/8/91	6/24/94	0.06240	0.03960	0.06360	pCi/g
6	B0C383	Eu-155	10/8/91	6/30/94	0.08380	0.04580	0.07390	pCi/g
7	B0C385	Eu-155	10/11/91	7/2/94	0.03840	0.04620	0.07790	pCi/g
7	B0C386	Eu-155	10/11/91	7/2/94	0.04890	0.04640	0.07930	pCi/g
7	B0C387	Eu-155	10/11/91	7/2/94	0.06530	0.04180	0.07200	pCi/g
9	B0C384	Eu-155	10/9/91	6/28/94	0.07440	0.05410	0.08830	pCi/g
10	B0C2Y1	Eu-155	10/3/91	7/9/94	0.08820	0.13700	0.21700	pCi/g
11	B0C388	Eu-155	10/15/91	7/7/94	0.06780	0.06730	0.11400	pCi/g
12	B0C2W9	Eu-155	9/24/91	7/9/94	0.05420	0.11100	0.17600	pCi/g
12	B0C2X0	Eu-155	9/24/91	7/9/94	0.08340	0.06740	0.11900	pCi/g
12	B0C2X1	Eu-155	9/24/91	7/9/94	0.03290	0.08570	0.13600	pCi/g
13	B0C2X9	Eu-155	10/1/91	7/8/94	0.01940	0.12200	0.21200	pCi/g
14	B0C2X6	Eu-155	10/1/91	7/8/94	-0.09100	0.18400	0.31100	pCi/g
14	B0C2X7	Eu-155	10/1/91	7/9/94	0.08020	0.06830	0.12100	pCi/g
14	B0C2X8	Eu-155	10/1/91	7/10/94	0.08390	0.09690	0.16900	pCi/g
15	B0C2W5	Eu-155	10/2/90	7/20/94	0.08520	0.08380	0.14700	pCi/g
15	B0C2W6	Eu-155	10/2/90	7/20/94	0.09060	0.09500	0.15600	pCi/g
15	B0C2W7	Eu-155	10/9/90	7/20/94	0.07470	0.07550	0.12500	pCi/g
15	B0C392	Eu-155	9/30/90	7/6/94	0.03700	0.04680	0.07920	pCi/g
15	B0C393	Eu-155	9/17/90	7/7/94	0.02760	0.06760	0.10900	pCi/g
15	B0C394	Eu-155	9/18/90	7/3/94	0.03830	0.07580	0.13000	pCi/g
15	B0C395	Eu-155	9/25/90	7/7/94	0.04140	0.03910	0.06630	pCi/g
E-1	B0C374	Eu-155	1/27/92	6/22/94	0.08080	0.06790	0.11700	pCi/g
E-2	B0C2W4	Eu-155	1/27/92	7/19/94	0.06930	0.18100	0.29500	pCi/g
E-4	B0C375	Eu-155	1/27/92	6/22/94	0.06410	0.06590	0.10400	pCi/g
E-9	B0C376	Eu-155	1/27/92	6/23/94	0.10500	0.08890	0.14900	pCi/g
BASALT	B0C373	Eu-155	6/12/91	6/23/94	0.00823	0.05320	0.08900	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
RINGOLD	B0C377	Eu-155	2/4/92	6/23/94	0.12600	0.06000	0.09630	pCi/g
1	B0C2W8	K-40	9/12/91	7/8/94	16.10000	1.87000	ND	pCi/g
2	B0C2X4	K-40	9/26/91	7/9/94	10.50000	1.28000	ND	pCi/g
2	B0C2X5	K-40	9/26/91	7/9/94	14.10000	1.66000	ND	pCi/g
3	B0C372	K-40	11/20/91	6/13/94	10.90000	1.28000	ND	pCi/g
3	B0C396	K-40	11/20/91	7/3/94	11.40000	1.41000	ND	pCi/g
3	B0C397	K-40	11/20/91	7/3/94	11.20000	1.37000	ND	pCi/g
4	B0C2Y0	K-40	10/3/91	7/8/94	12.50000	2.70000	ND	pCi/g
5	B0C389	K-40	10/15/91	7/3/94	15.50000	1.78000	ND	pCi/g
5	B0C390	K-40	10/21/91	7/6/94	16.60000	1.78000	ND	pCi/g
5	B0C391	K-40	10/21/91	7/7/94	16.10000	1.71000	ND	pCi/g
6	B0C2Y5	K-40	10/8/91	7/10/94	11.00000	1.39000	ND	pCi/g
6	B0C2Y6	K-40	10/8/91	7/10/94	10.90000	1.34000	ND	pCi/g
6	B0C2Y7	K-40	10/8/91	7/11/94	10.90000	1.37000	ND	pCi/g
6	B0C378	K-40	10/8/91	6/25/94	11.00000	1.20000	ND	pCi/g
6	B0C379	K-40	10/8/91	6/25/94	10.90000	1.20000	ND	pCi/g
6	B0C380	K-40	10/8/91	6/30/94	10.50000	1.18000	ND	pCi/g
6	B0C381	K-40	10/8/91	6/30/94	9.82000	1.09000	ND	pCi/g
6	B0C382	K-40	10/8/91	6/24/94	9.31000	1.13000	ND	pCi/g
6	B0C383	K-40	10/8/91	6/30/94	14.30000	1.53000	ND	pCi/g
7	B0C385	K-40	10/11/91	7/2/94	11.40000	1.34000	ND	pCi/g
7	B0C386	K-40	10/11/91	7/2/94	10.40000	1.27000	ND	pCi/g
7	B0C387	K-40	10/11/91	7/2/94	10.40000	1.28000	ND	pCi/g
9	B0C384	K-40	10/9/91	6/28/94	15.90000	1.81000	ND	pCi/g
10	B0C2Y1	K-40	10/3/91	7/9/94	9.29000	1.82000	ND	pCi/g
10	B0C2Y2	K-40	10/3/91	7/9/94	14.80000	2.58000	ND	pCi/g
10	B0C2Y3	K-40	10/3/91	7/9/94	11.20000	1.98000	ND	pCi/g
10	B0C2Y4	K-40	10/3/91	7/9/94	11.10000	1.93000	3.59	pCi/g
11	B0C388	K-40	10/15/91	7/7/94	18.70000	2.01000	ND	pCi/g
12	B0C2W9	K-40	9/24/91	7/9/94	14.70000	1.80000	ND	pCi/g
12	B0C2X0	K-40	9/24/91	7/9/94	10.90000	1.35000	ND	pCi/g
12	B0C2X1	K-40	9/24/91	7/9/94	ND	1.25000	ND	pCi/g
12	B0C2X2	K-40	9/24/91	7/9/94	13.80000	1.76000	ND	pCi/g
12	B0C2X3	K-40	9/24/91	7/9/94	13.80000	1.66000	ND	pCi/g
13	B0C2X9	K-40	10/1/91	7/8/94	12.80000	2.18000	ND	pCi/g
14	B0C2X6	K-40	10/1/91	7/8/94	16.10000	2.93000	ND	pCi/g
14	B0C2X7	K-40	10/1/91	7/9/94	14.80000	1.78000	ND	pCi/g
14	B0C2X8	K-40	10/1/91	7/10/94	17.20000	2.03000	ND	pCi/g
15	B0C2W5	K-40	10/2/90	7/20/94	16.20000	1.85000	ND	pCi/g
15	B0C2W6	K-40	10/2/90	7/20/94	14.90000	1.75000	ND	pCi/g
15	B0C2W7	K-40	10/9/90	7/20/94	15.40000	1.76000	ND	pCi/g
15	B0C392	K-40	9/30/90	7/6/94	13.10000	1.41000	ND	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
15	B0C393	K-40	9/17/90	7/7/94	9.99000	1.19000	ND	pCi/g
15	B0C394	K-40	9/18/90	7/3/94	13.60000	1.71000	ND	pCi/g
15	B0C395	K-40	9/25/90	7/7/94	12.10000	1.30000	ND	pCi/g
E-1	B0C374	K-40	1/27/92	6/22/94	12.90000	1.72000	ND	pCi/g
E-2	B0C2W4	K-40	1/27/92	7/19/94	10.20000	2.35000	ND	pCi/g
E-4	B0C375	K-40	1/27/92	6/22/94	14.70000	1.73000	ND	pCi/g
E-9	B0C376	K-40	1/27/92	6/23/94	18.50000	2.08000	ND	pCi/g
BASALT	B0C373	K-40	6/12/91	6/23/94	12.70000	1.41000	ND	pCi/g
RINGOLD	B0C377	K-40	2/4/92	6/23/94	19.70000	2.09000	ND	pCi/g
1	B0C2W8	Ra-226	9/12/91	7/8/94	0.65300	0.10200	ND	pCi/g
2	B0C2X4	Ra-226	9/26/91	7/9/94	0.41800	0.06870	0.11800	pCi/g
2	B0C2X5	Ra-226	9/26/91	7/9/94	0.52800	0.09560	ND	pCi/g
3	B0C372	Ra-226	11/20/91	6/13/94	0.37700	0.07010	ND	pCi/g
3	B0C396	Ra-226	11/20/91	7/3/94	0.34700	0.08540	ND	pCi/g
3	B0C397	Ra-226	11/20/91	7/3/94	0.48800	0.08230	ND	pCi/g
4	B0C2Y0	Ra-226	10/3/91	7/8/94	0.87400	0.24900	ND	pCi/g
5	B0C389	Ra-226	10/15/91	7/3/94	0.75200	0.12500	ND	pCi/g
5	B0C390	Ra-226	10/21/91	7/6/94	0.61400	0.08550	ND	pCi/g
5	B0C391	Ra-226	10/21/91	7/7/94	0.49900	0.07210	ND	pCi/g
6	B0C2Y5	Ra-226	10/8/91	7/10/94	0.44200	0.10100	ND	pCi/g
6	B0C2Y6	Ra-226	10/8/91	7/10/94	0.39800	0.08940	ND	pCi/g
6	B0C2Y7	Ra-226	10/8/91	7/11/94	0.47300	0.08910	ND	pCi/g
6	B0C378	Ra-226	10/8/91	6/25/94	0.36800	0.05970	ND	pCi/g
6	B0C379	Ra-226	10/8/91	6/25/94	0.41500	0.06480	ND	pCi/g
6	B0C380	Ra-226	10/8/91	6/30/94	0.41700	0.07020	ND	pCi/g
6	B0C381	Ra-226	10/8/91	6/30/94	0.33000	0.05800	ND	pCi/g
6	B0C382	Ra-226	10/8/91	6/24/94	0.39600	0.07220	ND	pCi/g
6	B0C383	Ra-226	10/8/91	6/30/94	0.82200	0.09870	ND	pCi/g
7	B0C385	Ra-226	10/11/91	7/2/94	0.29800	0.07360	ND	pCi/g
7	B0C386	Ra-226	10/11/91	7/2/94	0.30200	0.07910	ND	pCi/g
7	B0C387	Ra-226	10/11/91	7/2/94	0.37300	0.08140	ND	pCi/g
9	B0C384	Ra-226	10/9/91	6/28/94	0.44700	0.09600	ND	pCi/g
10	B0C2Y1	Ra-226	10/3/91	7/9/94	0.65800	0.14700	ND	pCi/g
10	B0C2Y2	Ra-226	10/3/91	7/9/94	0.61800	0.21000	ND	pCi/g
10	B0C2Y3	Ra-226	10/3/91	7/9/94	0.38700	0.13000	ND	pCi/g
10	B0C2Y4	Ra-226	10/3/91	7/9/94	0.43100	0.13900	0.26900	pCi/g
11	B0C388	Ra-226	10/15/91	7/7/94	1.13000	0.14000	ND	pCi/g
12	B0C2W9	Ra-226	9/24/91	7/9/94	0.82500	0.14500	ND	pCi/g
12	B0C2X0	Ra-226	9/24/91	7/9/94	0.51800	0.10500	ND	pCi/g
12	B0C2X1	Ra-226	9/24/91	7/9/94	0.64100	0.10600	ND	pCi/g
12	B0C2X2	Ra-226	9/24/91	7/9/94	0.74300	0.12300	ND	pCi/g
12	B0C2X3	Ra-226	9/24/91	7/9/94	0.52100	0.11600	ND	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
13	B0C2X9	Ra-226	10/1/91	7/8/94	0.73300	0.15300	0.30000	pCi/g
14	B0C2X6	Ra-226	10/1/91	7/8/94	0.60100	0.17200	0.34300	pCi/g
14	B0C2X7	Ra-226	10/1/91	7/9/94	0.50600	0.09420	ND	pCi/g
14	B0C2X8	Ra-226	10/1/91	7/10/94	0.89300	0.15300	ND	pCi/g
15	B0C2W5	Ra-226	10/2/90	7/20/94	0.39200	0.08920	ND	pCi/g
15	B0C2W6	Ra-226	10/2/90	7/20/94	0.35100	0.08700	ND	pCi/g
15	B0C2W7	Ra-226	10/9/90	7/20/94	0.41400	0.06850	0.11900	pCi/g
15	B0C392	Ra-226	9/30/90	7/6/94	0.62200	0.07770	ND	pCi/g
15	B0C393	Ra-226	9/17/90	7/7/94	0.55700	0.08950	ND	pCi/g
15	B0C394	Ra-226	9/18/90	7/3/94	0.50500	0.11500	ND	pCi/g
15	B0C395	Ra-226	9/25/90	7/7/94	0.47400	0.06440	ND	pCi/g
E-1	B0C374	Ra-226	1/27/92	6/22/94	0.72200	0.11900	ND	pCi/g
E-2	B0C2W4	Ra-226	1/27/92	7/19/94	0.49100	0.16600	0.32800	pCi/g
E-4	B0C375	Ra-226	1/27/92	6/22/94	0.81600	0.12400	ND	pCi/g
E-9	B0C376	Ra-226	1/27/92	6/23/94	0.77100	0.12800	ND	pCi/g
BASALT	B0C373	Ra-226	6/12/91	6/23/94	0.46900	0.07830	ND	pCi/g
RINGOLD	B0C377	Ra-226	2/4/92	6/23/94	1.16000	0.13900	ND	pCi/g
1	B0C2W8	Th-232	9/12/91	6/21/94	0.91200	0.16400	0.01120	pCi/g
2	B0C2X4	Th-232	9/26/91	6/21/94	0.67500	0.13200	0.01630	pCi/g
2	B0C2X5	Th-232	9/26/91	6/22/94	1.13000	0.19400	0.01150	pCi/g
3	B0C372	Th-232	11/20/91	6/29/94	0.46800	0.09870	0.01470	pCi/g
3	B0C396	Th-232	11/20/91	6/30/94	0.91800	0.15200	0.01360	pCi/g
3	B0C397	Th-232	11/20/91	6/30/94	1.36000	0.22900	0.01860	pCi/g
4	B0C2Y0	Th-232	10/3/91	6/22/94	1.04000	0.18200	0.01740	pCi/g
5	B0C389	Th-232	10/15/91	6/29/94	1.21000	0.21500	0.02600	pCi/g
5	B0C390	Th-232	10/21/91	6/29/94	1.25000	0.22300	0.01350	pCi/g
5	B0C391	Th-232	10/21/91	6/30/94	1.02000	0.20100	0.01520	pCi/g
6	B0C2Y5	Th-232	10/8/91	6/21/94	0.99000	0.18300	0.01280	pCi/g
6	B0C2Y6	Th-232	10/8/91	6/21/94	0.59800	0.12300	0.01670	pCi/g
6	B0C2Y7	Th-232	10/8/91	6/21/94	0.63100	0.13200	0.01860	pCi/g
6	B0C378	Th-232	10/8/91	6/29/94	0.91200	0.18700	0.01550	pCi/g
6	B0C379	Th-232	10/8/91	6/29/94	0.74800	0.15200	0.01310	pCi/g
6	B0C380	Th-232	10/8/91	6/29/94	0.61100	0.13500	0.01380	pCi/g
6	B0C381	Th-232	10/8/91	6/29/94	0.80800	0.16500	0.02090	pCi/g
6	B0C382	Th-232	10/8/91	6/29/94	0.57900	0.12900	0.01340	pCi/g
6	B0C383	Th-232	10/8/91	6/29/94	1.20000	0.21200	0.01920	pCi/g
7	B0C385	Th-232	10/11/91	6/29/94	0.72600	0.15200	0.02040	pCi/g
7	B0C386	Th-232	10/11/91	6/29/94	0.58500	0.13300	0.01410	pCi/g
7	B0C387	Th-232	10/11/91	6/29/94	0.81600	0.16000	0.01280	pCi/g
9	B0C384	Th-232	10/9/91	6/29/94	0.99300	0.19300	0.02190	pCi/g
10	B0C2Y1	Th-232	10/3/91	6/21/94	0.71600	0.13800	0.01890	pCi/g
10	B0C2Y2	Th-232	10/3/91	6/21/94	1.08000	0.19300	0.02440	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
10	B0C2Y3	Th-232	10/3/91	6/21/94	0.98100	0.18200	0.01270	pCi/g
10	B0C2Y4	Th-232	10/3/91	6/21/94	0.59800	0.12200	0.01670	pCi/g
11	B0C388	Th-232	10/15/91	6/29/94	1.58000	0.26100	0.01300	pCi/g
12	B0C2W9	Th-232	9/24/91	6/21/94	1.29000	0.22000	0.01220	pCi/g
12	B0C2X0	Th-232	9/24/91	6/21/94	0.92300	0.16900	0.02330	pCi/g
12	B0C2X1	Th-232	9/24/91	6/21/94	0.94900	0.17200	0.01170	pCi/g
12	B0C2X2	Th-232	9/24/91	6/21/94	0.73500	0.13900	0.01620	pCi/g
12	B0C2X3	Th-232	9/24/91	6/21/94	0.80100	0.15200	0.01770	pCi/g
13	B0C2X9	Th-232	10/1/91	6/22/94	0.84400	0.15100	0.01560	pCi/g
14	B0C2X6	Th-232	10/1/91	6/21/94	0.84900	0.15500	0.01100	pCi/g
14	B0C2X7	Th-232	10/1/91	6/21/94	1.05000	0.18600	0.01190	pCi/g
14	B0C2X8	Th-232	10/1/91	6/21/94	1.17000	0.19800	0.01150	pCi/g
15	B0C2W5	Th-232	10/2/90	7/24/94	1.09000	0.15000	0.01070	pCi/g
15	B0C2W6	Th-232	10/2/90	7/24/94	0.87000	0.11800	0.00870	pCi/g
15	B0C2W7	Th-232	10/9/90	7/24/94	1.30000	0.16900	0.00572	pCi/g
15	B0C392	Th-232	9/30/90	6/30/94	1.02000	0.17600	0.01600	pCi/g
15	B0C393	Th-232	9/17/90	6/30/94	0.95100	0.18700	0.01440	pCi/g
15	B0C394	Th-232	9/18/90	6/30/94	0.77600	0.13500	0.01680	pCi/g
15	B0C395	Th-232	9/25/90	6/30/94	0.99500	0.19900	0.01560	pCi/g
E-1	B0C374	Th-232	1/27/92	6/29/94	1.19000	0.22300	0.02720	pCi/g
E-2	B0C2W4	Th-232	1/27/92	7/24/94	0.48200	0.07700	0.00888	pCi/g
E-4	B0C375	Th-232	1/27/92	6/29/94	1.37000	0.25500	0.01610	pCi/g
E-9	B0C376	Th-232	1/27/92	6/29/94	1.07000	0.19100	0.01830	pCi/g
BASALT	B0C373	Th-232	6/12/91	6/29/94	0.61200	0.13000	0.01850	pCi/g
RINGOLD	B0C377	Th-232	2/4/92	6/29/94	1.45000	0.26500	0.01590	pCi/g
1	B0C2W8	Th-228	9/12/91	6/21/94	1.27000	0.21000	0.02200	pCi/g
2	B0C2X4	Th-228	9/26/91	6/21/94	0.57000	0.12000	0.01630	pCi/g
2	B0C2X5	Th-228	9/26/91	6/22/94	1.07000	0.19000	0.02260	pCi/g
3	B0C372	Th-228	11/20/91	6/29/94	0.52900	0.11000	0.02060	pCi/g
3	B0C396	Th-228	11/20/91	6/30/94	0.91000	0.15000	0.01810	pCi/g
3	B0C397	Th-228	11/20/91	6/30/94	1.30000	0.22000	0.01830	pCi/g
4	B0C2Y0	Th-228	10/3/91	6/22/94	1.27000	0.21000	0.01940	pCi/g
5	B0C389	Th-228	10/15/91	6/29/94	1.17000	0.21000	0.01960	pCi/g
5	B0C390	Th-228	10/21/91	6/29/94	1.30000	0.23000	0.02490	pCi/g
5	B0C391	Th-228	10/21/91	6/30/94	0.98900	0.20000	0.01520	pCi/g
6	B0C2Y5	Th-228	10/8/91	6/21/94	1.01000	0.19000	0.01280	pCi/g
6	B0C2Y6	Th-228	10/8/91	6/21/94	0.76700	0.15000	0.02220	pCi/g
6	B0C2Y7	Th-228	10/8/91	6/21/94	0.61300	0.13000	0.01830	pCi/g
6	B0C378	Th-228	10/8/91	6/29/94	0.94600	0.19000	0.01550	pCi/g
6	B0C379	Th-228	10/8/91	6/29/94	0.82000	0.16000	0.02410	pCi/g
6	B0C380	Th-228	10/8/91	6/29/94	0.66200	0.14000	0.02050	pCi/g
6	B0C381	Th-228	10/8/91	6/29/94	0.76700	0.16000	0.02090	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
6	B0C382	Th-228	10/8/91	6/29/94	0.64200	0.14000	0.02470	pCi/g
6	B0C383	Th-228	10/8/91	6/29/94	1.38000	0.24000	0.02700	pCi/g
7	B0C385	Th-228	10/11/91	6/29/94	0.80600	0.16000	0.02710	pCi/g
7	B0C386	Th-228	10/11/91	6/29/94	0.66400	0.15000	0.01410	pCi/g
7	B0C387	Th-228	10/11/91	6/29/94	0.97600	0.18000	0.01280	pCi/g
9	B0C384	Th-228	10/9/91	6/29/94	1.17000	0.22000	0.02150	pCi/g
10	B0C2Y1	Th-228	10/3/91	6/21/94	0.72400	0.14000	0.02210	pCi/g
10	B0C2Y2	Th-228	10/3/91	6/21/94	1.28000	0.22000	0.01840	pCi/g
10	B0C2Y3	Th-228	10/3/91	6/21/94	1.06000	0.19000	0.02140	pCi/g
10	B0C2Y4	Th-228	10/3/91	6/21/94	0.65500	0.13000	0.02350	pCi/g
11	B0C388	Th-228	10/15/91	6/29/94	1.57000	0.26000	0.02190	pCi/g
12	B0C2W9	Th-228	9/24/91	6/21/94	1.27000	0.22000	0.02250	pCi/g
12	B0C2X0	Th-228	9/24/91	6/21/94	1.08000	0.19000	0.01760	pCi/g
12	B0C2X1	Th-228	9/24/91	6/21/94	0.99600	0.18000	0.01980	pCi/g
12	B0C2X2	Th-228	9/24/91	6/21/94	0.80300	0.15000	0.02150	pCi/g
12	B0C2X3	Th-228	9/24/91	6/21/94	0.97300	0.18000	0.01730	pCi/g
13	B0C2X9	Th-228	10/1/91	6/22/94	0.87500	0.16000	0.02070	pCi/g
14	B0C2X6	Th-228	10/1/91	6/21/94	0.94100	0.17000	0.02170	pCi/g
14	B0C2X7	Th-228	10/1/91	6/21/94	1.13000	0.20000	0.02190	pCi/g
14	B0C2X8	Th-228	10/1/91	6/21/94	1.37000	0.22000	0.01940	pCi/g
15	B0C2W5	Th-228	10/2/90	7/24/94	1.23000	0.17000	0.01640	pCi/g
15	B0C2W6	Th-228	10/2/90	7/24/94	0.84500	0.12000	0.01490	pCi/g
15	B0C2W7	Th-228	10/9/90	7/24/94	1.45000	0.19000	0.01450	pCi/g
15	B0C392	Th-228	9/30/90	6/30/94	0.98600	0.17000	0.02130	pCi/g
15	B0C393	Th-228	9/17/90	6/30/94	0.96100	0.19000	0.02430	pCi/g
15	B0C394	Th-228	9/18/90	6/30/94	0.70300	0.13000	0.01350	pCi/g
15	B0C395	Th-228	9/25/90	6/30/94	1.08000	0.21000	0.02630	pCi/g
E-1	B0C374	Th-228	1/27/92	6/29/94	1.19000	0.22000	0.02190	pCi/g
E-2	B0C2W4	Th-228	1/27/92	7/24/94	0.53900	0.08300	0.01520	pCi/g
E-4	B0C375	Th-228	1/27/92	6/29/94	1.28000	0.24000	0.01610	pCi/g
E-9	B0C376	Th-228	1/27/92	6/29/94	0.95000	0.18000	0.02430	pCi/g
BASALT	B0C373	Th-228	6/12/91	6/29/94	0.64800	0.14000	0.02460	pCi/g
RINGOLD	B0C377	Th-228	2/4/92	6/29/94	1.58000	0.28000	0.02940	pCi/g
1	B0C2W8	U-234	9/12/91	6/22/94	0.74100	0.24000	0.05430	pCi/g
2	B0C2X4	U-234	9/26/91	6/22/94	0.47700	0.16000	0.04180	pCi/g
2	B0C2X5	U-234	9/26/91	6/22/94	0.80700	0.25400	0.07220	pCi/g
3	B0C372	U-234	11/20/91	6/29/94	0.52100	0.18700	0.05120	pCi/g
3	B0C396	U-234	11/20/91	6/25/94	0.81400	0.21800	0.05130	pCi/g
3	B0C397	U-234	11/20/91	6/25/94	0.82200	0.18200	0.03160	pCi/g
4	B0C2Y0	U-234	10/3/91	6/23/94	0.88300	0.21800	0.04240	pCi/g
5	B0C389	U-234	10/15/91	6/28/94	0.98800	0.33800	0.11000	pCi/g
5	B0C390	U-234	10/21/91	6/28/94	0.74600	0.25000	0.09680	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
5	B0C391	U-234	10/21/91	6/24/94	0.69900	0.17300	0.03860	pCi/g
6	B0C2Y5	U-234	10/8/91	6/24/94	0.59700	0.19600	0.05860	pCi/g
6	B0C2Y6	U-234	10/8/91	6/24/94	0.67300	0.23500	0.07870	pCi/g
6	B0C2Y7	U-234	10/8/91	6/24/94	0.62800	0.17500	0.05500	pCi/g
6	B0C378	U-234	10/8/91	6/28/94	0.65900	0.22200	0.07900	pCi/g
6	B0C379	U-234	10/8/91	6/28/94	0.74300	0.18500	0.04340	pCi/g
6	B0C380	U-234	10/8/91	6/28/94	0.44200	0.17700	0.10000	pCi/g
6	B0C381	U-234	10/8/91	7/14/94	0.64300	0.20600	0.08450	pCi/g
6	B0C382	U-234	10/8/91	6/28/94	0.73400	0.22300	0.05830	pCi/g
6	B0C383	U-234	10/8/91	6/28/94	1.02000	0.27300	0.06370	pCi/g
7	B0C385	U-234	10/11/91	6/28/94	0.52600	0.14900	0.04620	pCi/g
7	B0C386	U-234	10/11/91	6/28/94	0.65100	0.21500	0.08730	pCi/g
7	B0C387	U-234	10/11/91	6/28/94	0.65700	0.21000	0.05980	pCi/g
9	B0C384	U-234	10/9/91	6/28/94	0.90500	0.32800	0.12100	pCi/g
10	B0C2Y1	U-234	10/3/91	6/24/94	0.71500	0.21900	0.07200	pCi/g
10	B0C2Y2	U-234	10/3/91	7/14/94	1.20000	0.27800	0.06600	pCi/g
10	B0C2Y3	U-234	10/3/91	6/24/94	1.01000	0.25200	0.07140	pCi/g
10	B0C2Y4	U-234	10/3/91	6/24/94	0.71700	0.20200	0.06040	pCi/g
11	B0C388	U-234	10/15/91	6/28/94	0.89100	0.26900	0.06650	pCi/g
12	B0C2W9	U-234	9/24/91	6/22/94	0.57200	0.23700	0.09270	pCi/g
12	B0C2X0	U-234	9/24/91	6/22/94	0.69200	0.19200	0.05900	pCi/g
12	B0C2X1	U-234	9/24/91	6/22/94	0.59800	0.19200	0.06630	pCi/g
12	B0C2X2	U-234	9/24/91	7/14/94	0.52100	0.13800	0.05380	pCi/g
12	B0C2X3	U-234	9/24/91	6/22/94	0.92800	0.20600	0.04270	pCi/g
13	B0C2X9	U-234	10/1/91	6/22/94	1.34000	0.37400	0.08270	pCi/g
14	B0C2X6	U-234	10/1/91	6/22/94	1.20000	0.40500	0.13200	pCi/g
14	B0C2X7	U-234	10/1/91	6/22/94	0.73100	0.17400	0.03840	pCi/g
14	B0C2X8	U-234	10/1/91	6/24/94	1.14000	0.32000	0.07120	pCi/g
15	B0C2W5	U-234	10/2/90	7/18/94	0.70500	0.16500	0.04850	pCi/g
15	B0C2W6	U-234	10/2/90	7/18/94	0.75300	0.18200	0.04310	pCi/g
15	B0C2W7	U-234	10/9/90	7/18/94	0.80500	0.24900	0.07760	pCi/g
15	B0C392	U-234	9/30/90	6/24/94	0.83700	0.21000	0.05610	pCi/g
15	B0C393	U-234	9/17/90	6/24/94	0.85000	0.17600	0.03980	pCi/g
15	B0C394	U-234	9/18/90	6/24/94	0.95700	0.20900	0.04380	pCi/g
15	B0C395	U-234	9/25/90	6/25/94	1.03000	0.21900	0.03070	pCi/g
E-1	B0C374	U-234	1/27/92	7/14/94	0.75700	0.18900	0.07920	pCi/g
E-2	B0C2W4	U-234	1/27/92	7/18/94	0.39900	0.12300	0.04210	pCi/g
E-4	B0C375	U-234	1/27/92	6/29/94	1.51000	0.37800	0.06720	pCi/g
E-9	B0C376	U-234	1/27/92	7/1/94	0.54400	0.17200	0.06310	pCi/g
BASALT	B0C373	U-234	6/12/91	6/29/94	0.59100	0.18300	0.05190	pCi/g
RINGOLD	B0C377	U-234	2/4/92	6/29/94	1.10000	0.30600	0.07270	pCi/g
1	B0C2W8	U-235	9/12/91	6/22/94	0.03830	0.04730	0.06160	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
2	B0C2X4	U-235	9/26/91	6/22/94	0.07110	0.05620	0.04750	pCi/g
2	B0C2X5	U-235	9/26/91	6/22/94	0.00811	0.02750	0.07640	pCi/g
3	B0C372	U-235	11/20/91	6/29/94	-0.00200	0.00290	0.05820	pCi/g
3	B0C396	U-235	11/20/91	6/25/94	0.00577	0.01960	0.05430	pCi/g
3	B0C397	U-235	11/20/91	6/25/94	0.03600	0.03150	0.03380	pCi/g
4	B0C2Y0	U-235	10/3/91	6/23/94	0.02420	0.02980	0.03890	pCi/g
5	B0C389	U-235	10/15/91	6/28/94	0.03400	0.05290	0.08430	pCi/g
5	B0C390	U-235	10/21/91	6/28/94	0.28600	0.14000	0.07760	pCi/g
5	B0C391	U-235	10/21/91	6/24/94	0.02660	0.02930	0.03860	pCi/g
6	B0C2Y5	U-235	10/8/91	6/24/94	0.00988	0.02370	0.05370	pCi/g
6	B0C2Y6	U-235	10/8/91	6/24/94	0.03830	0.05180	0.08330	pCi/g
6	B0C2Y7	U-235	10/8/91	6/24/94	0.02430	0.02990	0.03910	pCi/g
6	B0C378	U-235	10/8/91	6/28/94	0.01120	0.02690	0.06080	pCi/g
6	B0C379	U-235	10/8/91	6/28/94	0.02060	0.02690	0.04110	pCi/g
6	B0C380	U-235	10/8/91	6/28/94	0.01990	0.03960	0.08530	pCi/g
6	B0C381	U-235	10/8/91	7/14/94	-0.00690	0.00805	0.07250	pCi/g
6	B0C382	U-235	10/8/91	6/28/94	0.02150	0.03340	0.05340	pCi/g
6	B0C383	U-235	10/8/91	6/28/94	0.01890	0.03220	0.06020	pCi/g
7	B0C385	U-235	10/11/91	6/28/94	0.01310	0.02230	0.04160	pCi/g
7	B0C386	U-235	10/11/91	6/28/94	0.04580	0.05170	0.07180	pCi/g
7	B0C387	U-235	10/11/91	6/28/94	0.02210	0.03420	0.05480	pCi/g
9	B0C384	U-235	10/9/91	6/28/94	0.07480	0.07960	0.08900	pCi/g
10	B0C2Y1	U-235	10/3/91	6/24/94	0.04470	0.04720	0.05320	pCi/g
10	B0C2Y2	U-235	10/3/91	7/14/94	0.05920	0.04860	0.05070	pCi/g
10	B0C2Y3	U-235	10/3/91	6/24/94	0.03300	0.03890	0.05930	pCi/g
10	B0C2Y4	U-235	10/3/91	6/24/94	0.03750	0.03950	0.04460	pCi/g
11	B0C388	U-235	10/15/91	6/28/94	0.09020	0.07250	0.06650	pCi/g
12	B0C2W9	U-235	9/24/91	6/22/94	0.15700	0.11600	0.11500	pCi/g
12	B0C2X0	U-235	9/24/91	6/22/94	0.04450	0.04170	0.04190	pCi/g
12	B0C2X1	U-235	9/24/91	6/22/94	0.06350	0.05590	0.05970	pCi/g
12	B0C2X2	U-235	9/24/91	7/14/94	0.00524	0.01340	0.03130	pCi/g
12	B0C2X3	U-235	9/24/91	6/22/94	0.01960	0.02410	0.03150	pCi/g
13	B0C2X9	U-235	10/1/91	6/22/94	0.02690	0.04180	0.06680	pCi/g
14	B0C2X6	U-235	10/1/91	6/22/94	0.05980	0.07210	0.08240	pCi/g
14	B0C2X7	U-235	10/1/91	6/22/94	0.00462	0.01380	0.03630	pCi/g
14	B0C2X8	U-235	10/1/91	6/24/94	0.38600	0.15900	0.05370	pCi/g
15	B0C2W5	U-235	10/2/90	7/18/94	0.04940	0.03660	0.03170	pCi/g
15	B0C2W6	U-235	10/2/90	7/18/94	0.03580	0.03290	0.02920	pCi/g
15	B0C2W7	U-235	10/9/90	7/18/94	0.01100	0.02640	0.05970	pCi/g
15	B0C392	U-235	9/30/90	6/24/94	0.04080	0.03820	0.03850	pCi/g
15	B0C393	U-235	9/17/90	6/24/94	0.04630	0.03350	0.03390	pCi/g
15	B0C394	U-235	9/18/90	6/24/94	0.08760	0.05070	0.03110	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
15	B0C395	U-235	9/25/90	6/25/94	0.03930	0.03340	0.03070	pCi/g
E-1	B0C374	U-235	1/27/92	7/14/94	0.01510	0.02710	0.05560	pCi/g
E-2	B0C2W4	U-235	1/27/92	7/18/94	0.02060	0.02610	0.03720	pCi/g
E-4	B0C375	U-235	1/27/92	6/29/94	0.07150	0.06300	0.06720	pCi/g
E-9	B0C376	U-235	1/27/92	7/1/94	0.08600	0.06180	0.05650	pCi/g
BASALT	B0C373	U-235	6/12/91	6/29/94	0.05040	0.04730	0.04750	pCi/g
RINGOLD	B0C377	U-235	2/4/92	6/29/94	0.03450	0.04520	0.06870	pCi/g
1	B0C2W8	U-238	9/12/91	6/22/94	0.79400	0.25100	0.06160	pCi/g
1	B0C2W8	U-238	9/12/91	7/8/94	0.70900	0.62900	ND	pCi/g
2	B0C2X4	U-238	9/26/91	6/22/94	0.64300	0.19300	0.04750	pCi/g
2	B0C2X5	U-238	9/26/91	6/22/94	0.70100	0.23100	0.06180	pCi/g
3	B0C372	U-238	11/20/91	6/13/94	0.56500	0.45500	ND	pCi/g
3	B0C372	U-238	11/20/91	6/29/94	0.54500	0.19200	0.06350	pCi/g
3	B0C396	U-238	11/20/91	6/25/94	0.77700	0.21100	0.04390	pCi/g
3	B0C397	U-238	11/20/91	6/25/94	0.76400	0.17300	0.03580	pCi/g
4	B0C2Y0	U-238	10/3/91	6/23/94	0.85800	0.21300	0.03890	pCi/g
5	B0C389	U-238	10/15/91	6/28/94	1.20000	0.38500	0.08430	pCi/g
5	B0C390	U-238	10/21/91	6/28/94	0.55600	0.20800	0.09990	pCi/g
5	B0C391	U-238	10/21/91	6/24/94	0.67800	0.16900	0.03600	pCi/g
6	B0C2Y5	U-238	10/8/91	6/24/94	0.53800	0.18400	0.05860	pCi/g
6	B0C2Y6	U-238	10/8/91	6/24/94	0.52800	0.20200	0.06730	pCi/g
6	B0C2Y7	U-238	10/8/91	6/24/94	0.81200	0.20600	0.03910	pCi/g
6	B0C2Y7	U-238	10/8/91	7/11/94	0.77500	0.73900	ND	pCi/g
6	B0C378	U-238	10/8/91	6/28/94	0.59700	0.20800	0.06080	pCi/g
6	B0C379	U-238	10/8/91	6/28/94	0.66600	0.17200	0.04340	pCi/g
6	B0C380	U-238	10/8/91	6/28/94	0.42400	0.17100	0.06880	pCi/g
6	B0C381	U-238	10/8/91	7/14/94	0.60600	0.20100	0.11000	pCi/g
6	B0C382	U-238	10/8/91	6/28/94	0.67500	0.21100	0.05830	pCi/g
6	B0C383	U-238	10/8/91	6/28/94	1.09000	0.28600	0.05620	pCi/g
7	B0C385	U-238	10/11/91	6/28/94	0.35400	0.11800	0.04820	pCi/g
7	B0C386	U-238	10/11/91	6/28/94	0.54400	0.19200	0.06340	pCi/g
7	B0C387	U-238	10/11/91	6/28/94	0.75300	0.22900	0.05980	pCi/g
9	B0C384	U-238	10/9/91	6/28/94	0.89300	0.32400	0.08900	pCi/g
10	B0C2Y1	U-238	10/3/91	6/24/94	0.66200	0.20800	0.05320	pCi/g
10	B0C2Y2	U-238	10/3/91	7/14/94	1.03000	0.24900	0.06600	pCi/g
10	B0C2Y3	U-238	10/3/91	6/24/94	1.08000	0.26400	0.04780	pCi/g
10	B0C2Y4	U-238	10/3/91	6/24/94	0.71800	0.20200	0.05510	pCi/g
11	B0C388	U-238	10/15/91	6/28/94	1.08000	0.30600	0.06650	pCi/g
12	B0C2W9	U-238	9/24/91	6/22/94	0.68000	0.26500	0.10500	pCi/g
12	B0C2X0	U-238	9/24/91	6/22/94	0.68700	0.19100	0.04190	pCi/g
12	B0C2X0	U-238	9/24/91	7/9/94	0.81300	0.49100	0.83200	pCi/g
12	B0C2X1	U-238	9/24/91	6/22/94	0.50800	0.17300	0.06920	pCi/g

Table A-2. Vadose Zone Radionuclide Data.

Site	New HEIS	Analyte	Sampling Date	Analysis Date	Result	Total Error	MDA	Units
12	B0C2X1	U-238	9/24/91	7/9/94	1.41000	1.11000	ND	pCi/g
12	B0C2X2	U-238	9/24/91	7/14/94	0.49800	0.13400	0.04820	pCi/g
12	B0C2X3	U-238	9/24/91	6/22/94	0.85400	0.19400	0.03900	pCi/g
13	B0C2X9	U-238	10/1/91	6/22/94	1.02000	0.30900	0.08270	pCi/g
13	B0C2X9	U-238	10/1/91	7/8/94	1.38000	1.26000	ND	pCi/g
14	B0C2X6	U-238	10/1/91	6/22/94	1.15000	0.39200	0.05540	pCi/g
14	B0C2X7	U-238	10/1/91	6/22/94	0.79100	0.18300	0.04200	pCi/g
14	B0C2X8	U-238	10/1/91	6/24/94	0.76900	0.24500	0.07540	pCi/g
15	B0C2W5	U-238	10/2/90	7/18/94	0.76200	0.17300	0.02910	pCi/g
15	B0C2W6	U-238	10/2/90	7/18/94	0.55100	0.14800	0.03620	pCi/g
15	B0C2W7	U-238	10/9/90	7/18/94	0.70300	0.22800	0.06520	pCi/g
15	B0C392	U-238	9/30/90	6/24/94	0.68200	0.18300	0.03850	pCi/g
15	B0C393	U-238	9/17/90	6/24/94	0.77200	0.16400	0.02730	pCi/g
15	B0C394	U-238	9/18/90	6/24/94	1.01000	0.21800	0.03850	pCi/g
15	B0C395	U-238	9/25/90	6/25/94	1.06000	0.22300	0.03350	pCi/g
E-1	B0C374	U-238	1/27/92	6/22/94	0.71100	1.40000	ND	pCi/g
E-1	B0C374	U-238	1/27/92	7/14/94	0.84300	0.20100	0.04270	pCi/g
E-2	B0C2W4	U-238	1/27/92	7/18/94	0.46400	0.13600	0.04960	pCi/g
E-4	B0C375	U-238	1/27/92	6/22/94	1.21000	1.10000	ND	pCi/g
E-4	B0C375	U-238	1/27/92	6/29/94	1.21000	0.32200	0.06270	pCi/g
E-9	B0C376	U-238	1/27/92	6/23/94	1.12000	1.36000	2.13000	pCi/g
E-9	B0C376	U-238	1/27/92	7/1/94	0.68200	0.19900	0.06870	pCi/g
BASALT	B0C373	U-238	6/12/91	6/23/94	0.15200	0.71400	ND	pCi/g
BASALT	B0C373	U-238	6/12/91	6/29/94	0.55800	0.17700	0.05550	pCi/g
RINGOLD	B0C377	U-238	2/4/92	6/23/94	1.47000	0.63100	ND	pCi/g
RINGOLD	B0C377	U-238	2/4/92	6/29/94	1.11000	0.30800	0.07960	pCi/g

MDA = Minimum Detectable Activity
ND = Not Determined

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APPENDIX B

RESULTS OF DUPLICATE ANALYSIS

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Table B-1. Results of Duplicate Analyses. RPD is the difference between the duplicates divided by their average. For type of sample, N=normal sample reported as analysis, D=duplicate.

New HEIS	Analyte	Result	Q	Total Error	MDA	Units	Type of Sample	RPD	Collection Date	Analysis Date
B0C2W4	CO-60	-0.12	J	0.115	0.176	pCi/g	D	-41.2	7/11/94	7/20/94
B0C2W4	CO-60	-0.079	J	0.108	0.179	pCi/g	N		1/27/92	7/19/94
B0C372	CO-60	-0.00044	J	0.0252	0.0426	pCi/g	D	206.2	11/20/91	6/22/94
B0C372	CO-60	0.029	J	0.0238	0.0427	pCi/g	N		11/20/91	6/13/94
B0C382	CO-60	0.00164	J	0.0231	0.0402	pCi/g	D	153.6	10/8/91	6/28/94
B0C382	CO-60	0.0125	J	0.0212	0.0371	pCi/g	N		10/8/91	6/24/94
B0C384	CO-60	-0.036	J	0.031	0.0472	pCi/g	D	-843.5	10/9/91	6/28/94
B0C384	CO-60	0.0222	J	0.0272	0.0491	pCi/g	N		10/9/91	6/28/94
B0C385	CO-60	0.024	J	0.0259	0.0477	pCi/g	D	760.0	10/11/91	7/2/94
B0C385	CO-60	-0.014	J	0.0279	0.0462	pCi/g	N		10/11/91	7/2/94
B0C2W4	CS-137	0.218	X	0.133	ND	pCi/g	D	35.5	7/11/94	7/20/94
B0C2W4	CS-137	0.312	X	0.112	ND	pCi/g	N		1/27/92	7/19/94
B0C2X6	CS-137	-0.033	J	0.071	0.116	pCi/g	D	-1963.9	10/1/91	7/8/94
B0C2X6	CS-137	0.0269	J	0.0691	0.123	pCi/g	N		10/1/91	7/8/94
B0C2X9	CS-137	0.0131	J	0.0507	0.0911	pCi/g	D	104.2	10/1/91	7/8/94
B0C2X9	CS-137	0.0416	J	0.0483	0.0916	pCi/g	N		10/1/91	7/8/94
B0C2Y0	CS-137	-0.012	J	0.0642	0.111	pCi/g	D	-121.3	10/3/91	7/9/94
B0C2Y0	CS-137	-0.049	J	0.0819	0.128	pCi/g	N		10/3/91	7/8/94
B0C372	CS-137	-0.0069	J	0.0169	0.0267	pCi/g	D	-575.3	11/20/91	6/22/94
B0C372	CS-137	0.00334	J	0.0135	0.0224	pCi/g	N		11/20/91	6/13/94
B0C382	CS-137	0.00597	J	0.0139	0.0241	pCi/g	D	-416.5	10/8/91	6/28/94
B0C382	CS-137	-0.017	J	0.0158	0.0242	pCi/g	N		10/8/91	6/24/94
B0C384	CS-137	0.00682	J	0.0176	0.0303	pCi/g	D	8325.0	10/9/91	6/28/94
B0C384	CS-137	-0.0065	J	0.019	0.0314	pCi/g	N		10/9/91	6/28/94
B0C385	CS-137	0.00697	J	0.0197	0.0328	pCi/g	D	50.0	10/11/91	7/2/94
B0C385	CS-137	0.00418	J	0.0151	0.0258	pCi/g	N		10/11/91	7/2/94
B0C2W4	EU-152	0.19	J	0.177	0.329	pCi/g	D	3600.0	7/11/94	7/20/94
B0C2W4	EU-152	-0.17	J	0.193	0.3	pCi/g	N		1/27/92	7/19/94
B0C2X6	EU-152	-0.12	J	0.161	0.261	pCi/g	D	-94.5	10/1/91	7/8/94
B0C2X6	EU-152	-0.043	J	0.158	0.267	pCi/g	N		10/1/91	7/8/94
B0C2X9	EU-152	0.0218	J	0.133	0.234	pCi/g	D	-313.0	10/1/91	7/8/94
B0C2X9	EU-152	-0.099	J	0.133	0.212	pCi/g	N		10/1/91	7/8/94
B0C372	EU-152	0.036	J	0.1	0.177	pCi/g	D	-14600.0	11/20/91	6/22/94
B0C372	EU-152	-0.037	J	0.09	0.148	pCi/g	N		11/20/91	6/13/94
B0C382	EU-152	0.0612	J	0.0876	0.157	pCi/g	D	166.9	10/8/91	6/28/94
B0C382	EU-152	0.00552	J	0.0865	0.149	pCi/g	N		10/8/91	6/24/94
B0C384	EU-152	0.0709	J	0.111	0.199	pCi/g	D	39.7	10/9/91	6/28/94
B0C384	EU-152	0.106	J	0.105	0.189	pCi/g	N		10/9/91	6/28/94
B0C385	EU-152	-0.017	J	0.0484	0.0788	pCi/g	D	-21.1	10/11/91	7/2/94
B0C385	EU-152	-0.021	J	0.0454	0.0709	pCi/g	N		10/11/91	7/2/94
B0C2W4	EU-154	-0.16	J	0.266	0.445	pCi/g	D	492.2	7/11/94	7/20/94

Table B-1. Results of Duplicate Analyses. RPD is the difference between the duplicates divided by their average. For type of sample, N=normal sample reported as analysis, D=duplicate.

New HEIS	Analyte	Result	Q	Total Error	MDA	Units	Type of Sample	RPD	Collection Date	Analysis Date
B0C2W4	EU-154	0.379	J	0.253	0.539	pCi/g	N		1/27/92	7/19/94
B0C2X6	EU-154	0.139	J	0.236	0.473	pCi/g	D	-1111.5	10/1/91	7/8/94
B0C2X6	EU-154	-0.2	J	0.242	0.376	pCi/g	N		10/1/91	7/8/94
B0C2X9	EU-154	0.079	J	0.197	0.372	pCi/g	D	55.5	10/1/91	7/8/94
B0C2X9	EU-154	0.0447	J	0.166	0.325	pCi/g	N		10/1/91	7/8/94
B0C372	EU-154	0.0338	J	0.0671	0.115	pCi/g	D	74.8	11/20/91	6/22/94
B0C372	EU-154	0.0154	J	0.0639	0.107	pCi/g	N		11/20/91	6/13/94
B0C382	EU-154	0.0558	J	0.0561	0.103	pCi/g	D	1212.7	10/8/91	6/28/94
B0C382	EU-154	-0.04	J	0.0616	0.102	pCi/g	N		10/8/91	6/24/94
B0C384	EU-154	-0.051	J	0.0837	0.135	pCi/g	D	-200.0	10/9/91	6/28/94
B0C384	EU-154	0	J	0.0726	0.123	pCi/g	N		10/9/91	6/28/94
B0C385	EU-154	0.0205	J	0.0707	0.122	pCi/g	D	66.2	10/11/91	7/2/94
B0C385	EU-154	0.0103	J	0.0678	0.116	pCi/g	N		10/11/91	7/2/94
B0C2W4	EU-155	0.0105	J	0.178	0.287	pCi/g	D	147.4	7/11/94	7/20/94
B0C2W4	EU-155	0.0693	J	0.181	0.295	pCi/g	N		1/27/92	7/19/94
B0C2X6	EU-155	0.0379	J	0.198	0.347	pCi/g	D	-485.5	10/1/91	7/8/94
B0C2X6	EU-155	-0.091	J	0.184	0.311	pCi/g	N		10/1/91	7/8/94
B0C2X9	EU-155	0.188	J	0.131	0.24	pCi/g	D	162.6	10/1/91	7/8/94
B0C2X9	EU-155	0.0194	J	0.122	0.212	pCi/g	N		10/1/91	7/8/94
B0C372	EU-155	0.0336	J	0.0465	0.0735	pCi/g	D	11.0	11/20/91	6/22/94
B0C372	EU-155	0.0301	J	0.0355	0.0605	pCi/g	N		11/20/91	6/13/94
B0C382	EU-155	0.0303	J	0.0371	0.0629	pCi/g	D	69.3	10/8/91	6/28/94
B0C382	EU-155	0.0624	J	0.0396	0.0636	pCi/g	N		10/8/91	6/24/94
B0C384	EU-155	0.00371	J	0.0562	0.088	pCi/g	D	181.0	10/9/91	6/28/94
B0C384	EU-155	0.0744	J	0.0541	0.0883	pCi/g	N		10/9/91	6/28/94
B0C385	EU-155	0.0294	J	0.0463	0.0775	pCi/g	D	26.5	10/11/91	7/2/94
B0C385	EU-155	0.0384	J	0.0462	0.0779	pCi/g	N		10/11/91	7/2/94
B0C2W4	K-40	12	X	2.75	ND	pCi/g	D	16.2	7/11/94	7/20/94
B0C2W4	K-40	10.2	X	2.35	ND	pCi/g	N		1/27/92	7/19/94
B0C2X6	K-40	12.8	X	2.8	ND	pCi/g	D	22.8	10/1/91	7/8/94
B0C2X6	K-40	16.1	X	2.93	ND	pCi/g	N		10/1/91	7/8/94
B0C2X9	K-40	11.4	X	2.05	ND	pCi/g	D	11.6	10/1/91	7/8/94
B0C2X9	K-40	12.8	X	2.18	ND	pCi/g	N		10/1/91	7/8/94
B0C2Y0	K-40	17.3	X	2.83	ND	pCi/g	D	32.2	10/3/91	7/9/94
B0C2Y0	K-40	12.5	X	2.7	ND	pCi/g	N		10/3/91	7/8/94
B0C372	K-40	9.69	X	1.23	ND	pCi/g	D	11.8	11/20/91	6/22/94
B0C372	K-40	10.9	X	1.28	ND	pCi/g	N		11/20/91	6/13/94
B0C382	K-40	10.2	X	1.22	ND	pCi/g	D	9.1	10/8/91	6/28/94
B0C382	K-40	9.31	X	1.13	ND	pCi/g	N		10/8/91	6/24/94
B0C384	K-40	16.3	X	1.88	ND	pCi/g	D	2.5	10/9/91	6/28/94
B0C384	K-40	15.9	X	1.81	ND	pCi/g	N		10/9/91	6/28/94

Table B-1. Results of Duplicate Analyses. RPD is the difference between the duplicates divided by their average. For type of sample, N=normal sample reported as analysis, D=duplicate.

New HEIS	Analyte	Result	Q	Total Error	MDA	Units	Type of Sample	RPD	Collection Date	Analysis Date
B0C385	K-40	11.6	X	1.43	ND	pCi/g	D	1.7	10/11/91	7/2/94
B0C385	K-40	11.4	X	1.34	ND	pCi/g	N		10/11/91	7/2/94
B0C2W4	RA-226	0.463		0.179	0.353	pCi/g	D	5.9	7/11/94	7/20/94
B0C2W4	RA-226	0.491		0.166	0.328	pCi/g	N		1/27/92	7/19/94
B0C2X6	RA-226	0.706		0.188	0.364	pCi/g	D	16.1	10/1/91	7/8/94
B0C2X6	RA-226	0.601		0.172	0.343	pCi/g	N		10/1/91	7/8/94
B0C2X9	RA-226	0.674		0.155	0.295	pCi/g	D	8.4	10/1/91	7/8/94
B0C2X9	RA-226	0.733		0.153	0.3	pCi/g	N		10/1/91	7/8/94
B0C2Y0	RA-226	0.624		0.183	0.347	pCi/g	D	33.4	10/3/91	7/9/94
B0C2Y0	RA-226	0.874	X	0.249	ND	pCi/g	N		10/3/91	7/8/94
B0C372	RA-226	0.461	X	0.0778	ND	pCi/g	D	20.0	11/20/91	6/22/94
B0C372	RA-226	0.377	X	0.0701	ND	pCi/g	N		11/20/91	6/13/94
B0C384	RA-226	0.389	X	0.089	ND	pCi/g	D	13.9	10/9/91	6/28/94
B0C384	RA-226	0.447	X	0.096	ND	pCi/g	N		10/9/91	6/28/94
B0C385	RA-226	0.313	X	0.0791	ND	pCi/g	D	4.9	10/11/91	7/2/94
B0C385	RA-226	0.298	X	0.0736	ND	pCi/g	N		10/11/91	7/2/94
B0C2W7	TH-232	1.32		0.17	0.0129	pCi/g	D	1.5	10/9/90	7/24/94
B0C2W7	TH-232	1.3		0.169	0.00572	pCi/g	N		10/9/90	7/24/94
B0C2X7	TH-232	1.14		0.203	0.0232	pCi/g	D	8.2	10/1/91	6/21/94
B0C2X7	TH-232	1.05		0.186	0.0119	pCi/g	N		10/1/91	6/21/94
B0C2Y1	TH-232	0.82		0.161	0.0129	pCi/g	D	13.5	10/3/91	6/21/94
B0C2Y1	TH-232	0.716		0.138	0.0189	pCi/g	N		10/3/91	6/21/94
B0C374	TH-232	1		0.187	0.0131	pCi/g	D	17.4	1/27/92	6/29/94
B0C374	TH-232	1.19		0.223	0.0272	pCi/g	N		1/27/92	6/29/94
B0C390	TH-232	1.06		0.182	0.0163	pCi/g	D	16.5	10/21/91	6/29/94
B0C390	TH-232	1.25		0.223	0.0135	pCi/g	N		10/21/91	6/29/94
B0C392	TH-232	1.11		0.204	0.0203	pCi/g	D	8.5	9/30/90	6/30/94
B0C392	TH-232	1.02		0.176	0.016	pCi/g	N		9/30/90	6/30/94
B0C2W7	TH228	1.51		0.19	0.0129	pCi/g	D	4.1	10/9/90	7/24/94
B0C2W7	TH228	1.45		0.19	0.0145	pCi/g	N		10/9/90	7/24/94
B0C2X7	TH228	1.11		0.2	0.0187	pCi/g	D	1.8	10/1/91	6/21/94
B0C2X7	TH228	1.13		0.2	0.0219	pCi/g	N		10/1/91	6/21/94
B0C2Y1	TH228	0.771		0.15	0.0238	pCi/g	D	6.3	10/3/91	6/21/94
B0C2Y1	TH228	0.724		0.14	0.0221	pCi/g	N		10/3/91	6/21/94
B0C374	TH228	1.05		0.19	0.0221	pCi/g	D	12.5	1/27/92	6/29/94
B0C374	TH228	1.19		0.22	0.0219	pCi/g	N		1/27/92	6/29/94
B0C390	TH228	1.01		0.18	0.0217	pCi/g	D	25.1	10/21/91	6/29/94
B0C390	TH228	1.3		0.23	0.0249	pCi/g	N		10/21/91	6/29/94
B0C392	TH228	1.24		0.22	0.0285	pCi/g	D	22.8	9/30/90	6/30/94
B0C392	TH228	0.986		0.17	0.0213	pCi/g	N		9/30/90	6/30/94
B0C2W7	U-234	0.774		0.21	0.0536	pCi/g	D	3.9	10/9/90	7/18/94

Table B-1. Results of Duplicate Analyses. RPD is the difference between the duplicates divided by their average. For type of sample, N=normal sample reported as analysis, D=duplicate.

New HEIS	Analyte	Result	Q	Total Error	MDA	Units	Type of Sample	RPD	Collection Date	Analysis Date
B0C2W7	U-234	0.805		0.249	0.0776	pCi/g	N		10/9/90	7/18/94
B0C2Y0	U-234	0.809		0.213	0.046	pCi/g	D	8.7	10/3/91	6/23/94
B0C2Y0	U-234	0.883		0.218	0.0424	pCi/g	N		10/3/91	6/23/94
B0C2Y6	U-234	0.673		0.235	0.0787	pCi/g	N		10/8/91	6/24/94
B0C2Y7	U-234	0.603		0.149	0.036	pCi/g	D	11.0	10/8/91	6/24/94
B0C374	U-234	0.542		0.208	0.0958	pCi/g	D	33.1	1/27/92	6/29/94
B0C374	U-234	0.757		0.189	0.0792	pCi/g	N		1/27/92	7/14/94
B0C386	U-234	0.523		0.16	0.0563	pCi/g	D	21.8	10/11/91	6/28/94
B0C386	U-234	0.651		0.215	0.0873	pCi/g	N		10/11/91	6/28/94
B0C392	U-234	0.695		0.157	0.0328	pCi/g	D	18.5	9/30/90	6/24/94
B0C392	U-234	0.837		0.21	0.0561	pCi/g	N		9/30/90	6/24/94
B0C2W7	U-235	0.0262	J	0.0332	0.0473	pCi/g	D	81.7	10/9/90	7/18/94
B0C2W7	U-235	0.011	J	0.0264	0.0597	pCi/g	N		10/9/90	7/18/94
B0C2Y0	U-235	-0.003	J	0.00299	0.0492	pCi/g	D	256.6	10/3/91	6/23/94
B0C2Y0	U-235	0.0242	J	0.0298	0.0389	pCi/g	N		10/3/91	6/23/94
B0C2Y6	U-235	0.0383	J	0.0518	0.0833	pCi/g	N		10/8/91	6/24/94
B0C2Y7	U-235	0.0426		0.0343	0.034	pCi/g	D	10.6	10/8/91	6/24/94
B0C374	U-235	0.0274	J	0.0426	0.068	pCi/g	D	57.9	1/27/92	6/29/94
B0C374	U-235	0.0151	J	0.0271	0.0556	pCi/g	N		1/27/92	7/14/94
B0C386	U-235	0.035	J	0.0369	0.0416	pCi/g	D	26.7	10/11/91	6/28/94
B0C386	U-235	0.0458	J	0.0517	0.0718	pCi/g	N		10/11/91	6/28/94
B0C392	U-235	0.033		0.0289	0.031	pCi/g	D	21.1	9/30/90	6/24/94
B0C392	U-235	0.0408		0.0382	0.0385	pCi/g	N		9/30/90	6/24/94
B0C2W7	U-238	0.742		0.204	0.0631	pCi/g	D	5.4	10/9/90	7/18/94
B0C2W7	U-238	0.703		0.228	0.0652	pCi/g	N		10/9/90	7/18/94
B0C2X6	U-238	2.82	X	2.72	ND	pCi/g	D	84.1	10/1/91	7/8/94
B0C2X6	U-238	1.15		0.392	0.0554	pCi/g	N		10/1/91	6/22/94
B0C2Y0	U-238	0.948		0.237	0.046	pCi/g	D	10.0	10/3/91	6/23/94
B0C2Y0	U-238	0.858		0.213	0.0389	pCi/g	N		10/3/91	6/23/94
B0C2Y6	U-238	0.528		0.202	0.0673	pCi/g	N		10/8/91	6/24/94
B0C2Y7	U-238	0.661		0.158	0.034	pCi/g	D	22.4	10/8/91	6/24/94
B0C372	U-238	0.661	X	0.557	ND	pCi/g	D	15.7	11/20/91	6/22/94
B0C372	U-238	0.565	X	0.455	ND	pCi/g	N		11/20/91	6/13/94
B0C374	U-238	0.694		0.242	0.0842	pCi/g	D	2.4	1/27/92	6/29/94
B0C374	U-238	0.711	X	1.4	ND	pCi/g	N		1/27/92	6/22/94
B0C386	U-238	0.524		0.16	0.0514	pCi/g	D	3.7	10/11/91	6/28/94
B0C386	U-238	0.544		0.192	0.0634	pCi/g	N		10/11/91	6/28/94
B0C392	U-238	0.642		0.149	0.036	pCi/g	D	6.0	9/30/90	6/24/94
B0C392	U-238	0.682		0.183	0.0385	pCi/g	N		9/30/90	6/24/94

MDA = Minimum Detectable Activity
ND = Not Determined