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Technical Position Paper

on Use of TA-21 Process Area Baseline Data for RFI Reports

LA-UR 97-3393

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Summary:

Technical area (TA) 21 baseline data were collected and analyzed for inorganic, organic and radionuclide constituents. The baseline data are spatially grouped into the non-process area, the process area, and the special impact areas. The data groups were based on a post hoc review of the radionuclide results. This report quantitatively evaluates the process area baseline data to determine if these data should be used as local background data. The TA-21 process area baseline inorganic data are not significantly different from the Los Alamos National Laboratory (LANL) -wide inorganic background data. There are two recommendations relative to the baseline inorganic data. First, LANL-wide background for inorganic chemicals will be used to evaluate data collected from potential release sites (PRSs) in the non-process area, the process area or the special impact area. Second, the ER Project should consider adding the baseline inorganic data to the LANL-wide background data base, because the process area baseline include four analytes not included in the LANL-wide soil background data (lithium, molybdenum, selenium and strontium). The TA-21 process area baseline radionuclide data are elevated relative to LANL-wide background. Thus, to better identify and bound releases from PRSs in the process area, radionuclide upper tolerance limits (UTLs) were calculated from the process area baseline data. The UTL is the upper 95% confidence limit of the 95th percentile. The process area radionuclide data include total uranium, americium-241, plutonium-238, plutonium-239, strontium-90, thorium-228, thorium-230, thorium-232, tritium, and uranium.

Introduction:

Baseline data were collected as a part of the TA-21 Resource Conservation and Recovery Act (RCRA) Facility Investigation (RFI) (LANL 1994, 1259). The process area baseline inorganic and radionuclide data are presented in Appendix A. The purpose of these baseline or local background data was to help distinguish PRS releases from the general elevated concentrations of certain constituents. This report evaluates the inorganic and radionuclide baseline data to determine whether baseline or LANL-wide background data should be used in RFI data assessment. There was only one organic chemical, fluoranthene, detected in one process-area Baseline sample. Because of the low detection frequency of organic chemicals, no statistical analyses were performed on these data.

Comparison of Inorganic Results:

Inorganic results were obtained by one of two sets of methods for the TA-21 baseline data. One extraction method resulted in a measurement of the "whole-rock" concentration of inorganics. This

total extraction method is not comparable to the typical inorganic extraction method (EPA 1992, 1207). All LANL-wide background data also include both total sample extraction and standard EPA extraction results, but only the standard EPA extraction results for the LANL-wide background data are presented in these comparisons. Because soil horizons were not reported for the TA-21 baseline data, the combined soil horizon (A, B, and C) LANL-wide background data were used.

Some of the inorganic results are reported as less than the detection limit (<DL). To facilitate statistical analysis of the data, all values reported as <DL were replaced by one-half of the detection limit. This replacement approach is recommended in the Environmental Protection Agency (EPA) risk assessment guidance (EPA 1992, 1166).

The TA-21 Baseline total and standard EPA extraction method data are graphically compared to the all soil horizon LANL-wide background data measured by the standard EPA extraction method (see Figures 1 to Figure 25). The graphical data presentation is through box plots which show the actual values (as squares) for each data group. The ends of the box represent the "inter-quartile" range of the data distribution. The inter-quartile range is specified by the 25th percentile and 75th percentile of the data distribution. The line within the box plot is the median (50th percentile) of the data distribution. Thus the box indicates concentration values for the central half of the data, and concentration shifts can be readily assessed by comparing the boxes. If the majority of the data is represented by a single concentration value (usually the detection limit), the box is reduced to a single line. The box plots show the overall arithmetic average of the data groups (as a dotted line)), which also helps to determine if there are differences between the data groups.

Statistical comparisons, using the Wilcoxon rank sum test [see Ryti et al. 1996, 1298) for description of this test], were made between the process area baseline and LANL-wide background data measured by the standard EPA extraction method (results are summarized in Table 1). There are two inorganics, calcium and zinc, for which the baseline data are significantly greater than the LANL-wide background data. Although there is a statistical difference between the average calcium baseline and LANL-wide results, the baseline results are within the range of results reported for the LANL-wide data. There are six values greater than the all soil horizon UTL, and one baseline sample was three times the LANL-wide zinc UTL (50.3 mg/kg). However, this difference is not significant in relation to the zinc screening action level (SAL) of 23 000 mg/kg. Thus, there are no differences of concern between the inorganic baseline data and the LANL-wide soil background data.

There are four inorganics, lithium, molybdenum, selenium and strontium, which were not included on the analyte list for the LANL-wide background soil samples. The summary statistics for these four inorganics are summarized in Table 2. Process area baseline upper tolerance limit (UTL) values were calculated for lithium, molybdenum, selenium and strontium (see Table 2). For these elements, we calculated parametric tolerance limits using the following equation:

$$UTL_{0.95,0.95} = \text{mean} + \text{standard deviation} * k_{0.95,0.95}$$

The k-factor depends on the number of background samples; complete tables of k-factors are published in the RCRA ground water statistical analysis document (EPA 1989, 1141) and Gilbert (1987, 0312). Readers are referred to the LANL Environmental Restoration (ER) Project policy paper on background comparisons for example k-factors (Ryti et al. 1996, 1298).

Because no important differences were detected between the baseline and LANL-wide background inorganic data, the LANL-wide background data shall be used in all future TA-21 RFI Reports. The LANL-wide background soil data may be supplemented by the process area baseline data for lithium, molybdenum, selenium and strontium. The LANL-wide inorganic background data has the following advantages:

- Extraction and analysis methods consistent with those used for RFI data;
- Larger number of samples, which better estimate statistical parameters, including UTLs; and,
- LANL-wide background data can be segregated by soil horizon and other geologic strata to make more defensible comparisons.

No formal statistical comparisons were made between the subsets of Baseline collected to characterize the non-process and special impact areas. The statistical comparisons for the process area were judged to be representative of local background conditions at TA-21, and therefore no additional inorganic chemical statistical comparisons were warranted.

Comparison of Radionuclide Results:

Elevated ambient radionuclide concentrations in the soils around TA-21 are the primary reason for collecting local "background" or the TA-21 baseline data. Stack releases are known for several radionuclides in the process area. Thus, given the historical information on activities within the TA-21 process area, a formal statistical comparison between baseline and background is not needed. A data summary is presented to show the range in concentrations measured at the process area baseline sampling locations (Table 3). Included in this data summary is the background screening

value used for the radionuclides at other LANL TAs and the number of baseline samples where the LANL-wide radionuclide background screening values are exceeded. The number of baseline samples greater than the LANL-wide background screening values is presented as a simple comparison of the baseline to LANL-wide background data.

Use of the baseline data has the following advantages:

- The radionuclide baseline data includes more constituents than the LANL-wide background data (thorium isotopes).
- The LANL-wide background data is based on the Environmental Surveillance perimeter and regional sampling stations, and is most relevant for fallout-related radionuclides (Environmental Restoration Project Decision Support Council and Earth Science Council, Environmental Restoration Records Processing Facility ID No. 56186).
- Use of baseline data will help to distinguish releases from specific PRSs at TA-21 from more widespread elevated radionuclide concentrations.

Calculation of Radionuclide Baseline Screening Values:

There are three steps to calculating radionuclide baseline screening values. First, elevated baseline radionuclide values that can be attributed to a specific PRS are eliminated from the baseline data. Second, the statistical data distribution for each radionuclide is estimated. Third, UTLs are estimated for radionuclides where either a lognormal or normal statistical distribution fit the baseline data. The UTL is the upper 95% confidence limit of the 95th percentile. The baseline screening values are based on the UTLs calculated for the TA-21 baseline data distributions. For radionuclides where the data distribution does not fit a lognormal or normal statistical data distribution, the maximum detected value for the radionuclide is used as a baseline screening value.

There are two TA-21 baseline sampling locations where elevated values of certain radionuclides have been related to PRS-specific releases. These locations are summarized in Table 4, and the radionuclide values eliminated from the TA-21 baseline data are also noted in Table 4.

The statistical distributions were estimated through graphical review of untransformed and log-transformed baseline radionuclide data. Figures 26 to 37 present the graphical statistical analysis of the process area radionuclide data after the outliers identified above were excluded. The graphical analysis of the data include frequency histograms, outlier box plots, and normal quantile plots. If data are normally distributed, the value corresponding to the "0" quantile is equal to the mean, the data are linear on the normal quantile scale, and the slope is the standard deviation.

Deviations from linearity on the normal quantile plot are strong evidence that the data are not normally distributed. Normally distributed data presented in a frequency histogram format have the well-known "bell-shaped" curve shape. The outlier box plot is useful in identifying values that do not fit within a normal statistical distribution. Table 5 summarizes the conclusions of this graphical analysis for each process area radionuclide.

UTLs were calculated for all baseline radionuclides except uranium and uranium isotopes. Uranium has an unusual distribution, which does not allow use of a simple statistical distribution model. This unusual statistical distribution may be a "mixture" distribution, where one underlying distribution represents natural background and another distribution represents wide-spread releases. Therefore, we propose to use the maximum detected value as a baseline screening value for uranium.

For the elements that are normally distributed without any data transformation, we calculated parametric tolerance limits using the following equation:

$$UTL_{0.95,0.95} = \text{mean} + \text{standard deviation} * k_{0.95,0.95} \quad (1)$$

The k-factor depends on the number of background samples; complete tables of k-factors are published in the RCRA ground water statistical analysis document (EPA 1989, 1141) and Gilbert (1987, 0312). Readers are referred to the LANL Environmental Restoration (ER) Project policy paper on background comparisons for example k-factors (Ryti et al. 1996, 1298).

The UTLs for lognormally distributed elements were estimated by a simulation process. These simulations were run in the S-plus statistical programming environment. The S-plus code is presented in Appendix B. These simulations were run for 10 000 trials, which were sufficient to estimate the lognormal UTLs to two or three significant digits.

The statistics representing the baseline radionuclides are summarized in Table 6. The UTLs will be used as baseline screening values for all radionuclides, except uranium and uranium isotopes. The maximum detected uranium value (10.7 mg/kg) will be used as the baseline screening value for total uranium. Because not every sample was analyzed for isotopic uranium as well as total uranium, there are no isotopic uranium results for this sample (Sample ID = AAA0153). This lack of isotopic uranium data for highest total uranium results, as well as the small number of samples, precludes the calculation of a UTL directly from isotopic uranium data. Because natural, enriched or depleted uranium may have been was used at TA-21, isotopic abundance of the uranium

isotopes were not estimated. Thus, baseline screening values for isotopic uranium are not available, and all process area baseline comparisons for uranium must be made to total uranium. Readers should pay careful attention to the LANL screening action levels presented in Table 7 for natural, depleted and enriched uranium. In particular, the enriched uranium screening action level is within both the LANL-wide and process area baseline total uranium background. Unless enriched uranium can be eliminated based on process knowledge, additional evaluation of total uranium is warranted. One such analysis is isotopic analysis to document the type of uranium associated with a PRS. Another option is a presentation of the estimated dose under the worst-case assumption of enriched uranium isotopic abundances.

The proposed radionuclide baseline screening values are listed in Table 7, which also presents the LANL-wide radionuclide background screening values and LANL screening action levels for comparison. One radionuclide, which is included in the LANL-wide background data and was not analyzed in the process area baseline data is cesium-137. We propose to use the LANL-wide cesium-137 background screening value for PRSs within the process area. Also note that the tritium baseline and LANL-background data units are presented in pCi/ml of soil moisture. This tritium screening value will require conversion before it can be compared to PRS tritium presented in units of soil mass (pCi/g).

Conclusions:

The process area baseline radionuclide data will provide a useful starting point for determining if releases have occurred from TA-21 PRSs in the process area. Except for this use of baseline data, all other comparisons of inorganics and naturally occurring radionuclides will be made between the appropriate subset of the LANL-wide background soil, bedrock or sediment data. Specifically, the previously defined special impact areas will not be treated differently than other parts of the process area.

References:

Environmental Restoration Project Decision Support Council and Earth Science Council. 1997. Application of LANL Background Data to ER Project Decision-Making Part II: Radionuclides in Soils, Sediments, and Tuff. Los Alamos National Laboratory, Environmental Restoration Records Processing Facility ID No. 56186, June 30, 1997 (Environmental Restoration Project Decision Support Council and Earth Science Council, Environmental Restoration Records Processing Facility ID No. 56186)

EPA (US Environmental Protection Agency), April 1989. "Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities. Interim Final Guidance," Office of Solid Waste, Waste Management Division, US Environmental Protection Agency, Washington DC. (EPA 1989, 1141)

EPA (US Environmental Protection Agency), April 1992. "Guidance for Data Useability in Risk Assessment (Part A)," Office of Emergency Remedial Response, US Environmental Protection Agency, Washington DC. (EPA 1992, 1166)

EPA (US Environmental Protection Agency), July 1992. "Test Methods for Evaluating Solid Waste, Physical/Chemical Methods," SW-846, Third Edition, Final Update 1, Office of Solid Waste and Emergency Response, Washington, DC. (EPA 1992, 1207)

Gilbert, R.O., 1987. Statistical Methods for Environmental Pollution Monitoring. Von Nostrand Reinhold Company Inc. New York. 320 pp. (Gilbert 1987, 0312)

LANL (Los Alamos National Laboratory), January 28, 1994. "Phase Report 1B, TA-21 Operable Unit RCRA Facility Investigation, Operable-Unit-Wide Surface Soil, Deposition Layer and Filter Building Investigation " Los Alamos National Laboratory Report LA-UR-93-4390, Los Alamos, New Mexico. (LANL 1994, 1259)

Ryti, R., P. Longmire, and E. McDonald, March 1996. "Application of LANL Background Data to ER Project Decision-Making Part I: Inorganics," Los Alamos National Laboratory Report LA-UR-96-1534, Los Alamos, New Mexico. (Ryti et al. 1996, 1298)

TABLE 1
SUMMARY OF STATISTICAL COMPARISONS OF BASELINE TO BACKGROUND DATA

Inorganic Chemical	Comparison of Baseline Data to LANL-wide Background Data as Measured by the Standard EPA Extraction and Analysis Procedure for Inorganics
Aluminum	Baseline data are not greater than LANL-wide background UTL
Arsenic	Baseline data are not greater than LANL-wide background UTL
Barium	Baseline data are not greater than LANL-wide background UTL
Beryllium	Baseline data are not greater than LANL-wide background UTL
Cadmium	All baseline values are less than the maximum detected background value of 2.7 mg/kg.
Calcium	Baseline data are marginally greater than background data (p=0.048), although the baseline data fall in the range of background values.
Chromium	Baseline data are not greater than LANL-wide background UTL
Cobalt	Baseline data are not greater than LANL-wide background UTL
Copper	Baseline data are not statistically greater than LANL-wide background. An outlier of 131 mg/kg was measured in the totals baseline data.
Iron	Baseline data are not greater than LANL-wide background
Lead	Baseline data are not statistically greater than LANL-wide background. Two outliers (46.7 and 53 mg/kg), values greater than the background UTL were measured in the standard extraction and analysis method baseline data.
Lithium	No background data exist for lithium.
Magnesium	Baseline data are not greater than LANL-wide background UTL
Manganese	Baseline data are not greater than LANL-wide background UTL
Molybdenum	No background data exist for molybdenum, and no detects were reported in the standard EPA extraction/analysis data.
Nickel	Baseline data are not statistically greater than LANL-wide background. An outlier of 49200 mg/kg was measured in the totals baseline data.
Potassium	Baseline data are not greater than LANL-wide background.
Selenium	No comparable background data exist for selenium.
Silver	No comparable background data exist for silver, and silver was not detected in the baseline data.
Sodium	Baseline data are not greater than LANL-wide background UTL.
Strontium	No background data exist for strontium.
Thallium	No detects in either the baseline or background data.
Vanadium	Baseline data are not greater than LANL-wide background.
Zinc	Baseline values are statistically significantly greater than background. Six outliers (55.4, 57.5, 59.7, 68.6, 89.6 and 153 mg/kg), values greater than the background UTL were measured in the standard extraction and analysis method baseline data.

TABLE 2
SUMMARY OF STATISTICAL PARAMETERS FOR BASELINE INORGANICS THAT ARE NOT INCLUDED IN THE LANL-WIDE BACKGROUND SOIL DATA

Inorganic Chemical	Minimum (mg/kg)	Median (mg/kg)	Maximum (mg/kg)	Mean (mg/kg)	Std Dev (mg/kg)	N	$UTL_{95,95}$ (mg/kg)
Lithium	3.8	7.7	18	9.20	4.23	12	20.8
Molybdenum	1.1	1.15	1.4	1.17	0.078	12	<2.8 *
Selenium	0.155	0.16	0.33	0.175	0.050	12	0.311
Strontium	8.5	19.7	47.2	22.6	10.8	12	52.1

Note - statistical parameters include non-detects where one-half of the detection limit is used to calculate these parameters.
* No detects were reported, and the maximum non-detect is reported.

TABLE 3
SUMMARY OF PROCESS AREA BASELINE RADIONUCLIDE DATA

Radionuclide (pCi/g) unless noted otherwise	Number of Baseline Samples	Baseline Minimum (pCi/g)	Baseline Maximum (pCi/g)	LANL-wide screening value (pCi/g)	Number of Baseline Values > LANL-wide screening Value
Americium-241	22	0.015	1.235	0.013	22
Plutonium-238	43	0.002	18.66	0.023	18
Plutonium-239	43	0.034	47.74	0.054	41
Strontium-90	43	-0.3	1.0	1.31	0
Thorium-228	15	0.81	1.62	NA	NA
Thorium-230	15	1.04	1.48	NA	NA
Thorium-232	15	0.88	1.52	2.47	0
Tritium (pCi/ml)	43	0.3	12.5	0.77	41
Uranium (total in mg/kg)	43	3.1	27	5.45	7
Uranium-234	13	1.19	11.1	1.94	2
Uranium-235	13	0.05	0.443	0.084	6
Uranium-238	13	0.82	8.26	1.82	1

NA - not available in the LANL-wide background data.

TABLE 4
SUMMARY OF ELEVATED BASELINE RADIONUCLIDE RESULTS *

Location ID	Related to SWMU	Elevated Radionuclides
21-1079	Septic System SWMU 21-024(e)	Plutonium-239 = 47.74 pCi/g Uranium - total = 27 mg/kg Uranium-234 = 11.1 pCi/g Uranium-235 = 0.443 pCi/g Uranium-238 = 8.26 pCi/g
21-1086	Old Filter Building Bldg 21-228	Plutonium-238 = 18.66 pCi/g

* These values were excluded from the Baseline data before analyzing statistical distributions or calculating UTLs.

TABLE 5
SUMMARY OF STATISTICAL DISTRIBUTION ANALYSIS OF BASELINE RADIONUCLIDE DATA

Radionuclide	Statistical Distribution Analysis
Americium-241	Data fit a lognormal statistical distribution
Plutonium-238	Data fit a lognormal statistical distribution
Plutonium-239	Data fit a lognormal statistical distribution
Strontium-90	Data fit a normal statistical distribution
Thorium-228	Data fit a normal statistical distribution
Thorium-230	Data fit a normal statistical distribution
Thorium-232	Data fit a normal statistical distribution
Tritium (pCi/ml)	Data fit a lognormal statistical distribution
Uranium (total in mg/kg)	Data fit neither a normal nor lognormal statistical distribution. The maximum detected total uranium value will be used as the background screening value.
Uranium-234	Data fit a normal statistical distribution
Uranium-235	Data fit a normal statistical distribution
Uranium-238	Data fit a normal statistical distribution

TABLE 6
SUMMARY OF STATISTICAL PARAMETERS FOR BASELINE RADIONUCLIDES

Radionuclide	Minimum (pCi/g*)	Median (pCi/g*)	Maximum (pCi/g*)	Mean (pCi/g*)	Std Dev (pCi/g*)	N	$UTL_{95,95}$ (pCi/g*)
Americium-241	0.015	0.1065	1.235	0.21	0.305	22	0.818
Plutonium-238	0.002	0.019	0.932	0.1	0.221	42	0.447
Plutonium-239	0.034	0.829	14.837	2.29	3.559	42	15.5
Strontium-90	-0.3	0.1	1	0.137	0.298	43	0.766
Thorium-228	0.81	1.41	1.62	1.335	0.253	15	1.98
Thorium-230	1.04	1.3	1.48	1.271	0.129	15	1.6
Thorium-232	0.88	1.37	1.52	1.317	0.211	15	1.86
Tritium (pCi/ml)	0.3	2.5	12.5	2.96	2.46	43	9.92
Uranium (total in mg/kg)	3.1	4.41	10.7	4.73	1.373	42	NC
Uranium-234	1.19	1.51	2.53	1.58	0.354	13	NC
Uranium-235	0.05	0.076	0.095	0.08	0.014	13	NC
Uranium-238	0.82	1.38	1.77	1.39	0.26	13	NC

NC - Not calculated, the maximum will be used as a baseline screening value.
* Unless otherwise noted.

TABLE 7
SUMMARY OF BASELINE RADIONUCLIDE SCREENING VALUES

Radionuclide	Screening Action Level (pCi/g*) a	Baseline Screening Value (pCi/g*)	Background Screening Value (pCi/g*)
Americium-241	22	0.818	0.013
Cesium-137	5.1	NA b	1.65
Plutonium-238	27	0.447	0.014
Plutonium-239	24	15.5	0.052
Strontium-90	4.4	0.766	1.31
Thorium-228	1.7	1.98	2.28
Thorium-230	0.18	1.60	2.29
Thorium-232	0.77	1.86	2.33
Tritium (pCi/ml) c	260 d	9.92	0.77
Uranium (total in mg/kg)	29 e 130 f 1.9 g	10.7 h	5.45

* Unless otherwise noted.
NA - not available.
a - Radiological SALs from LANL Facility for Information Analysis and Display (FIMAD) data table, Oct. 1995 revision.
b - The LANL-wide background screening values for cesium-137 will be used for TA-21 process area PRS comparisons.
c - units are pCi/ml soil moisture, to convert to pCi/g, use the following equation; UTL(per unit mass) = UTL(per unit moisture) * m / (100-m), where m=per cent soil moisture of sample
d - Units are pCi/g.
e - Based on isotopic abundance of natural uranium.
f - Based on isotopic abundance of depleted uranium.
g - Based on isotopic activity of enriched uranium (91% U-234, 5% U-235, 4% U-238).
h - Maximum value, not a calculated UTL.

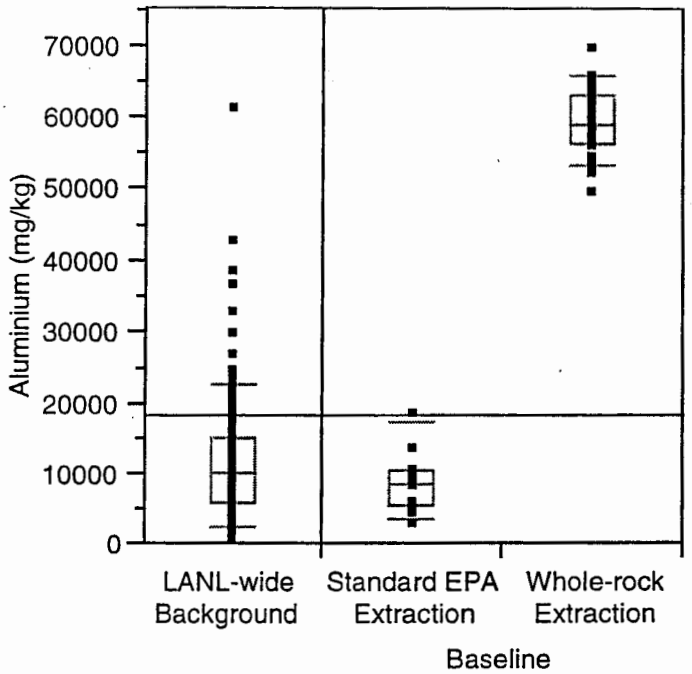

Figure 1. Comparison of the aluminum results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

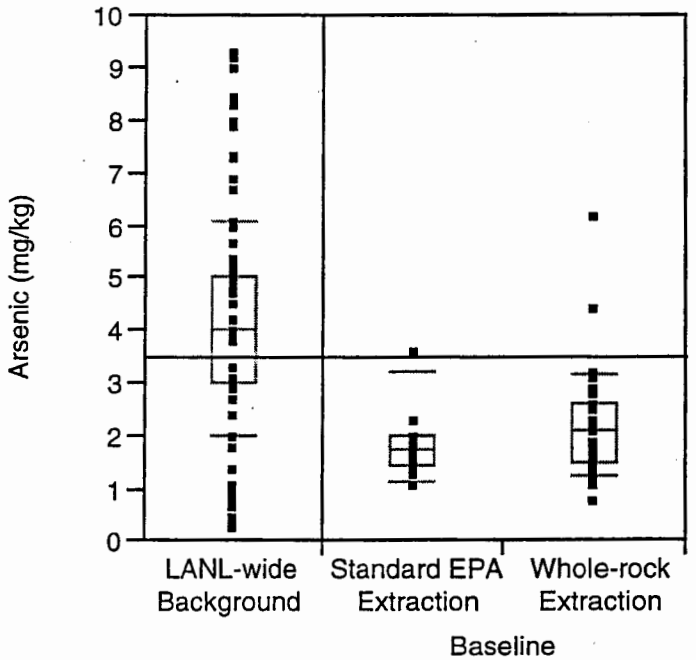

Figure 2. Comparison of the arsenic results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

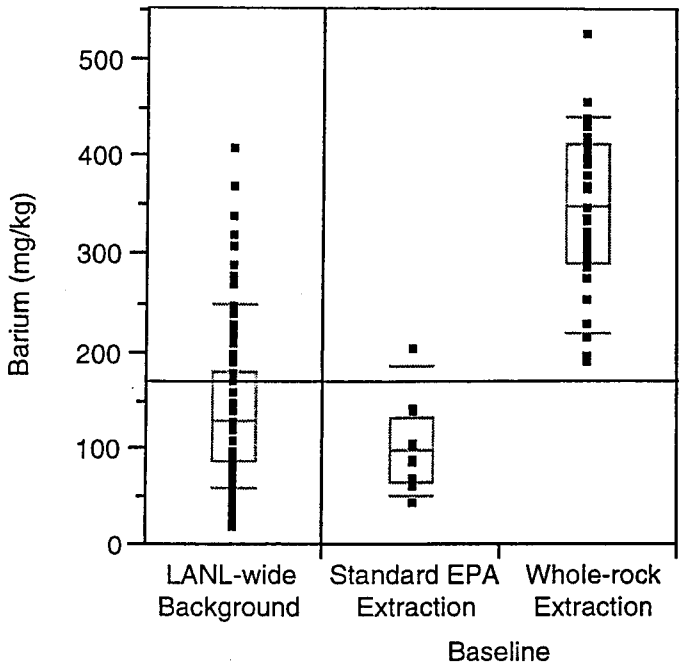

Figure 3. Comparison of the barium results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

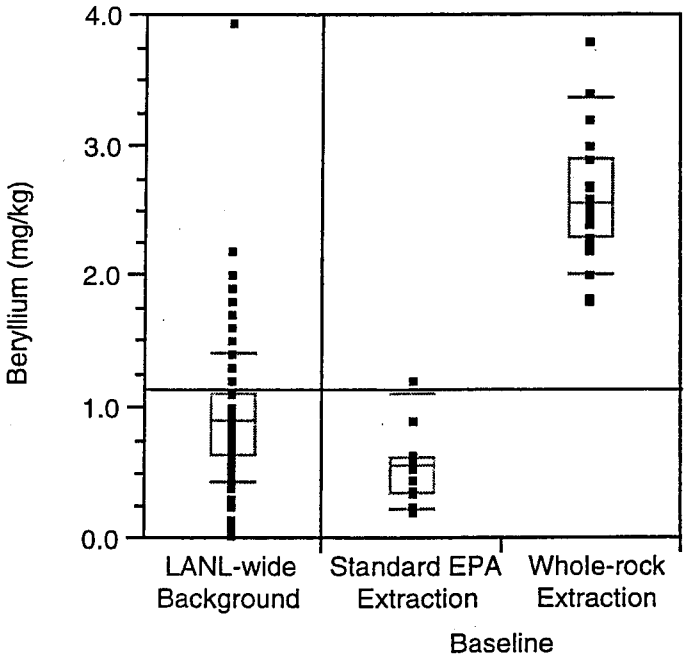

Figure 4. Comparison of the beryllium results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

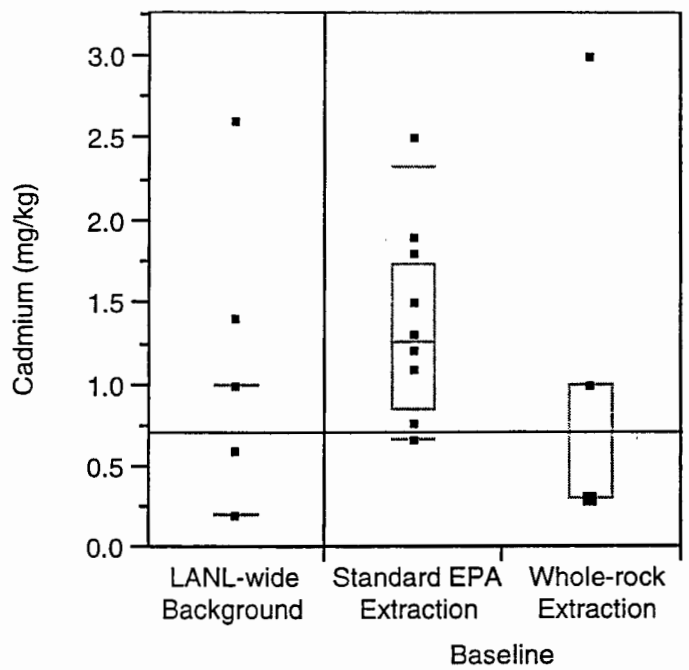

Figure 5. Comparison of the cadmium results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

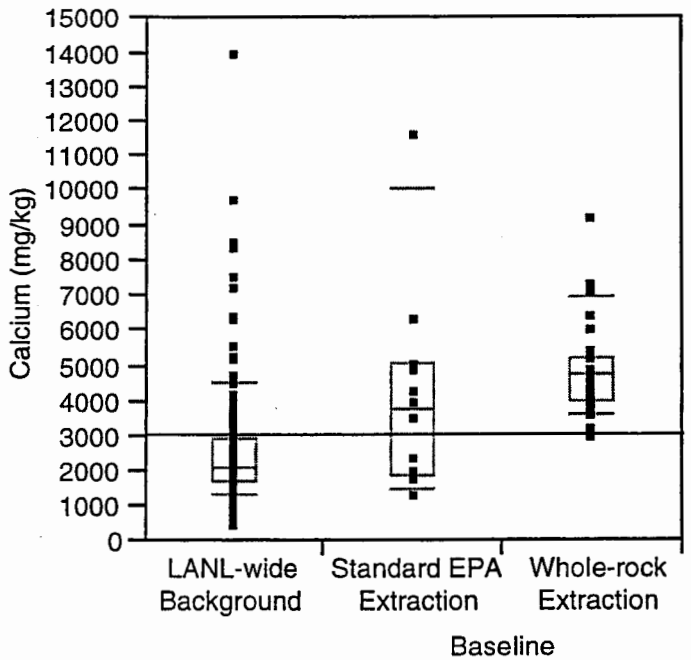

Figure 6. Comparison of the calcium results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

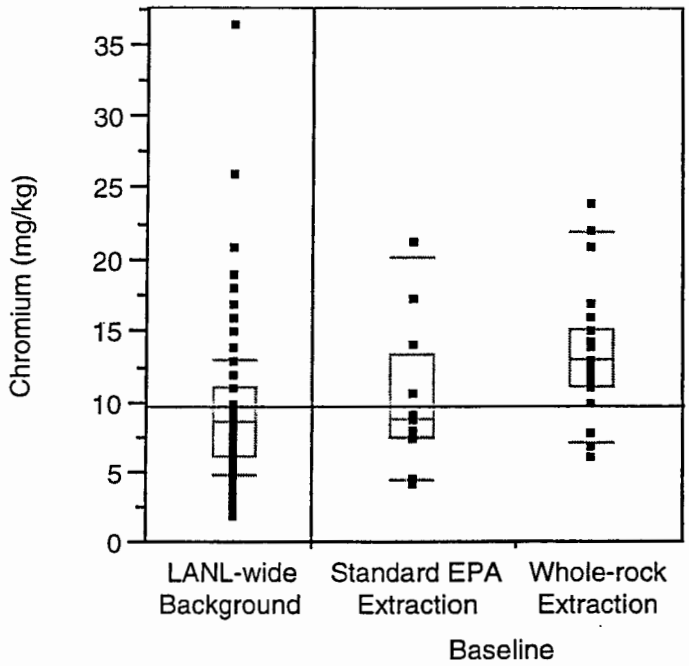

Figure 7. Comparison of the chromium results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

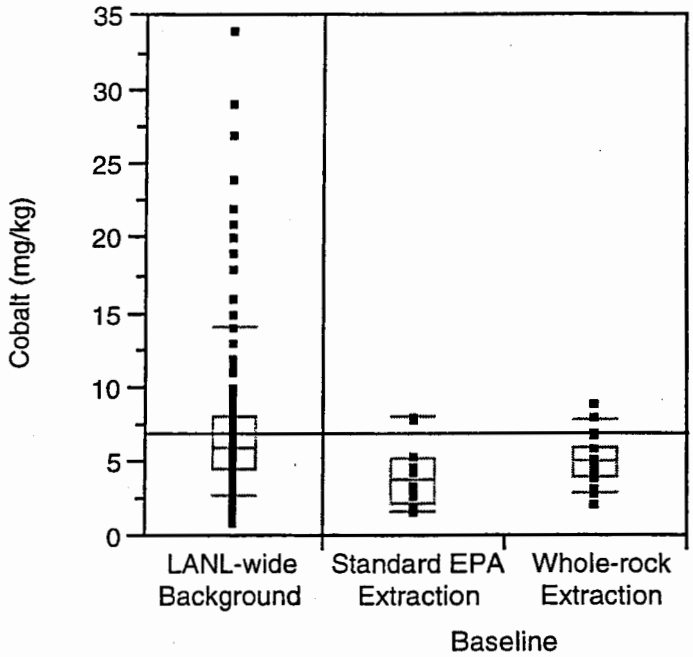

Figure 8. Comparison of the cobalt results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

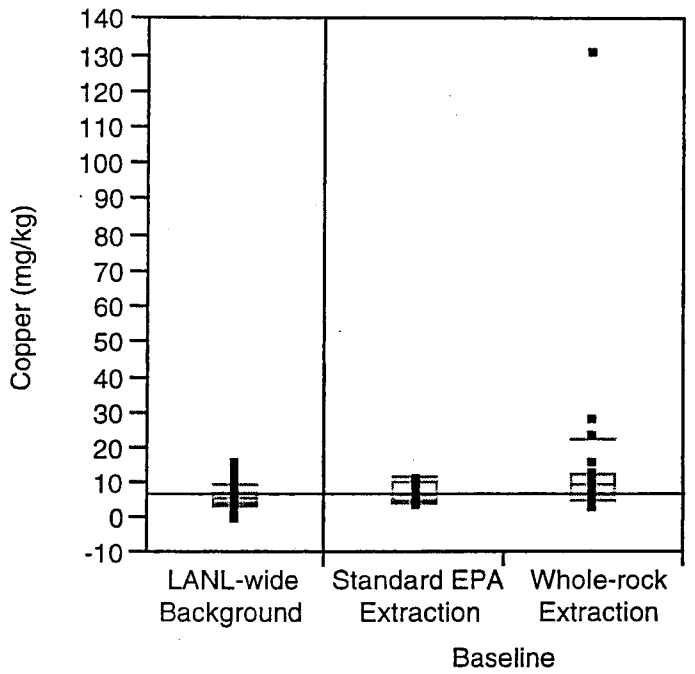

Figure 9. Comparison of the copper results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

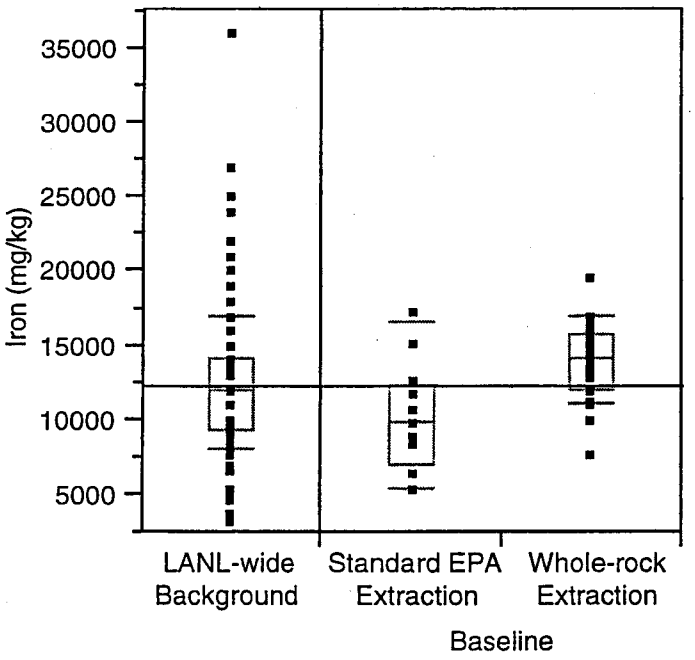

Figure 10. Comparison of the iron results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

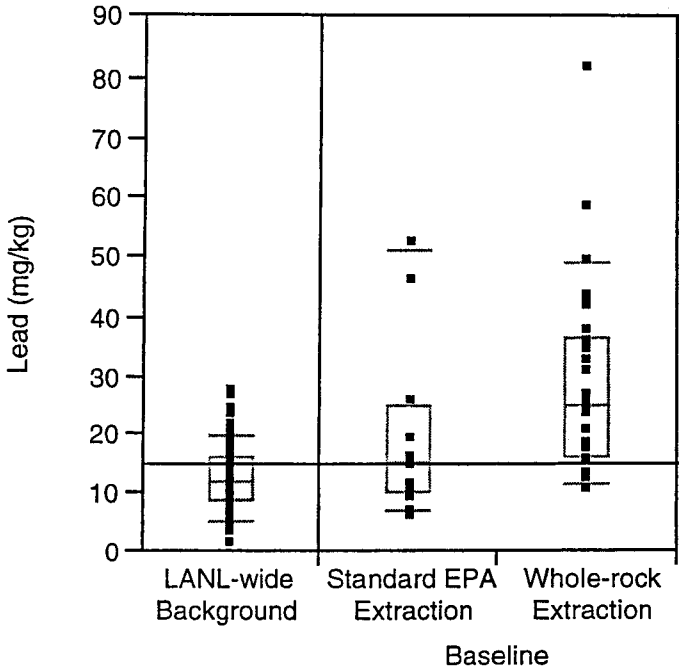

Figure 11. Comparison of the lead results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). Two TA-21 nitric acid leachable results are greater than the range of the LANL background soil data.

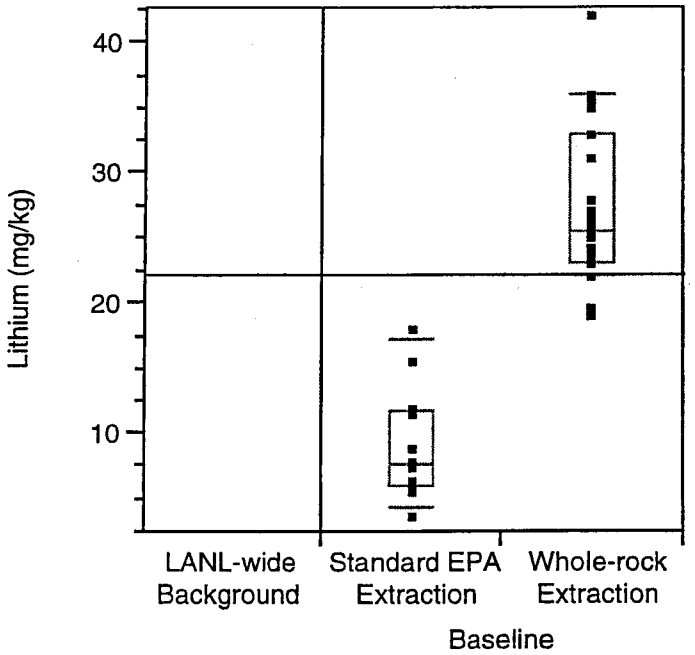

Figure 12. Comparison of the lead results for the TA-21 baseline data (nitric acid leachable or total sample analysis). There is no LANL-wide selenium background soil data.

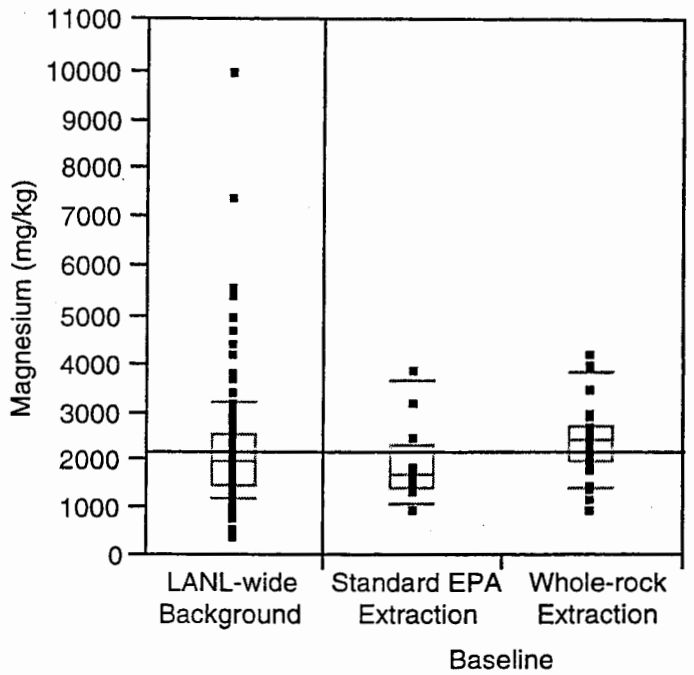

Figure 13. Comparison of the magnesium results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

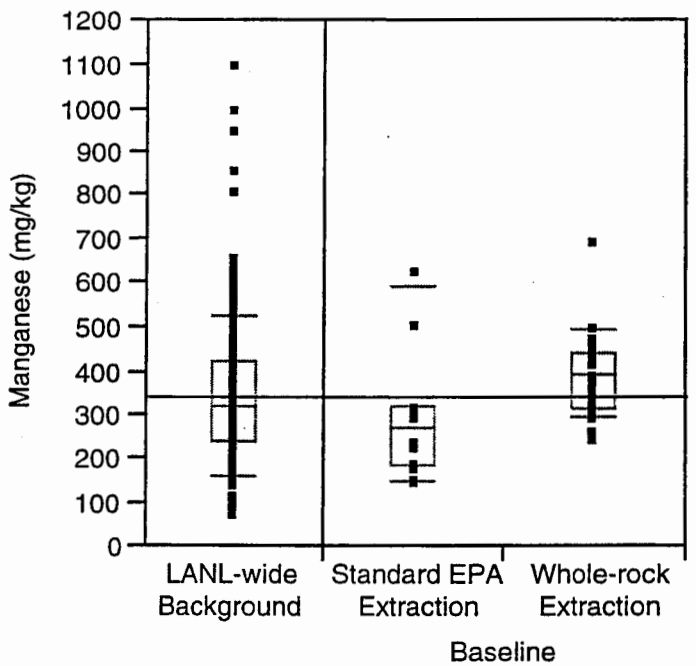

Figure 14. Comparison of the manganese results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

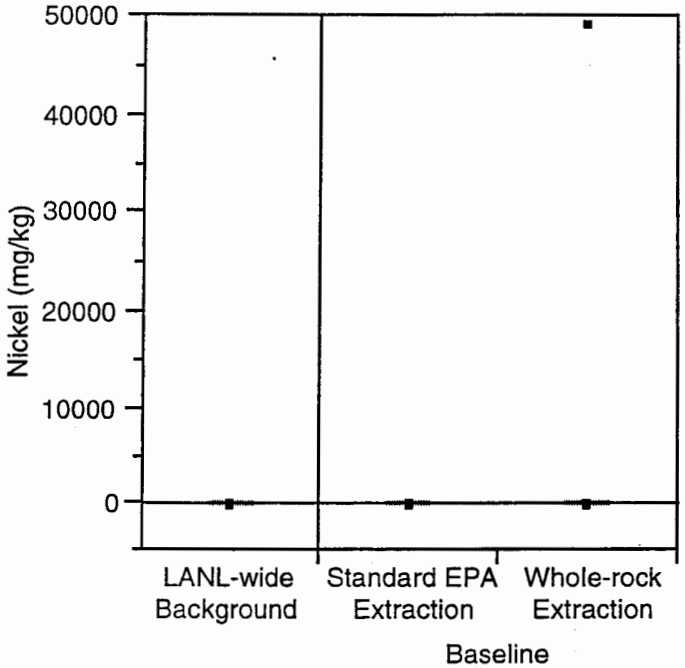

Figure 15. Comparison of the nickel results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

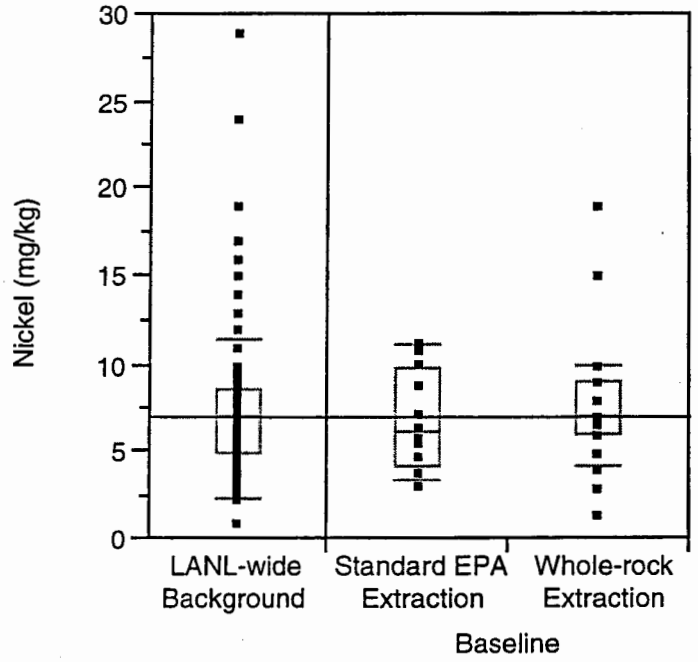

Figure 16. Comparison of the nickel results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The outlier in the whole-rock analysis was excluded. The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

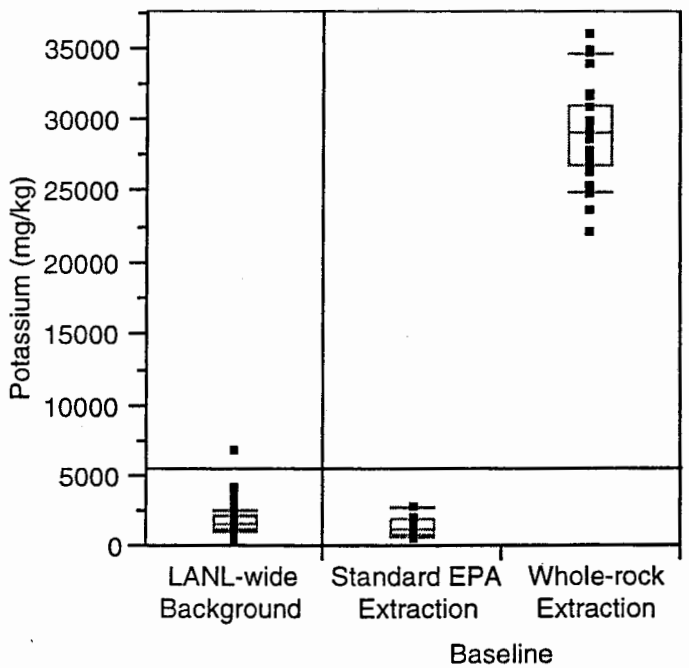

Figure 17. Comparison of the potassium results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

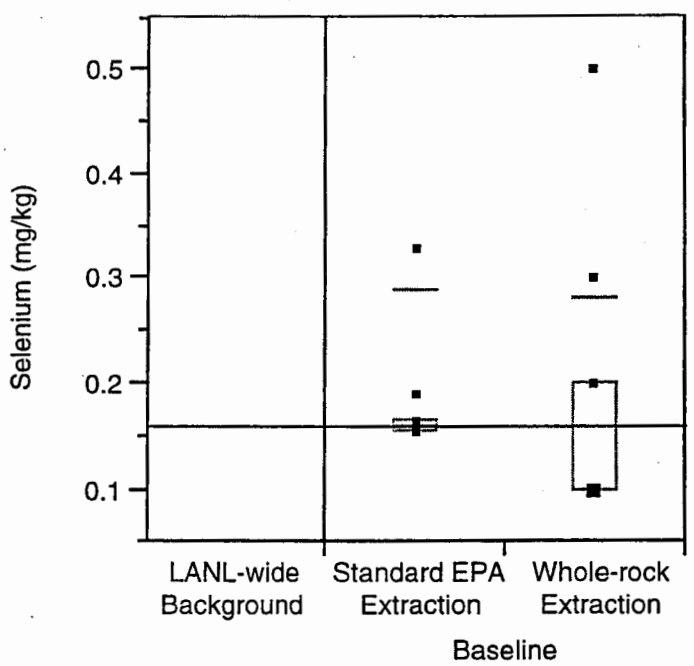

Figure 18. Comparison of the selenium results the TA-21 baseline data (nitric acid leachable or total sample analysis). There is no LANL-wide selenium background soil data.

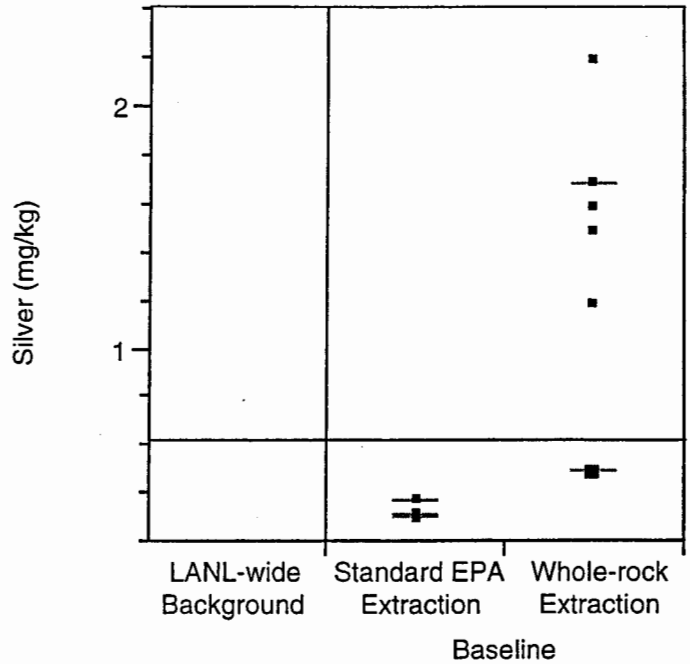

Figure 19. Comparison of the silver results for the TA-21 baseline data (nitric acid leachable or total sample analysis). There is no LANL-wide silver background soil data.

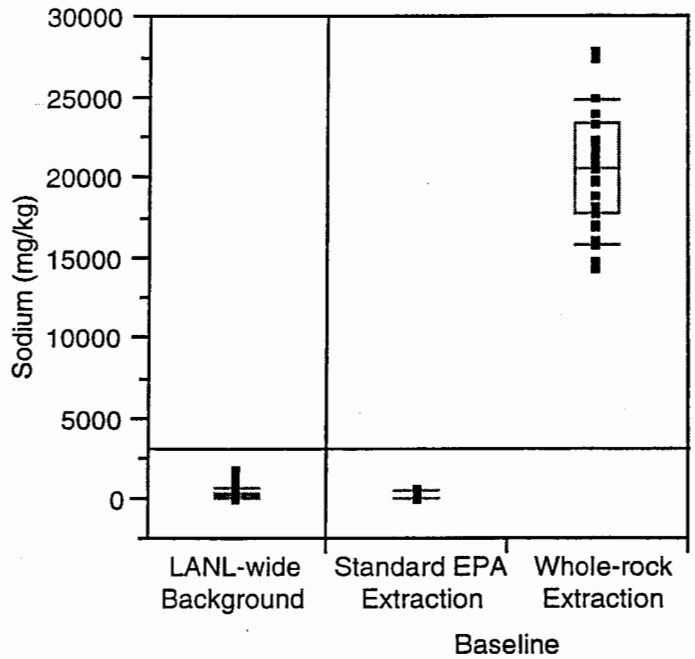

Figure 20. Comparison of the sodium results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

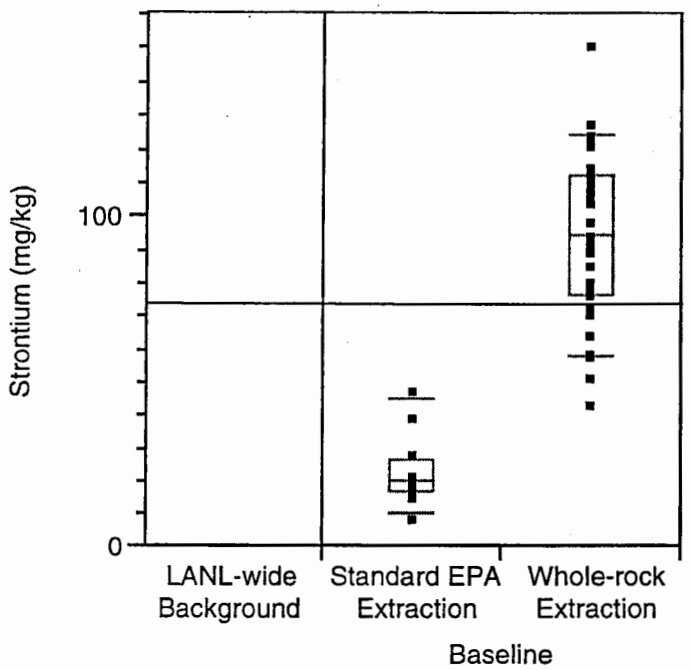

Figure 21. Comparison of the strontium results for the TA-21 baseline data (nitric acid leachable or total sample analysis). There is no LANL-wide strontium background soil data.

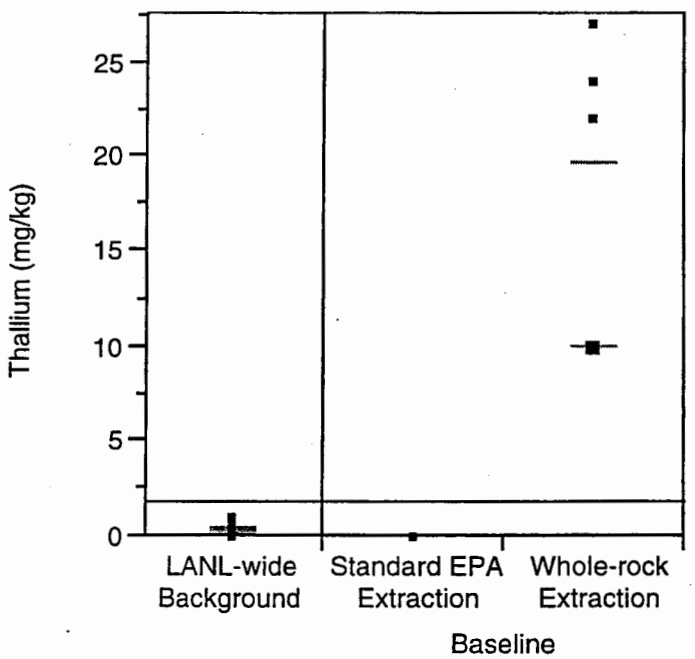

Figure 22. Comparison of the thallium results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

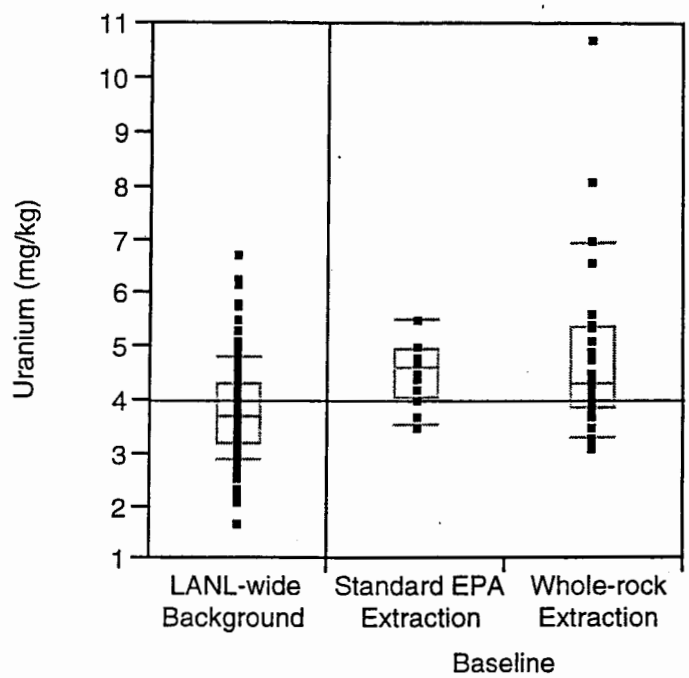

Figure 23. Comparison of the uranium results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

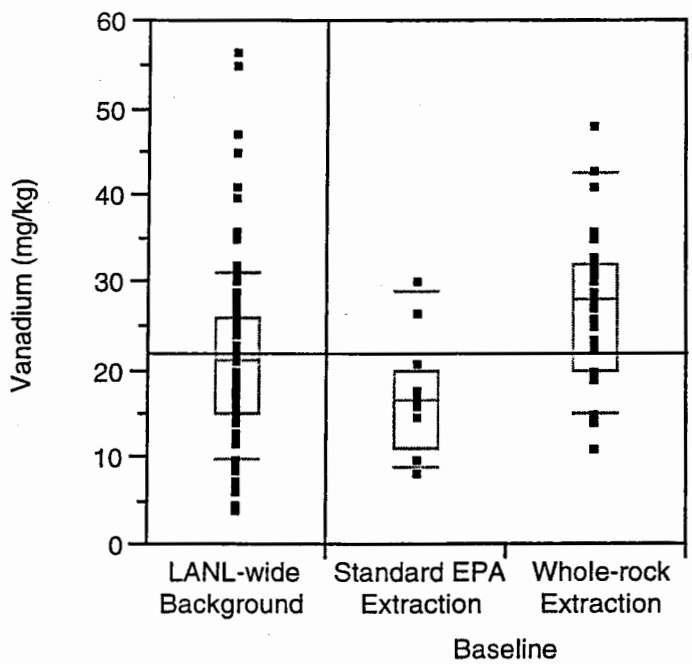

Figure 24. Comparison of the vanadium results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). The TA-21 nitric acid leachable results are within the range of the LANL background soil data.

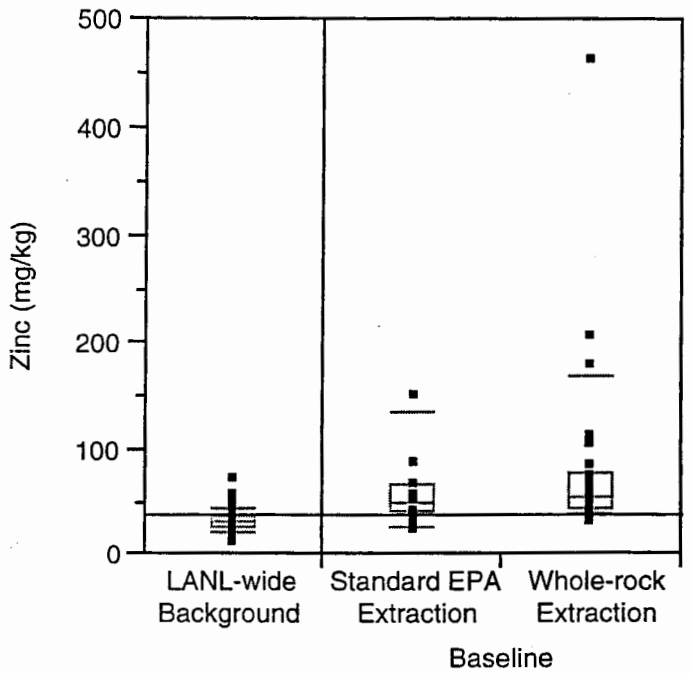

Figure 25. Comparison of the zinc results for the LANL combined soil background data (nitric acid leachable) versus the TA-21 baseline data (nitric acid leachable or total sample analysis). There are six TA-21 nitric acid leachable results above the LANL background soil UTL.

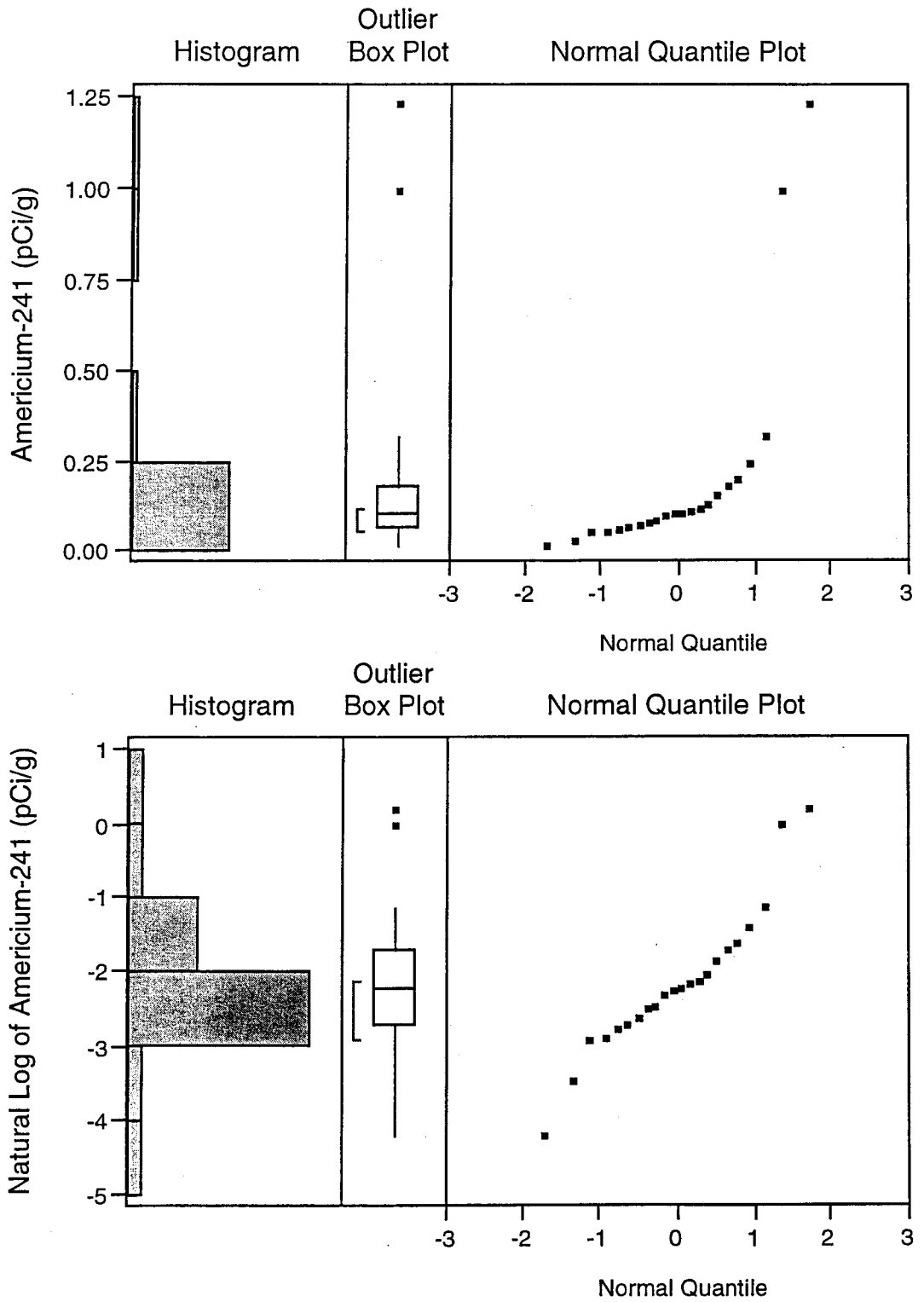

Figure 26. Distribution plots for americium-241 (in pCi/g) and log-transformed americium-241 process area baseline data.

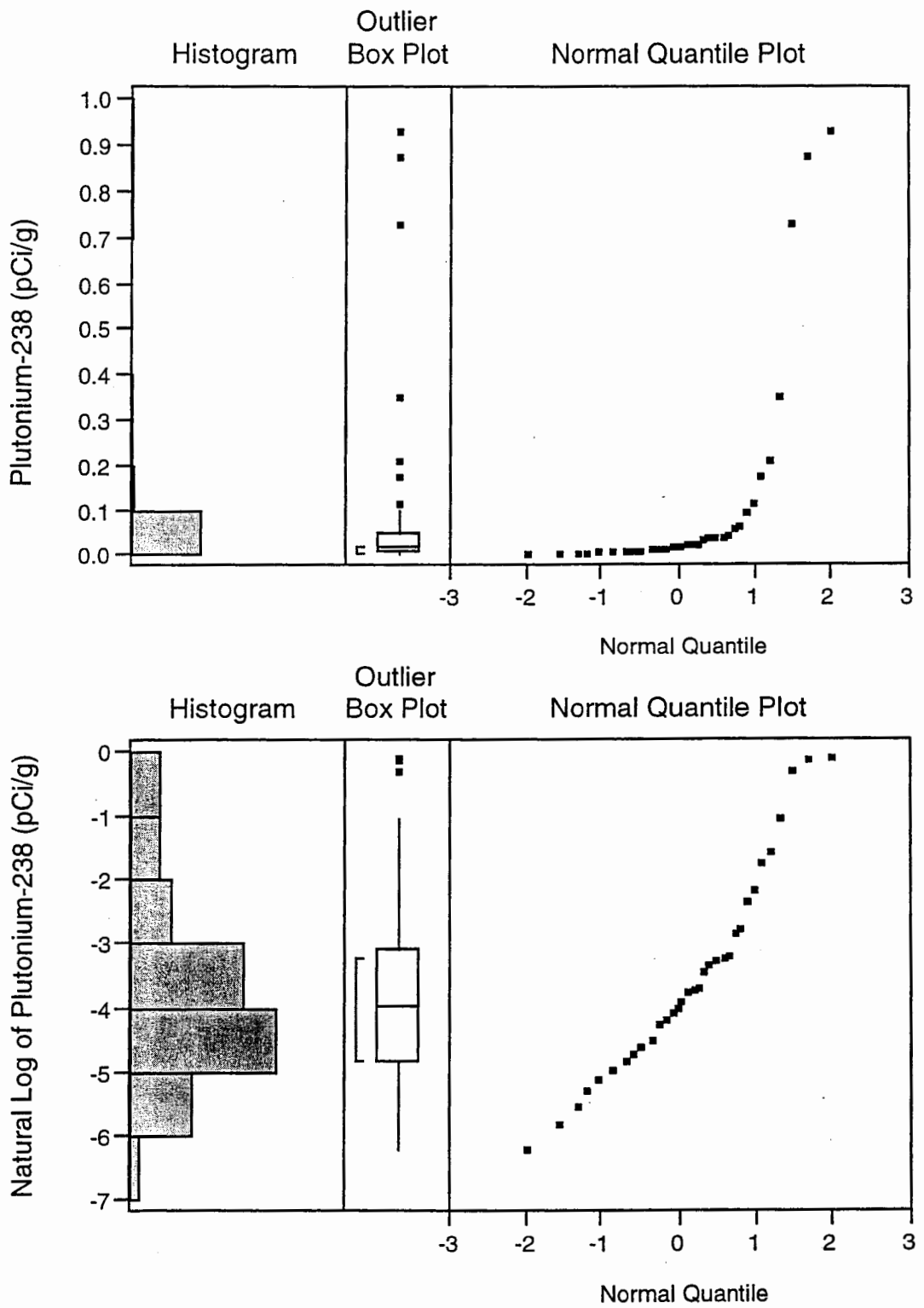

Figure 27. Distribution plots for plutonium-238 (in pCi/g) and log-transformed plutonium-238 process area baseline data.

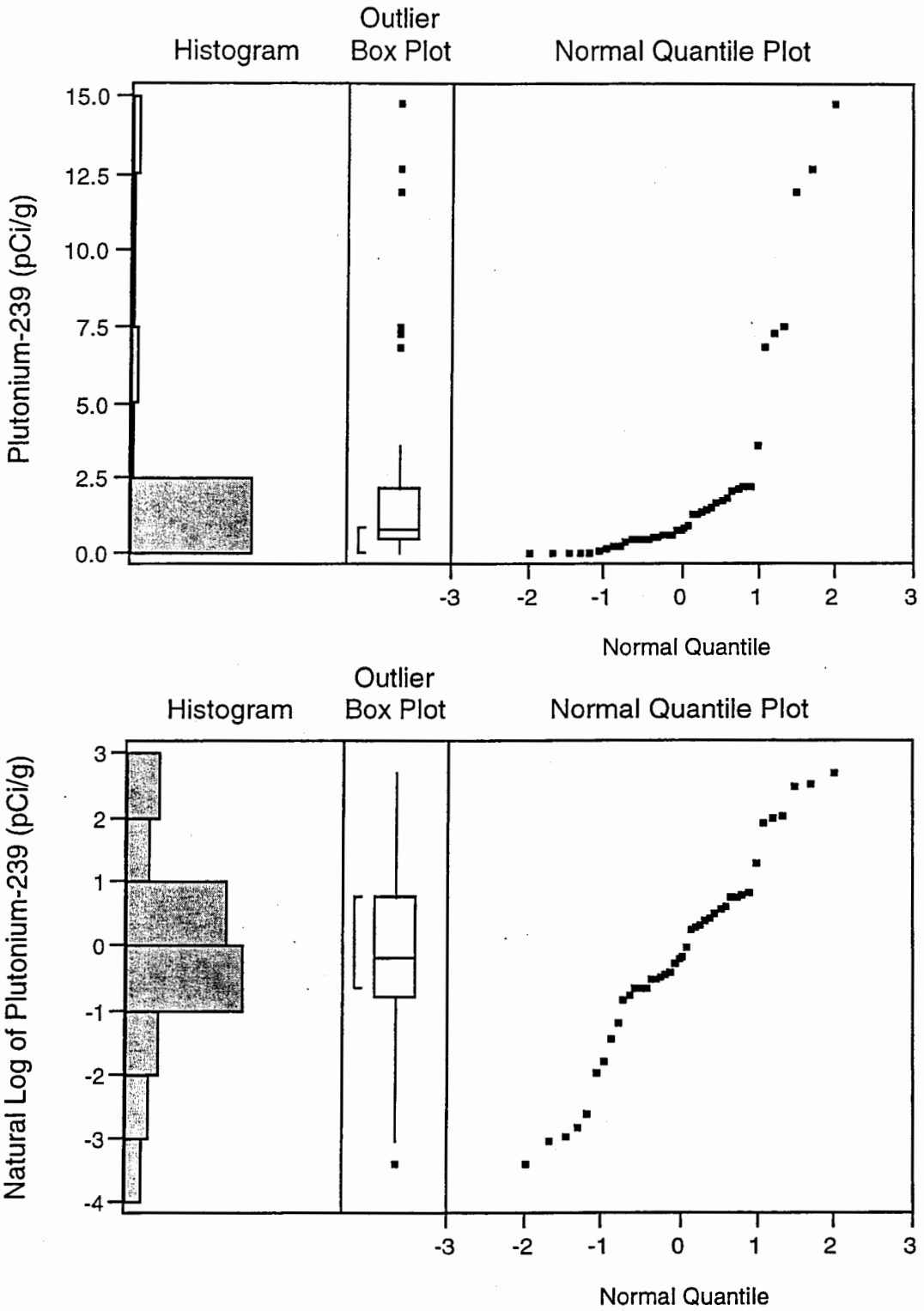

Figure 28. Distribution plots for plutonium-239 (in pCi/g) and log-transformed plutonium-239 process area baseline data.

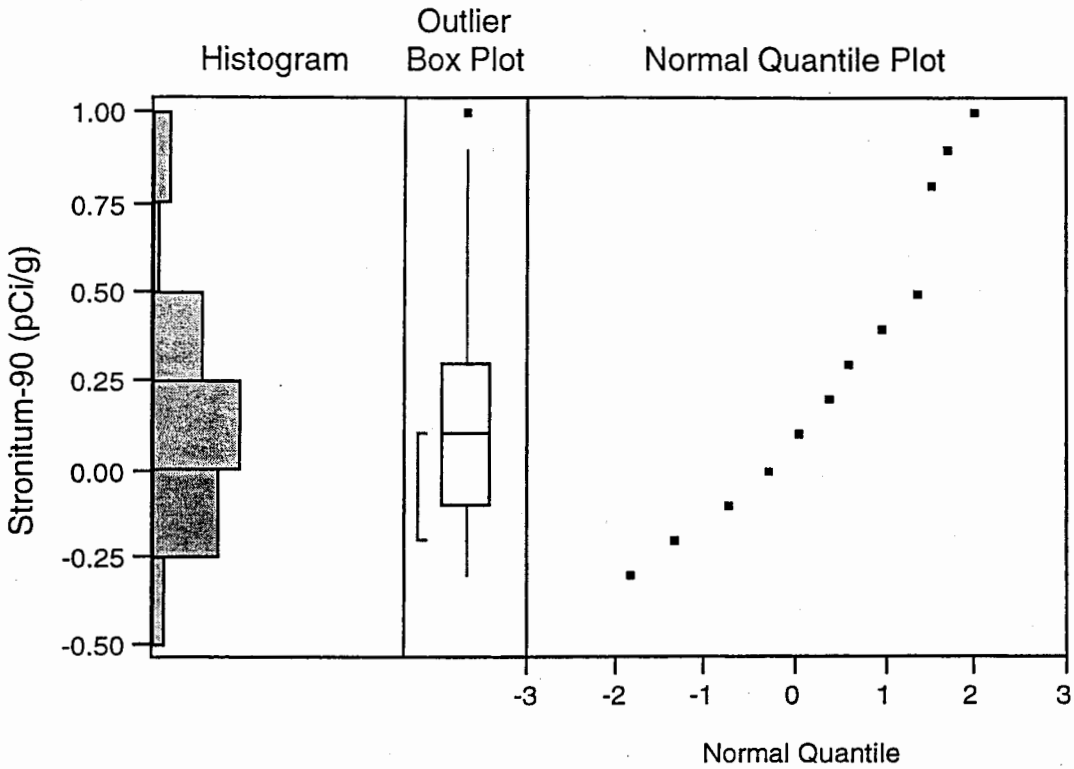

Figure 29. Distribution plot for strontium-90 (in pCi/g) process area baseline data.

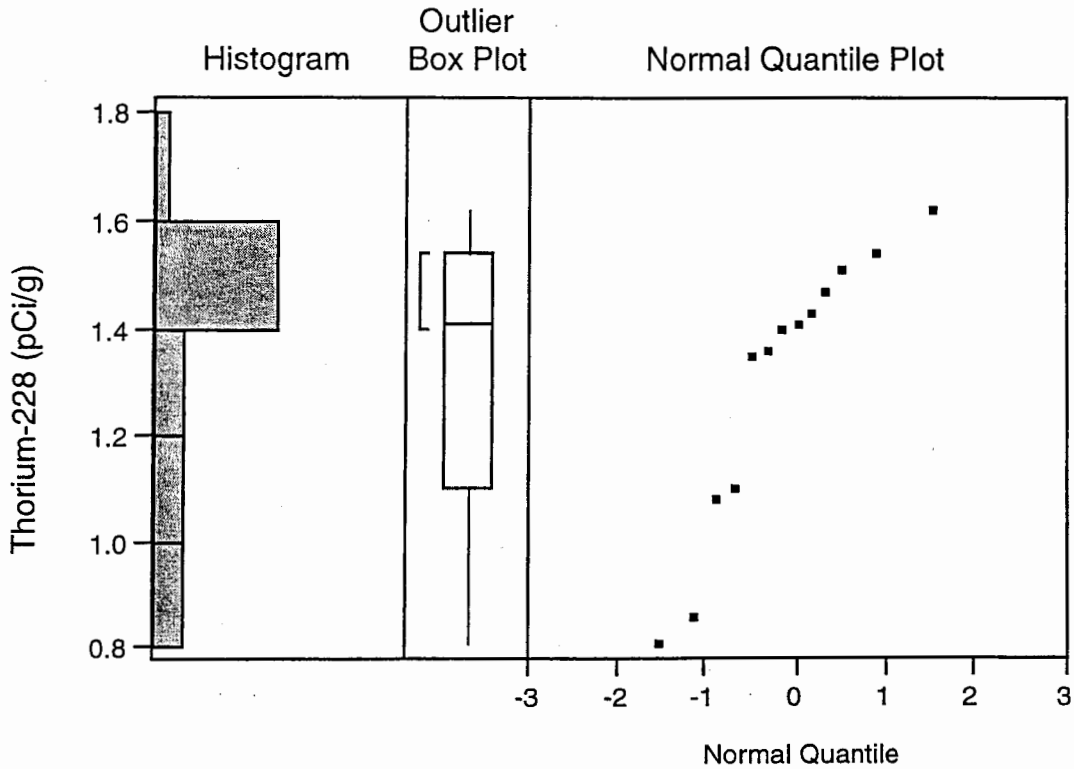

Figure 30. Distribution plot for thorium-228 (in pCi/g) process area baseline data.

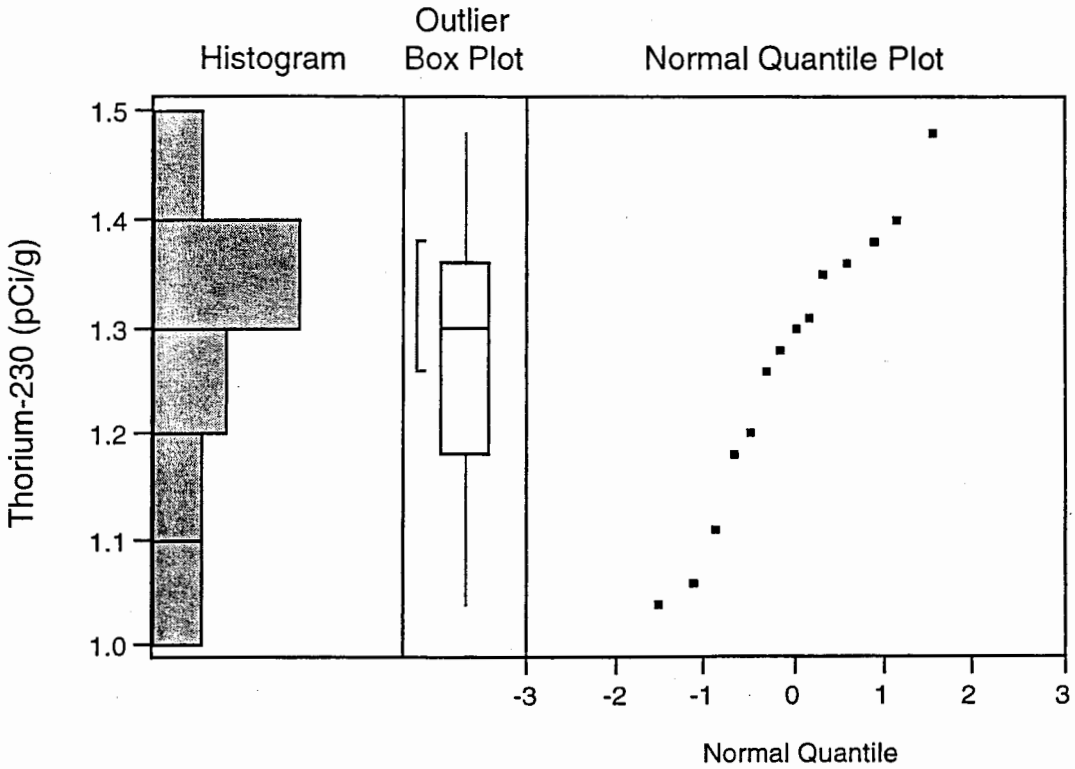

Figure 31. Distribution plot for thorium-230 (in pCi/g) process area baseline data.

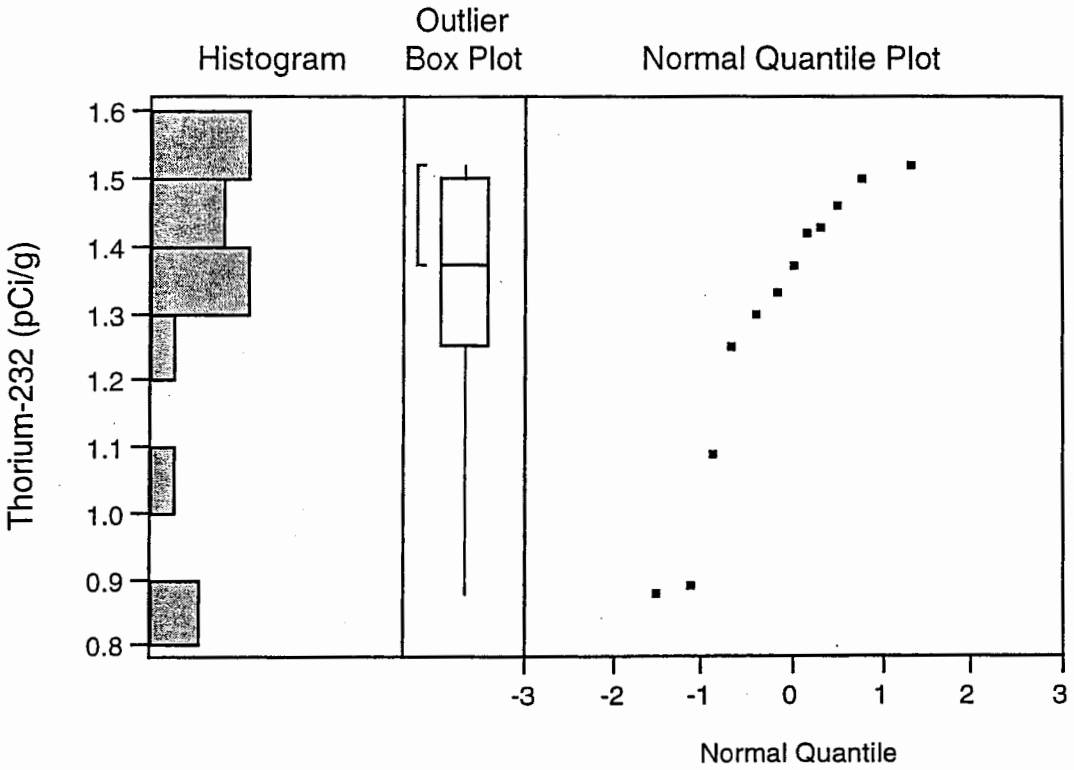

Figure 32. Distribution plot for thorium-232 (in pCi/g) process area baseline data.

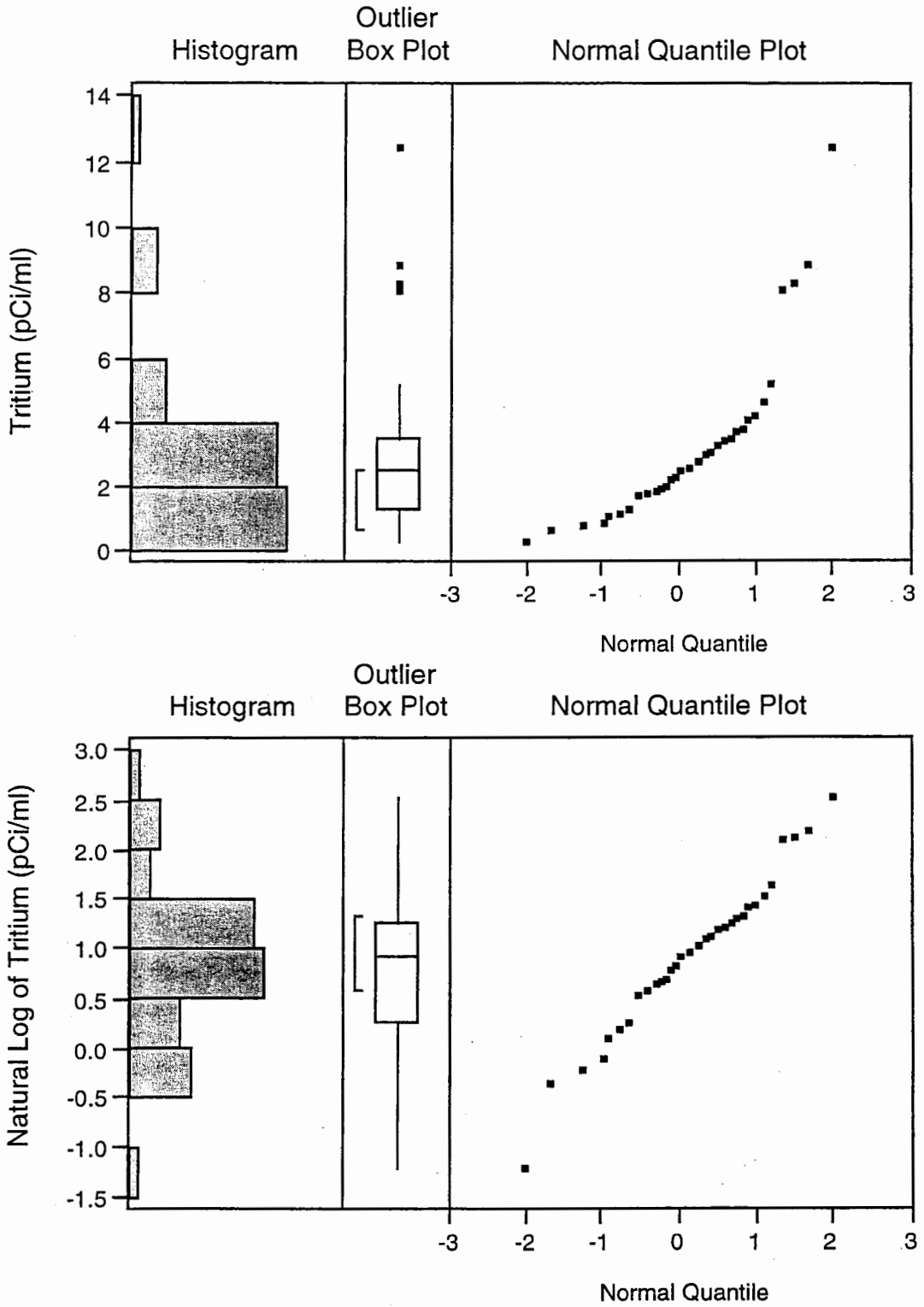

Figure 33. Distribution plots for tritium (in pCi/ml) and log-transformed tritium process area baseline data.

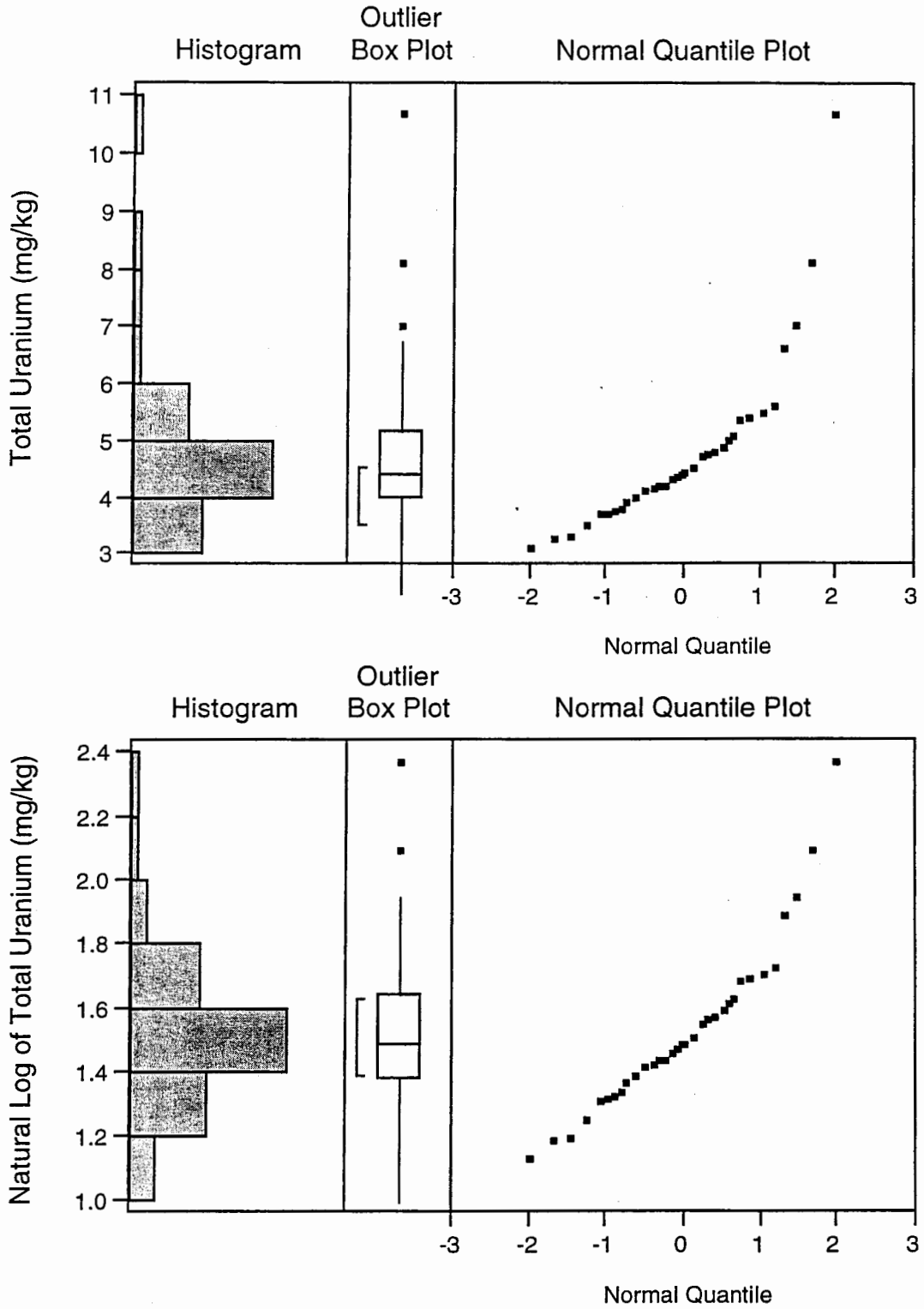

Figure 34. Distribution plots for total uranium (in mg/kg) and log-transformed total uranium process area baseline data.

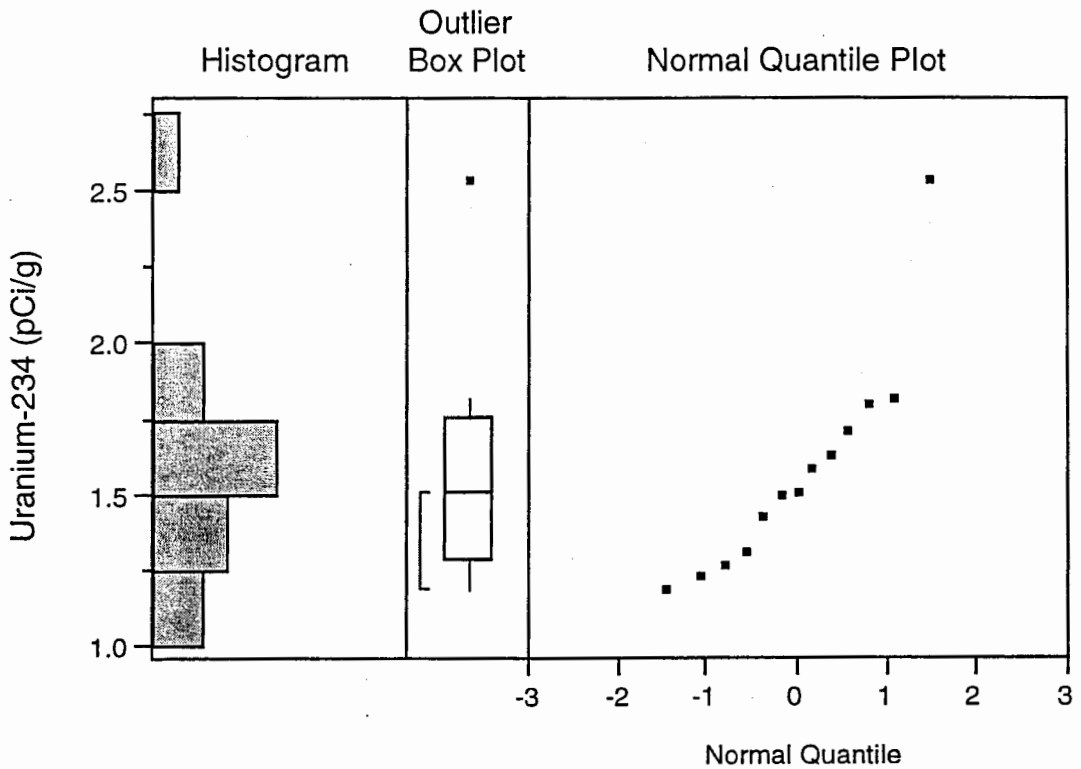

Figure 35. Distribution plot for uranium-234 (in pCi/g) process area baseline data.

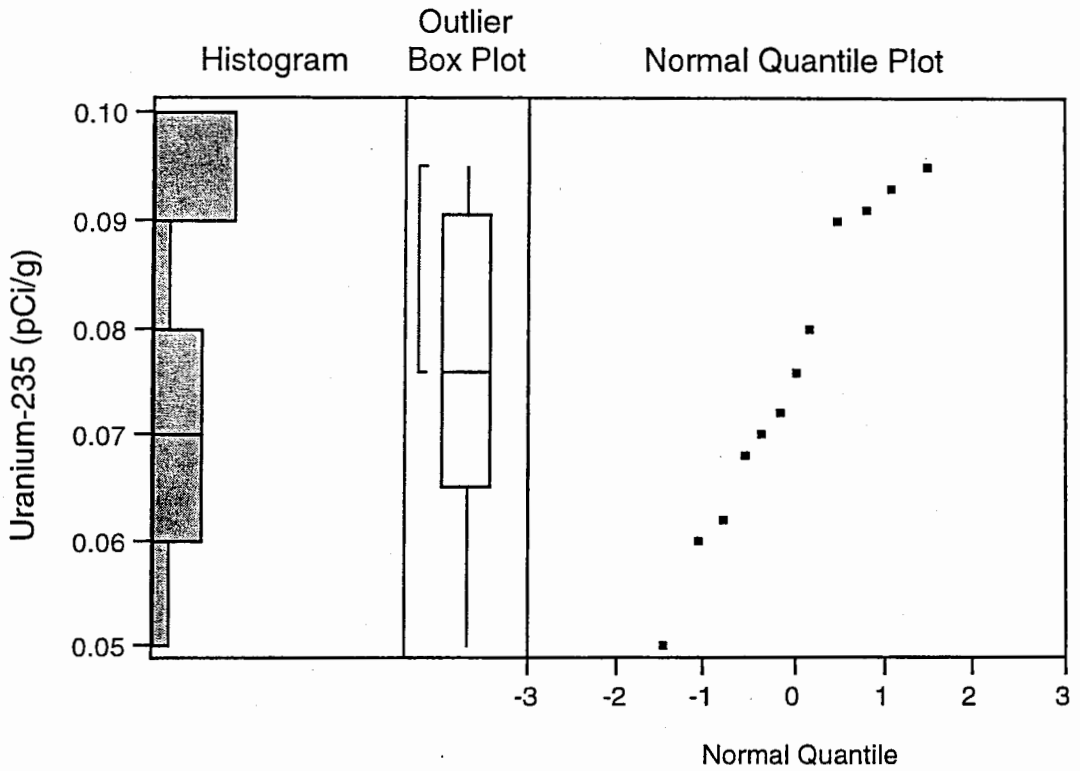

Figure 36. Distribution plot for uranium-235 (in pCi/g) process area baseline data.

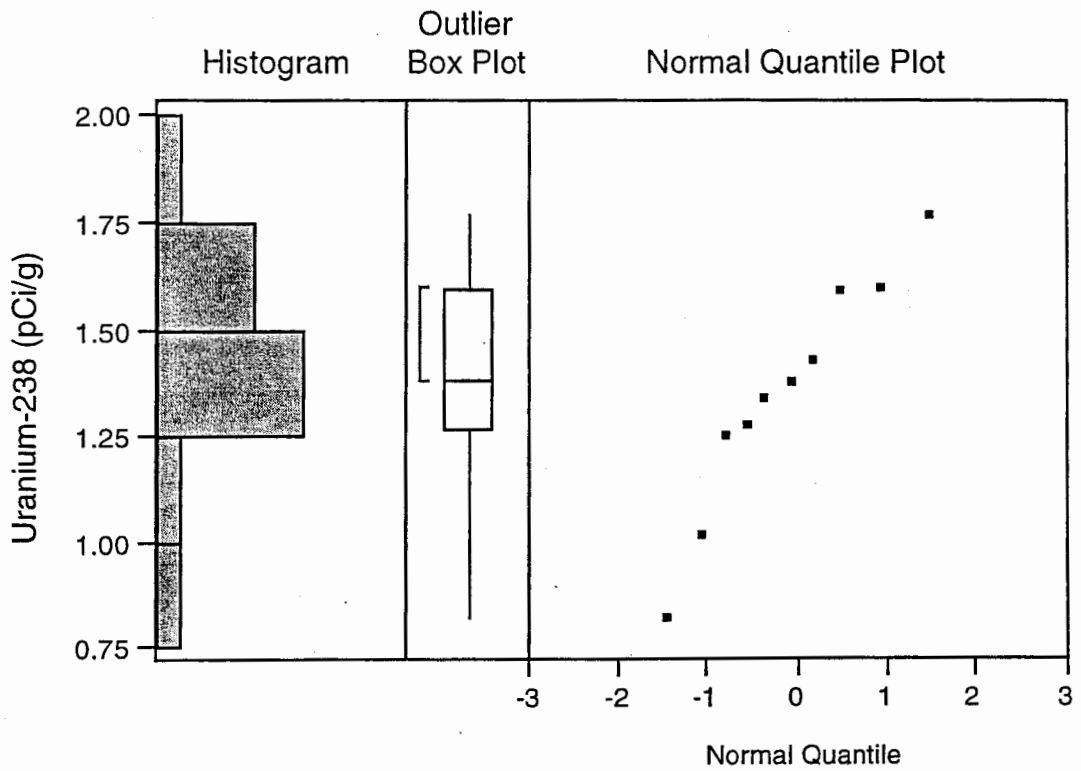

Figure 37. Distribution plot for uranium-238 (in pCi/g) process area baseline data.

Appendix A

Summary of Process Area Baseline Inorganic and Radionuclide Data

Location ID	Sample ID	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Lithium
21-1199	AAA0048	62500	<6	2.9	456	2.6	<2	4900	24	8	11	19600	16	27
21-1198	AAA0051	56100	<6	2.2	403	2.3	<2	6400	15	5	9	15700	14	25
21-1084	AAA0115	53400	7	1.4	412	1.81	<0.6	4500	12.4	4.1	7.2	13200	82	19.5
21-1099	AAA0121	49700	<3	1.5	421	1.82	<0.6	4900	11.9	4.71	8.2	11300	42	18.9
21-1095	AAA0126	58900	<3	1.9	317	2.51	<0.6	4300	11.6	4	8.4	12800	31	26.6
21-1096	AAA0128	61500	<3	1.1	196	3	<0.6	4200	6.2	3	4.9	7800	44	24.2
21-1100	AAA0130	56200	<3	1.5	228	2.43	<0.6	3200	7.9	3.3	3.2	10000	27	21.9
21-1119	AAA0136	62300	<3	2.2	304	2.6	<0.6	4500	12.8	4.6	9.6	14400	33	23.5
21-1125	AAA0140	58400	<3	2.1	370	2.4	<0.6	7300	14.4	5.2	9.4	15600	36	23.7
21-1133	AAA0142	64400	<3	2.6	336	2.68	<0.6	4700	15.1	5	8	16200	38	26.5
21-1136	AAA0144	60700	<3	2.8	369	2.55	<0.6	5400	16	6.8	10.8	16500	35	25.5
21-1144	AAA0146	56200	<3	3.1	296	2.26	<0.6	4000	12	4.3	131	15400	43	24
21-1155	AAA0148	59000	<6	2.6	312	3.2	<2	5200	13	7	13	13000	31	35.5
21-1162	AAA0150	66000	<6	2.2	290	2.9	<2	3800	11	4	6	12000	19	35
21-1162	AAA0151	65000	<6	2.2	287	3	<2	3600	10	3	6	11000	16	33
21-1168	AAA0153	66000	<6	4.4	394	3.4	3	6000	21	8	24	17000	50	42
21-1173	AAA0160	60000	<6	3.2	381	2.9	<2	9200	16	9	13	15000	36	35
21-1179	AAA0163	63000	<6	1.9	276	3	<2	4000	11	5	6	12000	26	36
21-1186	AAA0165	64000	<6	2.5	254	3.4	<2	4800	11	5	6	12000	25	36
21-1124	AAA0169	70000	<6	1.2	190	3.8	<2	3000	7	2.2	4	12000	21	36

Location ID	Sample ID	Aluminum	Antimony	Arsenic	Barium	Beryllium	Cadmium	Calcium	Chromium	Cobalt	Copper	Iron	Lead	Lithium
21-1143	AAA0176	63000	<6	2.6	435	2.7	<2	4700	15	5	10	14000	24	31
21-1149	AAA0180	58000	<6	1.5	419	2	<2	3900	14	6	6	13000	13	27.9
21-1154	AAA0184	54700	<6	1.4	403	2	<2	4400	15	6	11	15500	11	22
21-1160	AAA0186	53200	<6	2.3	325	2.5	<2	4900	14	4	12	16100	18	25
21-1166	AAA0188	52500	<6	1.3	214	2.7	<2	3600	7	3	9	11000	19	22
21-1172	AAA0190	57600	<6	1.7	337	2.3	<2	3700	12	4	7	14000	13	22
21-1178	AAA0192	56800	<6	1.6	440	2.4	<2	4800	17	6	12	15400	14	26
21-1184	AAA0194	60700	<6	1.8	397	2.3	<2	4900	15	6	11	15800	11	25
21-1192	AAA0196	53100	<6	0.8	348	2.2	<2	7100	13	4	10	13400	16	23
21-1193	AAA0198	61400	<6	1.7	527	2.4	<2	5300	22	7	16	19500	11	27
21-1079	AAA0240	54300	<6	6.2	431	2.7	3	4600	24	5	28	13700	59	23
21-1086	AAA0566	4850	<4.7	1.5	62	0.25	0.67	4870	4.7	2	4.6	5420	10.8	7.5
21-1092	AAA0568	8640	<4.8	1.8	104	0.53	1.2	3980	9.1	4.7	6.4	9900	12.2	11.9
21-1103	AAA0572	8500	<4.7	1.9	70	0.6	1.2	1780	8.8	4.6	5.2	9890	46.7	7.9
21-1300	AAA0574	5290	<4.9	1.3	46.4	0.37	0.67	1340	7.6	1.7	4.4	6490	53	5.7
21-1111	AAA0579	10700	<5.1	2	106	0.58	2.5	2370	8.8	3.4	10.8	12600	26.2	8.9
21-1113	AAA0582	6130	<4.7	1.4	91.3	0.35	1.3	5060	8.1	2.8	5.2	8500	7.5	6.4
21-1113	AAA0583	3140	<4.7	1.1	62.3	0.22	0.77	6330	4.3	1.9	4.4	5470	6.6	3.8
21-1115	AAA0587	6320	<4.9	1.6	104	0.45	1.1	4310	7.4	3.1	6.4	8980	9.8	5.9
21-1122	AAA0592	9480	<4.8	2	142	0.58	1.5	11600	17.3	5.4	11.6	11800	15.2	15.5
21-1167	AAA0604	13900	<4.9	2.3	141	0.89	1.9	1980	14.2	7.8	8.6	15100	15.2	11.4
21-1301	AAA0606	9850	<4.9	1.7	87.1	0.63	1.5	1800	10.7	4.3	9.1	10800	19.7	7.5
21-1189	AAA0611	18700	<5.9	3.6	205	1.2	1.8	3520	21.4	8.1	11.8	17300	16.6	18

Location ID	Sample ID	Magnesium	Manganese	Molybdenum	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Thallium	Uranium	Vanadium	Zinc
21-1199	AAA0048	3900	462	<4	10	26800	0.3	<1	14900	121	<20	3.76	43	48
21-1198	AAA0051	3000	394	<4	8	27200	0.3	<1	17200	112	<20	3.27	31	56
21-1084	AAA0115	2000	297	1	5	26400	<0.2	<1	19900	106	<20	3.3	25.1	86.1
21-1099	AAA0121	2200	264	1.5	6.54	22300	<0.2	<1	17000	124	<20	3.1	22.3	107
21-1095	AAA0126	2300	295	0.9	5	27900	<0.2	<1	20900	80.6	<20	4.5	23.5	71.1
21-1096	AAA0128	1200	300	1	<3	34800	<0.2	1.7	27400	51	<20	5.4	11	44
21-1100	AAA0130	1500	317	0.6	3	31000	<0.2	2.2	23400	58	<20	3.9	15	38.6
21-1119	AAA0136	2100	427	2	49200	31800	<0.2	<1	23300	80	<20	6.6	28	88
21-1125	AAA0140	2600	452	2	6	28800	0.2	<1	20600	111	<20	8.1	29	466
21-1133	AAA0142	2900	350	1.7	7	29400	0.2	1.6	22000	92	<20	4.2	29	65
21-1136	AAA0144	2700	437	1.3	7	28700	0.2	1.7	20600	98.3	<20	5.6	33	61
21-1144	AAA0146	2200	243	1.3	6	29900	0.2	1.5	22300	78.3	<20	5.1	23	116
21-1155	AAA0148	2600	388	<4	8	29000	0.2	<1	19000	85	<20	5.4	25	78
21-1162	AAA0150	2000	336	<4	6	35000	<0.2	<1	25000	73	<20	4.1	20	45
21-1162	AAA0151	1900	314	<4	6	34000	0.2	<1	24000	76	<20	4.5	19	43
21-1168	AAA0153	4000	498	<4	19	30000	0.2	<1	19000	107	<20	10.7	41	181
21-1173	AAA0160	3500	696	<4	10	27000	0.2	<1	17700	104	<20	7	30	59
21-1179	AAA0163	2000	364	<4	7	32000	<0.2	<1	24000	71	22	3.5	20	75
21-1186	AAA0165	2500	358	<4	8	32000	<0.2	<1	24000	59	24	3.8	20	55
21-1124	AAA0169	1000	310	<4	6	36000	<0.2	<1	28000	43	27	4.3	15	70

Location ID	Sample ID	Magnesium	Manganese	Molybdenum	Nickel	Potassium	Selenium	Silver	Sodium	Strontium	Thallium	Uranium	Vanadium	Zinc
21-1143	AAA0176	2700	415	<4	10	30000	<0.2	<1	21000	112	<20	4.1	31	47
21-1149	AAA0180	2000	307	<4	7	29000	0.2	<1	19800	112	<20	4	32	33
21-1154	AAA0184	2200	371	<4	7	26700	<0.2	1.2	18300	123	<20	4.42	35	36
21-1160	AAA0186	2400	421	<4	6	25000	<0.2	<1	16200	94	<20	5.38	32	49
21-1166	AAA0188	1400	390	<4	4	29000	<0.2	<1	21400	64	<20	4.9	14	54
21-1172	AAA0190	1800	330	7	7	29000	<0.2	<1	21600	94	<20	4.36	26	42
21-1178	AAA0192	3000	393	<4	9	24900	<0.2	1.2	15800	127	<20	4.77	36	47
21-1184	AAA0194	2700	479	<4	9	28000	<0.2	<1	19000	109	<20	4.19	32	40
21-1192	AAA0196	2400	420	<4	6	25500	<0.2	<1	17800	114	<20	4.14	27	38
21-1193	AAA0198	4200	502	<4	15	23800	<0.2	<1	14300	151	<20	3.72	48	48
21-1079	AAA0240	2700	464	<4	9	27700	0.5	<1	18100	89	<20	27	43	208
21-1086	AAA0566	1750	146	<2.3	3.1	962	<0.31	<0.62	152	21.8	<0.21	5.5	9.9	26.1
21-1092	AAA0568	1850	241	<2.3	5.8	1100	<0.31	<0.62	116	19.6	<0.21	4.8	17.6	45.1
21-1103	AAA0572	1380	314	<2.2	6.4	1480	<0.31	<0.61	86.4	14.8	<0.2	4.4	16.5	89.6
21-1300	AAA0574	954	191	<2.3	3.9	696	<0.32	<0.63	73.1	8.5	<0.21	4.8	8.4	45.4
21-1111	AAA0579	1870	294	<2.4	8.8	1540	<0.33	<0.66	85.3	19.8	<0.22	5.5	16.8	153
21-1113	AAA0582	1640	181	<2.3	3.9	985	<0.31	<0.62	94.3	20	<0.21	5	14.8	43.9
21-1113	AAA0583	1340	152	<2.2	7.2	688	<0.31	<0.61	46.8	17.3	<0.2	4.7	9.8	68.6
21-1115	AAA0587	1460	225	<2.3	4.8	869	<0.32	<0.64	93.7	19	<0.21	3.5	16.9	31.4
21-1122	AAA0592	3860	312	<2.3	11.3	2050	0.33	<0.63	102	47.2	<0.21	4.2	20.8	59.7
21-1167	AAA0604	2460	504	<2.3	10.1	2160	<0.32	<0.64	96.9	27.6	<0.21	4	26.5	39.7
21-1301	AAA0606	1620	318	<2.3	5.6	1600	<0.32	<0.63	82	15.9	<0.21	4.5	15.8	57.5
21-1189	AAA0611	3180	625	<2.8	10.8	3020	<0.38	<0.77	643	39.6	<0.26	3.7	30	55.4

Location ID	Sample ID	Am-241	Pu-238	Pu-239	Sr-90	Th-228	Th-230	Th-232	Tritium	Uranium	U-234	U-235	U-238
21-1199	AAA0048	0.063	0.006	0.052	-0.1				3.7	3.76			
21-1198	AAA0051		0.003	0.301	-0.3				5.2	3.27			
21-1084	AAA0115		0.003	0.075	-0.1				0.3	3.3			
21-1099	AAA0121	0.085	0.018	0.842	0.3	1.1	1.2	1.3	0.8	3.1	1.8	0.08	1.6
21-1095	AAA0126	0.073	0.017	2.271	0.3				0.8	4.5			
21-1096	AAA0128		0.015	2.129	-0.1				2.2	5.4			
21-1100	AAA0130		0.005	0.46	-0.2	1.41	1.28	1.43	0.7	3.9	1.19	0.072	1.28
21-1119	AAA0136	0.996	0.211	14.837	-0.1				1.2	6.6			
21-1125	AAA0140		0.174	0.655	0.2				1.8	8.1			
21-1133	AAA0142	0.106	0.025	1.558	-0.1	1.62	1.31	1.52	1.1	4.2	1.63	0.068	1.6
21-1136	AAA0144		0.036	2.235	0.9				1.7	5.6			
21-1144	AAA0146	0.054	0.011	0.966	0				2.8	5.1			
21-1155	AAA0148		0.038	2.119	0.8				3	5.4			
21-1162	AAA0150		0.011	0.519	0.1	1.54	1.36	1.52	1.9	4.1	1.5	0.076	1.59
21-1162	AAA0151		0.008	0.44	0.2	1.54	1.36	1.5	1.95	4.5	1.51	0.093	1.59
21-1168	AAA0153	0.131	0.024	1.317	-0.1				3.4	10.7			
21-1173	AAA0160	0.156	0.023	1.369	1				2.6	7			
21-1179	AAA0163		0.009	0.514	0				3.3	3.5			
21-1186	AAA0165		0.007	0.169	0.5	1.54	1.35	1.5	3.3	3.8	1.23	0.091	1.38
21-1124	AAA0169	0.098	0.015	0.774	0				0.8	4.3			
21-1143	AAA0176		0.059	1.793	0.1				0.9	4.1			

Location ID	Sample ID	Am-241	Pu-238	Pu-239	Sr-90	Th-228	Th-230	Th-232	Tritium	Uranium	U-234	U-235	U-238
21-1149	AAA0180	0.118	0.032	0.139	0	1.4	1.4	1.37	1.2	4	1.43	0.062	1.38
21-1154	AAA0184		0.038	6.837	-0.1				1.8	4.42			
21-1160	AAA0186	0.243	0.062	12.68	0.4				2.6	5.38			
21-1166	AAA0188		0.039	11.96	0.4				2.5	4.9			
21-1172	AAA0190	0.113	0.02	1.362	0.3	1.35	1.18	1.25	4.1	4.36	1.59	0.095	1.77
21-1178	AAA0192		0.01	0.593	0.1				8.9	4.77			
21-1184	AAA0194	0.031	0.004	0.603	0				8.1	4.19			
21-1192	AAA0196		0.007	0.815	0.2				8.3	4.14			
21-1193	AAA0198		0.002	0.049	-0.2	1.43	1.3	1.3	12.5	3.72	1.27	0.05	1.43
21-1079	AAA0240	1.235	0.35	47.74	0.4	1.47	1.38	1.42	3.8	27	11.1	0.443	8.26
21-1086	AAA0566		18.66	7.51	-0.3				2.8	5.5			
21-1092	AAA0568	0.318	0.731	3.63	0.1	1.08	1.04	1.09	2.5	4.8	1.71	0.07	1.02
21-1103	AAA0572	0.107	0.932	0.631	-0.1				2.3	4.4			
21-1300	AAA0574	0.197	0.096	0.512	-0.2				0.8	4.8			
21-1111	AAA0579	0.178	0.041	1.87	0.4	1.36	1.26	1.46	1.3	5.5			
21-1113	AAA0582	0.082	0.023	1.5	0.2	0.86	1.06	0.89	4.2	5	2.53	0.09	0.82
21-1113	AAA0583		0.014	0.625	-0.1	0.81	1.11	0.88	3.5	4.7	1.82	0.09	1.25
21-1115	AAA0587		0.113	1.67	0.1				1.8	3.5			
21-1122	AAA0592		0.878	7.32	0.1				4.6	4.2			
21-1167	AAA0604	0.056	0.01	0.059	0.4	1.51	1.48	1.33	3.1	4	1.31	0.06	1.34
21-1301	AAA0606	0.067	0.008	0.235	0.4				2	4.5			
21-1189	AAA0611	0.015	0.006	0.034	0.1				1.3	3.7			

Appendix B

S-Plus Code Used to Calculate Lognormal UTLs

File: lnorm_utl1.s

```
function(q,p,n,ave,sd,nt)
{
# lnorm_utl1.s is used as function LUTL1 in Splus
# This function is used to estimate the upper 95% CI of the 99th
# percentile for a lognormal distribution.  Uses Gilbert's MBE of LN.
#    q = the quantile to estimate
#    p = the confidence limit of q
#    n = number of values sampled
#  ave = mean of logtranformed data
#   sd = st. dev. of logtranformed data
#   nt = number of simulation trials
#.............................................................

# Calculate the qth quantile of the normal distribution
q1_qnorm(q)

# Initialize arrays
t1_rep(-1,n)
t2_rep(-1,nt)

i_0

repeat

 { i_i+1

# Get the "n" lognormal samples
   t1_rlnorm(n,ave,sd)

# Calculate the mean and sd the "Gilbert" way
   dummy_lnormUMV.s(t1)
   ave1_dummy$mu
   sd1_sqrt(dummy$s2)

# Calculate an estimate of the 99th percentile
   t2[i]_exp(ave1+q1*sd1)
   if(i>=nt) break
 }

# Find the upper p*100% of the qth percentile
quantile(t2,p)
}
```

File: lnormUMV.s

```
function(x)
{
# lnormUMV.s (Splus function)
# Calls: psi.s
# Min Variance Unbiased ests of parameters of lognormal(mu,var=s2) distn
# for X~lognorm(mu,s2), Y=log(X)~normal(mu,s2)
# returns:E=mean(X), V=var(X)
#       mu=mean(Y),s2=var(Y)
# ref:Gilbert('87),Stat Methods for Env Pollution Mon, pp165-166
        n <- length(x)
        y <- log(x)
        ymu <- mean(y)
        vy <- var(y)
        psi1 <- psi.s(vy/2, n)
        psi2 <- psi.s(2 * vy, n)
        psi3 <- psi.s((vy * (n - 2))/(n - 1), n)
        E <- exp(ymu) * psi1
        V <- exp(2 * ymu) * (psi2 - psi3)
        mu <- log(E^2/(V + E^2)^0.5)
        s2 <- log(V/E^2 + 1)
        return(E, V, mu, s2)
}
```

File: psi.s

```
function(t, n)
{
# psi.s (Splus function)
# called by lnormUMV.s
# psi function in Gilbert('87) Stat. Meth. Env. Pollution. Mon, pp 165
# for Min Variance Unbiased ests of parameters of lognormal(mu,var=s2) distn
        psi <- 0
        psi[1] <- ((n - 1) * t)/n
        for(i in 1:25) {
                psi[i + 1] <- (psi[i] * (n - 1)^2 * t)/((i + 1) * n * (n + (2 *
                        i - 1)))
                if(abs((psi[i + 1] - psi[i])/psi[i]) < 1e-09)
                        break
        }
        psi <- 1 + sum(psi)
        psi
}
```