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COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT RESOURCE CONSERVATION AND RECOVERY ACT BACKGROUND SOIL STUDY

DOE-FN/EPA
DOE-1581-93
3
LETTER

Department of Energy
Fernald Environmental Management Project
P.O. Box 398705
Cincinnati, Ohio 45239-8705
(513) 738-6357

APR 07 1993
DOE-1581-93

Mr. James A. Saric, Remedial Project Director
U.S. Environmental Protection Agency
Region V - 5HRE-8J
77 W. Jackson Boulevard
Chicago, Illinois 60604-3590

Mr. Graham E. Mitchell, Project Manager
Ohio Environmental Protection Agency
40 South Main Street
Dayton, Ohio 45402-2086

Dear Mr. Saric and Mr. Mitchell:

COMPREHENSIVE ENVIRONMENTAL RESPONSE, COMPENSATION, AND LIABILITY ACT RESOURCE CONSERVATION AND RECOVERY ACT BACKGROUND SOIL STUDY

The purpose of this letter is to transmit for your review and comment the revised Comprehensive Environmental Response Compensation and Liability Act (CERCLA)/Resource Conservation and Recovery Act (RCRA) Background Soil Study Report. The report is being provided for information and to support the development of the primary documents at the Fernald Environmental Management Project (FEMP). This study and the results have been referenced in the Site-Wide Characterization Report, the Operable Unit 2 Draft Remedial Investigation (OU 2 RI), and the soon to be submitted Operable Unit 4 Draft Remedial Investigation (OU 4 RI). The completion of this report provides a document that can be referenced in support of the overall cleanup process at the FEMP.

This correspondence transmits, by attachment, the revised CERCLA/RCRA Background Soil Report and responses to the United States Environmental Protection Agency (U.S. EPA) comments on the draft submittal. The U.S. EPA letter transmitting the conditional approval and comments on the report directs the Department of Energy (DOE) to utilize the arithmetic mean of the background data set for establishing contaminants of concern (COC) in the CERCLA risk assessments for the Remedial Investigation/Feasibility Study (RI/FS). As you are probably aware, this represents a departure from the approved Risk Assessment Work Plan Addendum which states the 95% Upper Tolerance Limit (UTL) for the background data set will be used for this purpose. It is the DOE position that use of the arithmetic mean in such a manner is inappropriate.

Recycled and Recyclable

The implications of this revised U.S. EPA direction have been the subject of considerable discussion between the U.S. EPA and the Department of Energy, Fernald Field Office (DOE-FN). On the basis of these discussions, it was decided that the site would move toward compliance with U.S. EPA direction regarding use of the arithmetic mean, but would also notify U.S. EPA of the impact of this decision on the OU 4 Draft RI Report and other reports. It was also decided that the FEMP would propose use of a screening process to preclude unwarranted calculations in the RI/FS risk assessment.

This screening process will be based on the premise that many of the affected contaminants of concern can be demonstrated to be at concentrations near background levels and present an inconsequential contribution of risk. For these constituents, only screening level risk calculations (i.e., default risk calculations) would be performed without more detailed fate and transport and risk analysis being completed. This position is supported by text within the approved Risk Assessment Work Plan Addendum and a U.S. EPA internal correspondence between Paul White, U.S. EPA statistician, and Pat Van Leeuwen, U.S. EPA toxicologist. Details on this screening process are currently being developed and will be forwarded as they become available.

Please recognize that the baseline risk assessments for the OU 4 Draft RI Report are substantially complete utilizing the 95% UTL. Significant additional work was required to modify the risk assessment in an attempt to accommodate U.S. EPA's direction. This additional work involved primarily the fate and transport modeling and risk calculations for six new COC's for OU 4. The parameters of issue are typically within the range of background and are not significant contributors to overall risk from the operable unit.

Required changes to fully accommodate this new direction cannot be completed by the April 19, 1993, submittal date of the OU 4 Draft RI Report to the U.S. EPA. Fernald Environmental Restoration Management Corporation will include discussions and/or calculations in the text of the OU 4 Draft RI Report showing the contribution of risks that any additional COCs provide.

The revised CERCLA/RCRA Background Report presents the results of the evaluation of background concentrations of inorganics and radionuclides for use in the RI/FS process and RCRA closure plans. The data presented and the results represent the background for soil in the vicinity of the FEMP. Subsequent addenda to this report are currently being planned to enhance the overall useability and interpretation of the analytical and statistical results. An addendum will be added that defines the intended use of the results and provides for the appropriate and applicable use of the background soil results.

If you or your staff have any questions, please contact Randy C. Janke at (513) 648-3123.

Sincerely,

Jack R. Craig
Fernald Remedial Action
Project Manager

FN:R.C. Janke

Enclosure: As Stated

cc w/ enc:

E. Helmer, USEPA-V, 5HSM-TUB
G. Jablonowski, USEPA-V, AT-18J
P. Van Leeuwen, USEPA-V, 5HSM-TUB
J. Michaels, PRC

cc w/o enc:

J. J. Fiore, EM-42, TREV
K. A. Hayes, EM-424, TREV
B. Barwick, USEPA-V, 5CS-TUB-3
J. Kwasniewski, OEPA-Columbus
P. Harris, OEPA-Dayton
M. Proffitt, OEPA-Dayton
T. Schneider, OEPA-Dayton
L. August, GeoTrans
AR Coordinator, FERMCO
R. L. Glenn, Parsons
P. Clay, FERMCO/19
D. Dubois, FERMCO/65-2
J. W. Thiesing, FERMCO/2

March 19, 1993

Table 1: Summary Statistics for Inorganic Constituents (all values reported in mg/kg)

Constituent	Distribution	Mean[a]	Upper 95% Tolerance Limit
Aluminum			
0" - 6"	Lognormal	7863	11880
48" - 54"	Lognormal	7304	14742
Antimony			
0" - 6"	N/A	3.9[b]	7.7
48" - 54"	N/A	3.3[b]	6.7
Arsenic			
0" - 6"	Lognormal	5.18	8.45
48" - 54"	Lognormal	4.32	8.82
Barium			
0" - 6"	Undefined	61.95	126.09
48" - 54"	Lognormal	45.30	98.72
Beryllium			
0" - 6"	N/A	0.26[c]	0.60
48" - 54"	Undefined	0.29	0.63
Boron			
0" - 6"[d]	Undefined	9.11	19.97
48" - 54"	Lognormal	29.97	42.76
Cadmium			
0" - 6"	Undefined	0.32	0.64
48" - 54"	N/A	0.23[c]	0.59
Calcium			
0" - 6"	Lognormal	1900	4339
48" - 54"[e]	Undefined	108000	335000

Table 1. continued

Constituent	Distribution	Mean[a]	Upper 95% Tolerance Limit
Chromium			
0" - 6"	Lognormal	10.43	15.50
48" - 54"	Lognormal	9.62	18.87
Cobalt			
0" - 6"	Lognormal	9.66	15.17
48" - 54"	Lognormal	8.13	15.68
Copper			
0" - 6"	Normal	7.33	16.43
48" - 54"	Normal	11.18	18.55
Cyanide			
0" - 6"	Undefined	0.10	0.25
48" - 54"	N/A	0.06[c]	0.11
Iron			
0" - 6"	Lognormal	14465	22323
48" - 54"	Lognormal	16267	27853
Lead			
0" - 6"	Lognormal	17.22	25.57
48" - 54"	Lognormal	7.34	13.35
Magnesium			
0" - 6"	Undefined	1646	2777
48" - 54"	Normal	23951	51599
Manganese			
0" - 6"	Lognormal	650	1772
48" - 54"	Undefined	468	940

Table 1. continued

Constituent	Distribution	Mean[a]	Upper 95% Tolerance Limit
Mercury			
0" - 6"	N/A	0.07[c]	0.30
48" - 54"	N/A	0.06[c]	0.29
Molybdenum			
0" - 6"	N/A	1.3[b]	2.6
48" - 54"	N/A	1.1[c]	2.7
Nickel			
0" - 6"	Lognormal	9.66	20.87
48" - 54"	Lognormal	16.58	28.37
Potassium			
0" - 6"	Normal	742	1402
48" - 54"	Lognormal	989	2109
Selenium			
0" - 6"	N/A	0.39[c]	0.72
48" - 54"	N/A	0.30[b]	0.61
Silicon			
0" - 6"	Normal	1114	1984
48" - 54"	Lognormal	892	1696
Silver			
0" - 6"	N/A	1.3[b]	2.6
48" - 54"	N/A	1.1[b]	2.2
Sodium			
0" - 6"	Normal	34.34	56.96
48" - 54"	Undefined	129.00	209.19

Table 1. continued

Constituent	Distribution	Mean[a]	Upper 95% Tolerance Limit
Thallium			
0" - 6"	N/A	0.26[c]	0.58
48" - 54"	N/A	0.21[b]	0.43
Vanadium			
0" - 6"	Lognormal	19.76	30.37
48" - 54"	Undefined	15.82	34.97
Zinc			
0" - 6"	Undefined	39.99	59.61
48" - 54"	Lognormal	44.95	59.19

[a] Except for cases noted in footnotes, all normal distibutions are reported as arithmetic means and lognormal and undefined distibutions are reported as geometric means.

[b] All of the values in the data set were not detectable, one-half the SQL was substituted as the best representative value for the mean and the SQL was substituted as the best representative value for the UTL.

[c] Less than or equal to 10% of measured concentrations were above the SQL, the median was substituted as the best estimate of the mean and the maximum detected value was substituted as the UTL.

[d] The calculated geometric standard deviation was greater than 2.00. This was caused by the combination of only 12 values out of 30 above SQL and the maximum concentration of 1140 µg/g. Summary statistic for 0"-6" without suspected outlier was used as the representative statistics for this data set.

[e] When the calculated geometric standard deviations was greater than 2.00, the median and maximum measured concentrations were used as the best representative values for the mean and UTL, respectively.

Source: DOE, 1993, CERCLA/RCRA Background Soil Study, FEMP, Final, March 1993.

Table 2. Summary Statistics for Radiological Constituents (all values reported in pCi/g)

Constituent	Distribution	Mean[a]	Upper 95% Tolerance Limit
Actinium^{227}			
0" - 6"	N/A	0.025[b]	0.09
48" - 54"	N/A	0.020[b]	0.06
Cesium^{137}			
0" - 6"	Lognormal	0.341[c]	0.711
48" - 54"	N/A	N/A[c]	N/A
Lead^{210}			
0" - 6"	Lognormal	0.904	1.330
48" - 54"	Undefined	0.446	1.139
Potassium^{40}			
0" - 6"	Lognormal	16.129	19.713
48" - 54"	Lognormal	16.420	28.634
Protactinium^{231}			
0" - 6"	N/A	0.15[d]	0.31
48" - 54"	N/A	0.12[d]	0.25
Radium^{224}			
0" - 6"	Undefined	0.798	0.983
48" - 54"	Lognormal	0.550	0.962
Radium^{226}			
0" - 6"	Lognormal	1.168	1.450
48" - 54"	Undefined	0.841	1.148

Table 2. continued

Constituent	Distribution	Mean[a]	Upper 95% Tolerance Limit
Radium^{228}			
0" - 6"	Undefined	1.053	1.275
48" - 54"	Lognormal	0.701	1.247
Ruthenium^{106}			
0" - 6"	N/A	N/A[c]	N/A
48" - 54"	N/A	N/A[c]	N/A
Strontium^{90}			
0" - 6"	N/A	N/A[c]	N/A
48" - 54"	N/A	0.25[b, c]	0.56
Technetium^{99}			
0" - 6"	N/A	N/A[c]	N/A
48" - 54"	N/A	N/A[c]	N/A
Thorium^{228}			
0" - 6"	Normal	1.047	1.560
48" - 54"	Normal	0.739	1.475
Thorium^{230}			
0" - 6"	Normal	1.385	2.175
48" - 54"	Normal	1.152	2.153
Thorium^{232}			
0" - 6"	Lognormal	0.998	1.362
48" - 54"	Normal	0.731	1.458

Table 2. continued

Constituent	Distribution	Mean[a]	Upper 95% Tolerance Limit
Total Thorium			
0" - 6"	N/A	9.073 mg/kg[e]	12.382 mg/kg[e]
48" - 54"	N/A	6.646 mg/kg[e]	13.255 mg/kg[e]
Uranium^{234}			
0" - 6"	Lognormal	0.979	1.244
48" - 54"	Normal	0.674	1.061
Uranium$^{235/236}$			
0" - 6"	Lognormal	0.066	0.148
48" - 54"	Lognormal	0.057	0.125
Uranium^{238}			
0" - 6"	Lognormal	1.039	1.222
48" - 54"	Undefined	0.723	1.218
Total Uranium			
0" - 6"	N/A	3.123 mg/kg[e]	3.706 mg/kg[e]
48" - 54"	N/A	2.178 mg/kg[e]	3.683 mg/kg[e]

a Except for cases noted in footnotes, all normal distributions are reported as arithmetic means and all lognormal and undefined distributions are reported as geometric means.

b When less than or equal to 10 percent of measured values were above the SQL, the median was substituted as the best estimate of the mean and the maximum detectable value was substituted as the best estimate of UTL.

c This radionuclide is a fission product and its presence in the environment is due only to atmospheric releases of radiation (e.g., weapons testing). This radionuclide is not naturally occurring, and is only expected to be present at or near detectable activities in the surface soil.

d All of the values in the data set are not detectable, one-half the SQL was substituted as the best representative value for the mean and the SQL was substituted as the best representative value for the UTL.

e Individual activity concentrations of the three isotopes for uranium and thorium were converted to mass concentrations. The three isotope mass concentrations were added to obtain the total thorium or uranium mass concentration.

Source: DOE, 1993, CERCLA/RCRA Background Soil Study, FEMP, Final, March, 1993.

RESPONSES TO COMMENTS ON THE DRAFT "CERCLA/RCRA BACKGROUND SOIL STUDY"

U.S. EPA Radiation Section

1. Commenting Organization: U.S. EPA Commentor: Gene Jablonowski
Section #: Table 4-6 Pg. #: 4-144, 4-191 Line #: Code: C
Original Comment # 1

Comment: For each of the seventeen radioactive analytes listed in Table 4-4, Summary of Radiological Results by Boring and Depth, please include a column for the laboratory detection limit of each analyte sample. This would aid in comparing the results to the analytical procedures and help in understanding the data validation qualifier that was given for each sample.

Response: Laboratory detection limits were presented in the project specific Sampling and Analysis Plan (SAP). The SAP was included in the December 1992 report as Appendix A. The detection limits were established by DOE at the outset of the program and subsequently used by the analytical lab to adjust counting times of the routine analytical procedure.

It is inappropriate to include a programmatic detection limit in a separate column of the results table, because actual detection limits are matrix specific and vary from sample to sample. The analytical lab does not list detection limits for samples that have detectable results. Radiological values reported with a less-than symbol (and chemical values reported with a "U") are sample quantitation limits for individual non-detectable analyses. In cases where an analyte has detectable and non-detectable results, the ordered presentation of data by analyte in Tables 4-5 and 4-6 can act as guides to the routine detection limit.

Action: No action required.

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2. Commenting Organization: U.S. EPA Commentor: Gene Jablonowski
Section #: Table 4-6 Pg. #: Line #: Code: C
Original Comment # 2

Comment: Please explain why the "Data Validation Qualifier" column in Table 4-4, Summary of Radiological Results by Boring and Depth, lacks specific qualification (indicated by a "-" in the column) of some or all of the data for cesium-137, lead-210, potassium-40, radium-224, radium-226, radium-228, ruthenium-106, strontium-90, technetium-99, thorium-228, thorium-230, thorium-232, uranium-234, uranium-235/236, and uranium-238.

Response: A data validation qualifier is applied only if there is a reason to qualify the analytical result. The footnotes on page 4-61 explain the individual qualifiers for radiological results presented in Table 4-4; however, the dash (-) was inadvertently not defined. A dash indicates that "the analysis meets all requirements of the indicated analytical support level," in this case level V.

Action: The definition of the dash (-) has been added to the footnotes of Tables 4-4 and 4-6.

3. Commenting Organization: U.S EPA Commentor: Gene Jablonowski
Section #: Table 4-9 Pg. #: 4-217 Line #: Code: C
Original Comment # 3

Comment: In Table 4-9, Summary Statistics for Radiological Constituents, the sample geometric mean is 0.044 pCi/g for uranium-238 at the 0" to 6" depth while the range of detection is 0.85 pCi/g to 1.33 pCi/g. Please explain how the sample geometric mean can be an order of magnitude lower than the low end of the range detection.

Response: The reported geometric mean was a typographical error. See also the response to comment number 12.

Action: Table 4-9 has been updated with the correct value for the geometric mean.

4. Commenting Organization: U.S. EPA Commentor: Gene Jablonowski
Section #: Figure 4-5 Pg. #: 4-230, 4-241 Line #: Code: C
Original Comment # 4

Comment: For Figure 4-5, Histograms of Radionuclides, please indicate the purpose of the black bars for the thorium and isotope distributions.

Response: Non-detectable sample results were presented in the figures by shading the reported Sample Quantitation Limit (SQL) black. Detectable sample results were portrayed with a cross-hatch pattern. The purpose of the black shading was stated on page 4-200 of the December 1992 report.

Action: The following statement has been added to the bottom of each page of histograms that contain black shading: "Frequencies represented by black shading are based on Sample Quantitation Limits (SQLs) for non-detectable results. Cross-hatched frequencies are based on reported analytical results."

5. Commenting Organization: U.S. EPA Commentor: Gene Jablonowski
Section #: Table 6-1 Pg. #: 6-7, 6-9 Line #: Code: E
Original Comment # 5

Comment: For Table 6-1, Summary of Statistics, please indicate units for the mean and the upper 95% tolerance limit; include a column indicating the type of distribution (normal, lognormal, or undefined) for the constituent data; and a column indicating the type of mean calculated (arithmetic or geometric).

Response: Units were inadvertently left out of the column headings in the version of Table 6-1 sent to U.S. EPA.

Action: Units have been noted in each column heading and means have been distinguished as geometric or arithmetic.

6. Commenting Organization: U.S. EPA Commentor: Gene Jablonowski
Section #: Table 6-2 Pg. #: 6-12 Line #: Code: E
Original Comment # 6

Comment: In Table 6-2, Constituents that Display Statistically Significant Variations between Sampling Depths, it is stated for uranium-238 that "surface mean > subsurface means." On the other hand, Tables 4-9 and 6-1 states for uranium-238 that the subsurface means are greater than the surface mean. Please correct Table 6-2.

Response: The geometric mean for U-238 at 0 to 6 inches in Tables 4-9 and 6-1 was incorrectly reported due to a typographical error. The statement in Table 6-2 - "surface mean > subsurface means" - is correct.

Action: The final version of the report has the correct values for the geometric mean of U-238 at 0 to 6 inches. See also the response to comment response number 12.

General Comments

7. Commenting Organization: Commentor:
Section #: Pg. #: Line #: Code:
Original Comment # 1

Comment: The U.S. Environmental Protection Agency (EPA) attempted to replicate a few sample calculations of each type used in the study; these attempts were unsuccessful. In some cases, the differences were more substantial. It is not known whether these problems were due to data transcription problems or to errors in the calculation algorithms because the U.S. Department of Energy (DOE) does not adequately detail the methods it used. In general, the approach appears to be technically sound, but the report contains obvious errors. Enough information should be provided to allow EPA to replicate any calculation. The specific comments on data gaps presented below should be addressed.

Response: See responses to comment response numbers 12, 13 and 15.

Action: See actions in comment response numbers 12, 13 and 15.

8. Commenting Organization: Commentor:
Section #: Pg. #: Line #: Code:
Original Comment # 2

Comment: The radionuclide data for thorium and uranium is limited to isotopic analyses; no data is presented for total uranium or thorium. DOE has primarily used total uranium and thorium data to delineate contamination for the operable unit (OU) 2 remedial investigation (RI). In cases where total uranium or thorium data was not available, DOE estimated these values from isotopic values, assuming secular equilibrium. EPA's comments on the OU 2 RI report indicated that DOE should further justify this approach. However, EPA believes that it would be appropriate to document total uranium and thorium concentrations using compound-specific analytical data. If DOE cannot verify its methods for estimating total uranium and thorium from relative isotopic concentrations, DOE may have to document the cleanup for each isotope. DOE should consider this as a significant data gap.

Response: When analyzing for total uranium in a sample, be it a solid or a liquid, the requestor may or may not simultaneously request an analysis for isotopic uranium. A total uranium analysis determines the mass concentration of uranium in a sample but gives no information as to the isotopic distribution of uranium in the sample. The isotopic uranium analysis provides the activity concentration for the principal isotopes of uranium and if requested, can also be reported as a mass concentration.

Total uranium analyses may be used for two purposes. First, if the isotopic distribution is known, the less expensive total uranium analysis is useful in getting a larger data set for a fixed budget. Secondly, if the distribution of isotopes of uranium is not known and a total uranium is requested, the total uranium can serve as a quality control check on the isotopic uranium analysis.

Simply stated the isotopic uranium is the preferred analysis, especially when the isotopic distribution of uranium is unknown. No information can be gained from a total uranium analysis that cannot be known with similar or greater accuracy from an isotopic analysis. While isotopic uranium analyses are reported as activity concentration by isotope, the total mass concentration of uranium in a sample can be calculated by multiplying the activity concentration of each isotope by its specific activity (i.e., the activity of the isotope in a unit mass of that isotope). This does not give one an estimate of the mass concentration, it gives the mass concentration to the level of uncertainty of the analysis. This uncertainty is generally less for an isotopic analysis than for a total uranium analysis.

The following equation is used to calculate the mass concentration of uranium from the activity concentration of the three principal isotopes of uranium present in nature and processed at FEMP:

$$M_u = A_{U\text{-}238}/SpA_{U\text{-}238} + A_{U\text{-}235}/SpA_{U\text{-}235} + A_{U\text{-}234}/SpA_{U\text{-}234}$$

Where:

M_u is the mass concentration of uranium in the sample in units of micrograms of uranium per gram (µg/g) of soil.

$A_{U\text{-}238}$ is the activity concentration of U-238 in the sample by isotopic analysis in units of picocuries per gram (pCi/g) of soil.

$SpA_{U\text{-}238}$ is the specific activity of U-238 (0.336 picocuries per microgram of U-238)

$A_{U\text{-}235}$ is the activity concentration of U-235 in the sample by isotopic analysis in units of pCi/g of soil.

$SpA_{U\text{-}235}$ is the specific activity of U-235 (2.16 pCi/µg of U-235).

$A_{U\text{-}234}$ is the activity concentration of U-234 in the sample by isotopic analysis in units of pCi/g of soil.

$SpA_{U\text{-}234}$ is the specific activity of U-234 (6.25×10^3 pCi/µg of U-234).

The reviewer should note that greater than 99% of the mass of uranium in a typical FEMP sample comes from U-238. This is also true in nature. Also noteworthy is the fact that even with equal activity concentrations for U-238 and U-234 (i.e., secular equilibrium), very little mass is contributed by the U-234. This is due to the much shorter half-life of U-234 relative to U-238.

The case for thorium is similar but it should be noted that the reported total thorium from the contract laboratory is simply a different way of reporting the result of the isotopic thorium analysis. That is, no total thorium analysis is performed (nor necessary), the isotopic analysis is reported both as activity concentration and mass concentration. In the case of thorium, the isotope Th-232 accounts for approximately 100 percent of the thorium mass in almost all samples. Only in the most unusual circumstances is it necessary to calculate the mass contribution from the other thorium isotopes present. This again is due to the very long half-life of Th-232 when compared to the other isotopes. The specific activity for Th-232, Th-230, and Th-228 are 0.11 pCi/µg, 20,200 pCi/µg and 8.20×10^8 pCi/µg, respectively.

Action: Provide a mass concentration for uranium and thorium in the tables for the various sampling depths.

Specific Comments

9. Commenting Organization: Commentor:
Section #: 4.1, Table 4-1 Pg. #: Line #: Code:
Original Comment # 1

Comment: Discrepancies exist between the physical descriptions of sampling locations and the U.S. Department of Agriculture (USDA) soil classifications presented. First, the location of boring 1759 is described as nearly level, but its soil classification, EcE2, indicates moderately eroded, steeply sloping soil (USDA, 1951, Soil Survey Manual, USDA Handbook No. 18; Table 4-2 of the study). DOE should state whether this location was a relatively level portion of a generally sloping area. Second, the location of boring 1870 is described as gently sloping but is classified as MsD2, indicating that the location is moderately eroded and very strongly sloping; the location of boring 1974 is described as sloping but is classified as EcE2; and the location of boring 1977 is described as gently sloping but is classified as WyC2, indicating that the location is moderately eroded and moderately strongly sloping. These discrepancies should be addressed. Third, footnote 2 should include definitions for slope classification D and E.

Response: The "Description of Location" in Table 4-1 is the field geologists description noted during the field program for this project. The US Soil Conservation Service mapping is based on aerial photo analyses and field mapping and is more generalized than the field description collected during the sampling for this program. The Soil Conservation Service was tasked with mapping an entire county and transcribing the information to maps at 1;15,840 scale. The description of the field geologist is a more accurate description of the boring location than the Soil Conservation Service mapping. The Soil Conservation Service information is provided in the report for informational purposes, but should be considered secondary to the field description collected during the field program.

DOE recognizes that the footnotes were incomplete and did not adequately describe slope classifications D and E.

Action: The footnotes of Table 4-1 were corrected to include definitions for slope classifications D and E:

D = 15 to 25 percent slopes
E = 25 to 35 percent slopes

10. Commenting Organization: Commentor:
Section #: 4.3, Paragraph 1 Pg. #: 4-14 Line #: Code:
Original Comment # 2

Comment: DOE states that it included the lower of each pair of duplicate assays. This would tend to bias the estimate low, but that is acceptable for a background study such as this. However, spot checks of the duplicate data in Appendix F with the main data tables, 4-3 and 4-4, showed that DOE actually used the first sample of each pair of duplicates. These incorrect calculations were also carried forward for all later tabulations and calculations. DOE should correct the data tables and calculations appropriately.

Response: Each duplicate pair was collected at the same time but assigned different sample numbers. When it came time to choose one analysis from a duplicate pair, DOE consistently chose the lowest sample number and not the lowest analytical result. This method ensured that the sample set was not biased toward artificially low numbers. Note that the second sentence of paragraph two on page 4-14 of the December 1992 report says "In cases where duplicate soil samples were collected, the lowest sample (identification) number of a duplicate pair was chosen..."

Action: No action required.

11. Commenting Organization: Commentor:
Section #: 4.3, Tables 4-3 and 4-4 Pg. #: Line #: Code:
Original Comment # 3

Comment: Table 4-3 includes both laboratory and data validation qualifiers, while Table 4-4 contains only the latter. These table should have comparable formats; it is better to have only data validation qualifiers in the main text with the laboratory qualifiers and to relegate other data validation details to an appendix. Also, the qualifier M is used in Table 4-4 but is not defined in footnote c. DOE should add laboratory qualifiers, if applicable, to Table 4-4 or delete them from Table 4-3 and to define the qualifier M.

Response: The laboratory applies qualifiers to inorganic data but it does not apply qualifiers to radionuclide data; consequently, Table 4-3 has laboratory qualifiers and Table 4-4 does not. DOE contends that it is necessary to show all pertinent data in a format that allows the reader to easily review data. The laboratory qualifiers are necessary to evaluate the data and their presence does not detract from the readability of the text/table.

DOE inadvertently did not include the definition of the "M" qualifier in Table 4-4.

Action: DOE updated the footnote to include a definition of "M:" "The matrix spike percent recovery is not within the control limits of 70 to 130 percent."

12. Commenting Organization: Commentor:
Section #: 4.4.2 Pg. #: 4-199 Line #: Code:
Original Comment # 4

Comment: DOE should define all symbols used in the equations and the text. EPA tried to compare these equations with similar equations used in other methods of outlier assessment. It was difficult to evaluate the equations because the symbols are not defined, but there appear to be errors in the subscripts. DOE should check these equations to ensure their accuracy and should define all symbols used.

Response: DOE used "Rosner's Test for Detecting Outliers" (Gilbert, 1987, Section 15.3) to detect outliers. The equations used in Section 4.4.2 were correct; however, EPA may have had difficulty evaluating their accuracy because the symbols and limits on the summations were not defined.

Action: The text and equations have been modified to define all symbols used in equations. Additionally, an appendix will be added to the report. The appendix includes a brief discussion and example calculation for each statistical procedure, including Rosner's test for outliers. A revised Table 4-7 is attached to this comment response document. See also comment response number 13.

13. Commenting Organization: Commentor:
Section #: 4.4.3, Table 4-7 Pg. #: Line #: Code:
Original Comment # 5

Comment: All the symbols used in the formulas should be defined. Also, the formulas should be verified, especially those for the geometric mean and related terms. EPA did not recognize the formula given for the geometric mean (especially the undefined symbol S_y), and the formula EPA used (antilogarithm of the sum of the logarithms of the data points divided by the number of points) gave results different from those in Tables 4-8 and 4-9. Also, the same order should be used to list formulas in Table 4-7 and corresponding results in Tables 4-8 and 4-9.

Response: The equations presented in the December 1992 document were reviewed for accuracy and appropriateness. Based on this review, several of the equations were modified. The order of presentation in Table 4-7 has been revised to match the order of the results in Tables 4-8 and 4-9. A copy of the revised Table 4-7 is attached to this comment response. The statistical results of Tables 4-8 and 4-9 have been recalculated for cases where equations were modified. Copies of revised Tables 4-8 and 4-9 are attached to this comment response.

The equations for geometric mean and geometric standard deviation originally presented in Table 4-7 were improperly labeled. The equations in the December 1992 report represent an *estimate* of the true mean and standard deviation of a lognormal distribution. These equations were deleted and replaced with equations for determining the *true* geometric mean and geometric standard deviation. The equation for geometric mean that EPA defined in their comments was correct.

The equation for the upper 95 percent one sided confidence limit for normal distributions was modified to replace the Z statistic with the t statistic. For large sample sizes, such as those in this study, the Z and t values are approximately equal. The Z statistic was used in this case to maintain consistency with the use of the Z statistic in calculations of the 95 percent confidence interval for normal distributions.

The equations for the 95 percent confidence interval on the median (normal and lognormal distributions) were modified. The equation for the case of normal distributions was modified to match the original source. The equation for lognormal distributions was deleted, because the equation calculated an approximate result. For some cases of lognormal data, the equation gave an interval that did not include the median. A two-sided confidence interval for the true median of any continuous distribution can be obtained from tables if the data are not correlated. The 95% confidence intervals for lognormal distributions, shown in revised Tables 4-8 and 4-9 (attached), are calculated

from Table A-14 of Gilbert (1987). This table gives integer values corresponding to the observation whose value is the lower and upper limit of the confidence interval rank from an ordered data set.

Some data sets have low frequencies of detection or complex/unknown distributions and did not yield logical summary statistics when the standard statistical formulas were used for calculations. Because the statistical formulas are inappropriate for the data sets, the following treatments were used.

A) A number of data sets had no detectable values. In the case of naturally occurring constituents (e.g. antimony), the only available approximation of the true mean is one-half the arithmetic mean Sample Quantitation Limit (SQL), and the only available estimate of the true 95% Upper Tolerance Limit (95% UTL) is the arithmetic mean SQL. In the case of non-naturally occurring constituents (e.g. Sr-90 from atmospheric weapons testing), it is impossible to calculate a mean and 95% UTL.

B) A number of data sets had less-than-or-equal-to 10% detectable values. In this case, the best approximation of the true mean is to calculate the median (assuming that each nondetectable result is equal to one-half its SQL), and the best approximation of the 95% UTL is the maximum detectable value.

C) A number of undefined and lognormal data sets had geometric standard deviations greater than 2.00 and geometric means that did not fall within the 95% confidence interval for the mean. In these cases, the 95% UTL was several times higher than the maximum detected concentration. This occurred primarily to data sets with a large number of nondetectable values and/or a very wide range of detection. For such data, the median and the 95% confidence interval for the median is the best approximation of the true mean, and the maximum detectable result is the best available representation of the true 95% UTL.

Action: Tables 4-7, 4-8 and 4-9 have been modified to reflect changes to equations and recalculated statistical results. To clarify the use of equations, an appendix has been added to the report that shows a sample calculation for each statistic.

14. Commenting Organization: Commentor:
Section #: 4.4.3, Figures 4-5 and 4-6 Pg. #: Line #: Code:
Original Comment # 6

Comment: These figures are useful, but the significance of the solid and cross-hatched bars (apparently nondetect and detect results, respectively) should be defined. Also, EPA spot-checked six histograms and found errors in two (thorium-232 and arsenic in samples from 36 to 42 inches depth); DOE should check and correct all histograms after Tables 4-3 and 4-4 are corrected. Finally, the inorganic data (Figure 4-6) should precede the radionuclide data (Figure 4-5) as done elsewhere in the study.

Response: See comments response number 4 for a discussion of the shading of histograms.

DOE concurs that several minor errors are present in the histograms.

DOE agrees that inorganic data should be presented before radiological data as is done throughout the rest of the document.

Action: See comment response number 4 for resolution of the definition of shading in histograms.

DOE has reviewed the histograms and corrected any errors in the figures.

Figure original 4-6 has been renamed Figure 4-5 and, vice-versa, original Figure 4-5 has been renamed Figure 4-6.

15. Commenting Organization: Commentor:
Section #: 4.4.4, Paragraph 2 Pg. #: 4-279, Line #: Code:
Original Comment # 7

Comment: DOE states that nonparametric analysis of variance (ANOVA) techniques were used because so many data sets were not normally distributed. However, this paragraph and Table 4-10 describe and use the parametric F-test. (The F-distribution is the ratio of two chi-square distributions, each divided by its degrees of freedom; the chi-square distribution is a special case of the gamma distribution.) DOE should clarify this discrepancy.

Also, DOE should use the ANOVA calculations to evaluate the subsurface soil in groupings other than by depth. For instance, the data should be sorted by glaciofluvial deposits, till, or soil classification rather than by depth. With only 30 samples in 10 classifications, this data sorting may not be effective for small data sets. However,grouping into soil associations would provide insight into the differing characteristics of the various soils that can then be applied to on-site investigations.

Response: DOE recognizes that there was a discrepancy between the text and the defined equations.

The intent of the background study was to treat the glacial overburden in bulk. Consequently, the work plan outlined that soil background would be investigated in terms of weathering only, i.e. analyzed by depth. The classification of samples according to USCS soil type was made qualitatively by the field geologist and no quantitative grain size analyses were performed. Consequently, DOE cannot create quantitative groupings of soil types. DOE believes it is inappropriate to perform ANOVA on the two qualitative groupings of subsurface soil samples. The histograms of individual analytes grouped according to soil type provide a qualitative tool for interested readers to investigate possible differences in concentration that may be due to grain size/soil type. A review of the histograms does not identify any analytes that show dramatic visual differences in concentration vs soil type like the dramatic visual differences that are noted in histograms of concentration vs depth (e.g. lead).

Action: DOE has refined the ANOVA calculations presented in the original report. The final report 1) applies parametric ANOVA for normal distributions, 2) applies parametric

ANOVA for log transformed lognormal data, and 3) uses the Kruskal-Wallis test for mixed distributions. Section 4.4.4 has been revised to better explain ANOVA and the Kruskal-Wallis test. Additionally, a discussion of the applicability of ANOVA techniques has been included with sample calculations in an appendix.

16. Commenting Organization: Commentor:
Section #: 6.0, Paragraph 2 Pg. #: 6-1 Line #: Code:
Original Comment # 8

Comment: This text introduces the summary table of background results. This table will be used to define background values for various future reports. Therefore, DOE should define which of the many statistics give in Table 4-7 it is using and should justify its choice. For example, it should explain which mean and upper tolerance limits are included in Table 6-1 and why.

Response: The intent of the background study was to establish a set of statistics to describe the background nature of soils. The intent was not to establish one list of numbers that all workers, be they RCRA or CERCLA, would use. DOE envisions that every program on site will have its own needs for background - some programs may be dealing only with surface soils and would choose surface soil values from the background report, and other programs will be dealing with subsurface soils and will choose subsurface values from the background report. The final authoritative Tables in the report should be Tables 4-8 and 4-9. Table 6-1 in the conclusions section is a summary table only.

Action: No action required.

17. Commenting Organization: Commentor:
Section #: 6.0, Paragraph 3 Pg. #: 6-1 Line #: Code:
Original Comment # 9

Comment: Most of the significant variations between soil layers may be explained by two seemingly separate mechanisms:

- The surface excess of members of the actinide decay chains is due to concentration from loss of carbonate.
- The surface deficiency of lighter metals (alkalis, alkaline earths, and transition metals) is due to natural leaching.

These two mechanisms may be linked by the relative abundance of certain metals and their respective stable mineral phases; for example, lower concentrations of calcite, dolomite, and siderite could be associated with lower concentrations of calcium, magnesium, and iron in leached soils. DOE should provide further explanation of the increase abundance of radionuclides with reference to the minerals found in the soils discussed in this study. Also, this section's explanation of variance should appear in Section 4.4 or Section 5.0.

Response: EPA is correct in their paraphrasing of DOE: the surface excess of actinide decay chain members is most likely a result of concentration due to carbonate loss, and the surface deficiency of lighter metals is most likely a result of natural leaching.

DOE did not perform mineralogical analyses. Detailed mineralogical analyses for soil profiles are not known to the DOE. The US SCS report presents data that confirms DOEs results, i.e. carbonate loss and leaching of light metals has occurred in surface soils of Butler County.

Action: Section 6 has been revised to reference the statements of the US SCS regarding carbonate loss in surface soils.

18. Commenting Organization: Commentor:
Section #: 6.0, Table 6-2 Pg. #: Line #: Code:
Original Comment # 10

Comment: A possible explanation for the excess of uranium, thorium, and their daughters in the surface soil is volume reduction because of carbonate loss. To evaluate this possibility, DOE should consider analyzing portions of the remaining soil samples for carbonate.

Response: DOE does not intend to analyze remaining soil for mineralogy. The US SCS report for Butler County contains data that confirms DOEs conclusions for the ANOVA results. See comment response number 17.

Action: No action required. See action for comment response number 17.

19. Commenting Organization: Commentor:
Section #: Appendices Pg. #: Line #: Code:
Original Comment # 11

Comment: The appendices should be paginated. This would ensure that copies are complete (Appendix E lacks pages for the first and last borings, 1755 and 1879) and in order (the duplicate data in Appendix F is thoroughly scrambled). Before page numbers are added, the appendices should be checked for completeness to avoid errors (like the omission three pages of thorium data from Table 4-6).

Response: DOE regrets that pages disordered or dropped during photocopying.

Action: DOE has checked for completeness and applied page numbers to the appendices.

20. Commenting Organization: Commentor:
Section #: Appendix F Pg. #: Line #: Code:
Original Comment # 12

Comment: This appendix should include the data validator's complete discussion of the quality control results and their significance. Relevant parts of this discussion should be summarized in Section 4.4.2 of the text.

Response: Rinsates, reagent blanks and bottle blanks were evaluated in the data validation process. Blind soil duplicates were not used in the data validation process.

Action: Section 4.4.2 has been revised to include a discussion of how quality control samples were used in the data validation process.

Table 4-7. Formulas for Summary Statistics

Statistic	Formula
Shapiro-Wilk Test (Gilbert 1987, Equations 12.3 and 12.4)	$$W = \frac{1}{d}\left[\sum_{i=1}^{k} a_i \left(x_{(n-i+1)} - x_{(i)}\right)\right]^2$$ where: $$d = \sum_{i=1}^{n} x_i^2 - \frac{1}{n}\left(\sum_{i=1}^{n} x_i\right)^2$$ $k = \frac{n}{2}$ if n is even $= \frac{n-1}{2}$ if n is odd a_i = Shapiro-Wilk coefficient x_i = i^{th} data value in the ranked data set x_i^2 = square of the ith data value in the ranked data set n = number of data points
Arithmetic Mean (Gilbert 1987, Equation 4.3)	$$\bar{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$$ where: n = number of data points x_i = data set value $\bar{x}$ = arithmetic mean
Arithmetic Standard Deviation (Gilbert 1987, Equation 4.4)	$$s^2 = \frac{1}{n-1}\sum_{i=1}^{n}(x_i - \bar{x})^2$$ $$s = \sqrt{s^2}$$ where: n = number of data points x_i = data set value $\bar{x}$ = arithmetic mean s^2 = arithmetic variance s = arithmetic standard deviation
Geometric Mean (Gilbert 1987, Equation 13.1)	$$\bar{y} = \frac{1}{n}\sum_{i=1}^{n} y_i$$ $$x_g = \exp(\bar{y})$$ where: n = number of data points y_i = ln transform of the data set value = ln x_i $\bar{y}$ = arithmetic mean of the ln transformed data x_g = geometric mean

Table 4-7. continued

Statistic	Formula
Geometric Standard Deviation (Gilbert 1987, Equation 13.2)	$s_y^2 = \frac{1}{n-1} \sum_{i=1}^{n} (y_i - \bar{y})^2$ $s_y = \sqrt{s_y^2} \qquad s_g = \exp(s_y)$ where: n = number of data points y_i = ln transform of the data set value = ln x_i $\bar{y}$ = arithmetic mean of the ln transformed data s_y^2 = arithmetic variance of the ln transformed data s_y = arithmetic standard deviation of the ln transformed data s_g = geometric standard deviation
95% Confidence Interval on the Mean for Normal Distribution (Gilbert 1987, Equation 11.6 and 11.7)	$\bar{x} - t_{0.975,n-1} \frac{s}{\sqrt{n}} < \mu < \bar{x} + t_{0.975,n-1} \frac{s}{\sqrt{n}}$ where $\bar{x}$ = arithmetic mean $t_{0.975,n-1}$ = student t distribution value n = number of data points s = arithmetic standard deviation μ = true mean
95% Confidence Interval on the Arithmetic Mean for Lognormal (Gilbert 1987, Equation 13.13 and 13.14)	$\exp\left(\bar{y} + 0.5\, s_y^2 + \frac{s_y H_{0.025}}{\sqrt{n-1}}\right) < \exp(\mu) <$ $\exp\left(\bar{y} + 0.5\, s_y^2 + \frac{s_y H_{0.975}}{\sqrt{n-1}}\right)$ where: $\bar{y}$ = arithmetic mean of the ln transformed data s_y^2 = arithmetic variance of the ln transformed data s_y = arithmetic standard deviation of the ln transformed data H = value used to compute one-sided confidence limit on a lognormal mean n = number of data points exp (μ) = true mean

Table 4-7. continued

Statistic	Formula
Upper 95% One-Sided Confidence Limit on the Mean for Normal Distribution (Gilbert 1987, Equation 11.6)	$$UCL_{0.95} = \bar{x} + t_{0.95,n-1} \frac{s}{\sqrt{n}}$$ where: $\bar{x}$ = arithmetic mean $t_{0.95,n-1}$ = student t distribution value n = number of data points s = standard deviation
Upper 95% One-Sided Confidence Limit on the Arithmetic Mean for Lognormal Distribution (Gilbert 1987, Equation 13.13)	$$UCL_{0.95} = \exp\left(\bar{y} + 0.5\, s_y^2 + \frac{s_y H_{0.95}}{\sqrt{n-1}}\right)$$ $\bar{y}$ = arithmetic mean of the ln transformed data s_y^2 = arithmetic variance of the ln transformed data s_y = arithmetic standard deviation of the ln transformed data $H_{0.95}$ = value used to compute one-sided confidence limit on a lognormal mean n = number of data points
Nonparametic Median (Gilbert 1987, Equation 13.15 and 13.16)	If n is odd: $$median = x_{[(n+1)/2]}$$ If n is even: $$median = \frac{1}{2}\left(x_{[n/2]} + x_{[(n+2)/2]}\right)$$ where: x = value of the data point at the specific positions in the data set sorted in ascending order n = number of data points
95% Confidence Interval on the Nonparametic Median for Normal Distribution (Gilbert 1987, Equation 13.21 and 13.22)	$$L = \left(\frac{n + 1 - Z_{0.975}\sqrt{n}}{2}\right)$$ $$U = \left(\frac{n + 1 + Z_{0.975}\sqrt{n}}{2}\right)$$ where: n = number of data points (i.e., n ≥ 20) If n < 20 see Appendix G for procedure $Z_{0.975}$ = Z distribution value for the 97.5% confidence limit for one-tailed test (95% confidence limit for two-tailed test) L = rank corresponding to the observation whose value is the lower limit of the confidence interval) U = rank corresponding to the observation whose value is the upper limit of the confidence interval)

Table 4-7. continued

Statistic	Formula
95% Confidence Interval on the Nonparametric Median for Lognormal Distribution (Gilbert 1987, Equation 13.4)	See Appendix G
Upper 95% Tolerance Limit for the 95th Quantile for Normal Distribution (Gilbert 1987, Equation 11.2)	$UTL_{0.95} = \bar{x} + K_{0.95,0.95}$ where: $\bar{x}$ = arithmetic mean s = arithmetic standard deviation K = factor for estimating upper 95 percent confidence limit for the true 95th quantile
Upper 95% Tolerance Limit for Lognormal Distribution (Gilbert 1987, Equation 13.24)	$UTL_{0.95} = \exp(\bar{y} + s_y Z_{0.95})$ where: $UTL_{0.95}$ = 95% confidence limit for the 95th quantile $\bar{y}$ = arithmetic mean of the ln transformed data s_y = arithmetic standard deviation of the ln transformed data $Z_{0.95}$ = Z distribution value for the 95% confidence limit for one-tailed test
Analysis of variance for normal and lognormal data	See Appendix G
Analysis of variance for Kruskal-Wallis Test	$K_w = \left[\frac{12}{m(m+1)} \sum_{j=1}^{k} \frac{R_j^2}{n_j}\right] - 3(m+1)$ $K'_w = \frac{K_w}{1 - \frac{1}{m(m^2-1)} \sum_{i=1}^{g} t_j (t_j^2 - 1)}$ where: m = total number of data values over all data sets R_j = sum of ranks of the j th data set n_j = number of values in the j th data set k = number of data sets K_w = Kruskal-Wallis value when there are no ties in the ranks K'_w = modified Kruskal-Wallis value for ties in the ranks g = number of groups with ties t_j = number of ties in the j th group

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Table 4-8: Summary Statistics for Inorganic Constituents (all values are reported in mg/kg)

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Aluminum												
0" - 6"	30/30	5350 - 15000	Lognormal	N/A	N/A	7863	1.29	7408 - 8953	8800	7455	6710 - 8570	11880
36" - 42"	30/30	3300 - 15900	Lognormal	N/A	N/A	8453	1.53	7935 - 11048	10700	9005	6960 - 10800	16967
48" - 54"	21/21	3250 - 16100	Lognormal	N/A	N/A	7304	1.53	6651 - 10008	9596	7460	5870 - 9930	14742
Glaciofluvial	17/17	3300 - 16100	Lognormal	N/A	N/A	6767	1.55	6026 - 9711	9227	6410	5260 - 8350	13947
Till	32/32	4280 - 15900	Lognormal	N/A	N/A	9114	1.41	8574 - 11071	10813	9800	7770 - 11100	16115
Antimony												
0" - 6"	0/22[a]	Avg SQL = 7.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36" - 42"	0/22[a]	Avg SQL = 6.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
48" - 54"	0/15[a]	Avg SQL = 6.7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glaciofluvial	0/15[a]	Avg SQL = 6.4	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Till	0/21[a]	Avg SQL = 6.8	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Arsenic												
0" - 6"	26/26	3.40 - 9.20	Lognormal	N/A	N/A	5.18	1.35	4.82 - 6.14	6.00	5.05	4.20 - 5.80	8.45
36" - 42"	26/26	2.70 - 14.50	Lognormal	N/A	N/A	5.33	1.50	4.94 - 6.95	6.72	5.00	4.20 - 5.80	10.35
48" - 54"	18/18	1.60 - 8.40	Lognormal	N/A	N/A	4.32	1.54	3.88 - 6.11	5.82	4.55	3.90 - 5.50	8.82
Glaciofluvial	14/14	3.50 - 10.60	Lognormal	N/A	N/A	5.22	1.34	4.63 - 6.55	6.33	5.00	4.00 - 6.00	8.48
Till	28/28	1.60 - 14.50	Lognormal	N/A	N/A	4.93	1.57	4.61 - 6.66	6.42	4.70	4.10 - 5.80	10.37

Table 4-8. continued

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Barium												
0" - 6"	30/30	31.00 - 331.00	Undefined	N/A	N/A	61.95	1.54	58.19 - 81.55	78.93	61.55	48.20 - 69.70	126.09
0" - 6" with suspected outlier deleted[b]	29/29	31.00 - 94.10	Lognormal	N/A	N/A	58.48	1.35	54.75 - 68.90	67.48	59.90	48.20 - 69.70	95.66
36" - 42"	30/30	13.70 - 134.00	Lognormal	N/A	N/A	56.30	1.69	53.41 - 81.21	77.88	54.40	45.60 - 66.20	133.21
48" - 54"	21/21	16.30 - 123.00	Lognormal	N/A	N/A	45.30	1.61	41.28 - 64.96	62.00	48.30	38.70 - 55.00	98.72
Glaciofluvial	17/17	13.70 - 104.00	Lognormal	N/A	N/A	41.56	1.68	37.02 - 65.99	61.84	45.10	32.50 - 54.60	97.40
Till	32/32	28.80 - 134.00	Undefined	N/A	N/A	60.44	1.53	57.03 - 78.66	76.32	56.85	47.10 - 66.20	122.24
Beryllium												
0" - 6"	1/30[c]	0.60 - 0.60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.26	N/A	N/A
36" - 42"	9/30	0.48 - 0.65	Undefined	N/A	N/A	0.29	1.58	0.27 - 0.38	0.37	0.23	0.23 - 0.24	0.61
48" - 54"	6/20	0.49 - 0.68	Undefined	N/A	N/A	0.29	1.60	0.27 - 0.42	0.40	0.23	0.22 - 0.49	0.63
Glaciofluvial	2/17	0.62 - 0.68	Undefined	N/A	N/A	0.24	1.52	0.21 - 0.33	0.32	0.23	0.22 - 0.23	0.47
Till	13/32	0.48 - 0.65	Undefined	N/A	N/A	0.32	1.57	0.30 - 0.43	0.41	0.24	0.23 - 0.52	0.68
Boron												
0" - 6"	12/30	12.60 - 1140.00	Undefined	N/A	N/A	10.70	2.71[d]	N/A	N/A	N/A	N/A	N/A
0" - 6" with suspected outlier deleted[e]	11/29	12.60 - 25.40	Undefined	N/A	N/A	9.11	1.61	8.57 - 12.52	12.07	6.70	6.40 - 13.70	19.97
36" - 42"	28/30	18.60 - 47.10	Normal	28.40	9.23	N/A	N/A	24.96 - 31.85	31.27	28.65	24.80 - 33.90	48.90
48" - 54"	21/21	19.90 - 45.90	Lognormal	N/A	N/A	29.97	1.24	27.90 - 34.05	33.41	29.70	25.50 - 35.20	42.76
Glaciofluvial	17/17	19.60 - 39.60	Lognormal	N/A	N/A	29.73	1.23	27.42 - 34.06	33.34	29.50	25.90 - 35.20	41.84
Till	30/32	18.60 - 47.10	Normal	28.58	9.12	N/A	N/A	25.29 - 31.87	31.31	28.65	25.50 - 33.90	48.62

Table 4-8. continued

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Cadmium												
0" - 6"	6/29	0.52 - 0.95	Undefined	N/A	N/A	0.32	1.53	0.30 - 0.41	0.40	0.26	0.25 - 0.27	0.64
36" - 42"	4/29	0.63 - 1.30	Undefined	N/A	N/A	0.27	1.73	0.25 - 0.40	0.38	0.23	0.22 - 0.24	0.66
36" - 42" with suspected outlier deleted[f]	2/27[c]	0.63 - 0.91	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23	N/A	N/A
48" - 54"	2/20[c]	0.47 - 0.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23	N/A	N/A
Glaciofluvial	1/17[c]	0.59 - 0.59	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23	N/A	N/A
Till	5/30	0.47 - 1.30	Undefined	N/A	N/A	0.28	1.68	0.27 - 0.40	0.39	0.23	0.23 - 0.24	0.66
Till with suspected outlier deleted[g]	3/28	0.47 - 0.91	Undefined	N/A	N/A	0.25	1.42	0.24 - 0.31	0.30	0.23	0.23 - 0.24	0.45
Calcium												
0" - 6"	30/30	856 - 5340	Lognormal	N/A	N/A	1900	1.65	1797 - 2685	2580	1760	1410 - 2250	4339
36" - 42"	30/30	3310 - 191000	Undefined	N/A	N/A	53113	3.59[h]	N/A	N/A	93550	67800 - 105000	N/A
48" - 54"	21/21	7440 - 335000	Undefined	N/A	N/A	92432	2.05[h]	N/A	N/A	108000	88900 - 117000	N/A
Glaciofluvial	17/17	6990 - 150000	Normal	96782	36780	N/A	N/A	77871 - 115693	112356	105000	85800 - 118000	188218
Till	32/32	3310 - 191000	Undefined	N/A	N/A	55137	3.44[h]	NA	NA	95650	70600 - 111000	N/A
Chromium												
0" - 6"	30/30	6.70 - 17.70	Lognormal	N/A	N/A	10.43	1.27	9.83 - 11.80	11.60	9.85	9.00 - 11.10	15.50
36" - 42"	30/30	4.60 - 20.00	Lognormal	N/A	N/A	10.95	1.53	10.28 - 14.32	13.87	11.55	8.80 - 13.50	22.00
48" - 54"	21/21	4.50 - 22.40	Lognormal	N/A	N/A	9.62	1.51	8.77 - 12.97	12.46	9.70	7.90 - 13.30	18.87
Glaciofluvial	17/17	4.70 - 22.40	Lognormal	N/A	N/A	9.05	1.54	8.06 - 12.84	12.21	8.80	7.10 - 10.40	18.32
Till	32/32	6.50 - 20.00	Lognormal	N/A	N/A	11.77	1.41	11.07 - 14.25	13.93	12.25	9.70 - 13.60	20.68

Table 4-8. continued

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Cobalt												
0" - 6"	30/30	4.30 - 16.50	Lognormal	N/A	N/A	9.66	1.32	9.08 - 11.17	10.96	9.70	8.90 - 11.60	15.17
36" - 42"	30/30	4.50 - 16.50	Lognormal	N/A	N/A	8.79	1.43	8.24 - 10.84	10.56	8.65	7.40 - 10.80	15.85
48" - 54"	21/21	3.60 - 17.90	Lognormal	N/A	N/A	8.13	1.49	7.40 - 10.86	10.37	8.00	6.60 - 10.30	15.68
Glaciofluvial	17/17	4.50 - 14.80	Lognormal	N/A	N/A	7.35	1.40	6.60 - 9.42	9.08	7.30	5.90 - 8.80	12.75
Till	32/32	4.70 - 17.90	Lognormal	N/A	N/A	9.63	1.38	9.06 - 11.51	11.26	9.15	8.20 - 11.40	16.43
Copper												
0" - 6"	27/30	3.20 - 17.30	Normal	7.33	4.10	N/A	N/A	5.80 - 8.86	8.60	6.25	5.30 - 8.50	16.43
36" - 42"	30/30	7.00 - 24.30	Lognormal	N/A	N/A	12.47	1.38	11.69 - 14.97	14.63	12.00	10.70 - 14.10	21.22
48" - 54"	20/21	6.80 - 16.80	Normal	11.18	3.11	N/A	N/A	9.77 - 12.60	12.35	10.20	9.80 - 12.40	18.55
Glaciofluvial	17/17	8.40 - 19.00	Lognormal	N/A	N/A	11.17	1.25	10.25 - 12.96	12.67	11.00	9.70 - 12.30	16.17
Till	32/32	6.80 - 24.30	Lognormal	N/A	N/A	12.58	1.37	11.84 - 14.91	14.60	12.80	10.40 - 14.90	21.03
Cyanide												
0" - 6"	12/30	0.14 - 0.29	Undefined	N/A	N/A	0.10	1.74	0.09 - 0.15	0.14	0.07	0.07 - 0.15	0.25
36" - 42"	2/30[c]	0.17 - 5.60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.06	N/A	N/A
48" - 54"	0/21[a]	Avg SQL = 0.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glaciofluvial	1/17[c]	5.60 - 5.60	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.06	N/A	N/A
Till	1/32[c]	0.17 - 0.17	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.06	N/A	N/A

Table 4-8. continued

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Iron												
0" - 6"	30/30	9370 - 24900	Lognormal	N/A	N/A	14465	1.30	13608 - 16607	16311	14500	12200 - 16500	22323
36" - 42"	30/30	8970 - 30700	Lognormal	N/A	N/A	18120	1.44	16976 - 22451	21870	18400	14600 - 22100	33026
48" - 54"	21/21	9360 - 30500	Lognormal	N/A	N/A	16267	1.39	14886 - 20222	19621	15600	13300 - 21400	27853
Glaciofluvial	17/17	9360 - 29600	Lognormal	N/A	N/A	14858	1.41	13340 - 19144	18449	13700	11400 - 17600	26020
Till	32/32	10700 - 30700	Lognormal	N/A	N/A	19419	1.36	18287 - 22944	22461	20150	15800 - 23400	32137
Lead												
0" - 6"	28/28	11.00 - 36.40	Lognormal	N/A	N/A	17.22	1.27	16.19 - 19.55	19.22	17.70	14.60 - 18.50	25.57
0" - 6" with suspected outlier deleted[i]	27/27	11.00 - 23.80	Lognormal	N/A	N/A	16.75	1.21	15.83 - 18.46	18.21	17.70	14.30 - 18.50	23.04
36" - 42"	28/28	5.20 - 18.40	Lognormal	N/A	N/A	9.06	1.42	8.45 - 11.17	10.88	8.25	7.40 - 11.30	16.13
48" - 54"	19/19	3.00 - 13.00	Lognormal	N/A	N/A	7.34	1.44	6.64 - 9.51	9.18	7.00	6.70 - 10.00	13.35
Glaciofluvial	15/15	5.20 - 15.20	Lognormal	N/A	N/A	8.19	1.34	7.32 - 10.19	9.85	7.60	6.70 - 10.10	13.21
Till	30/30	3.60 - 18.40	Lognormal	N/A	N/A	8.80	1.43	8.25 - 10.83	10.56	8.10	7.30 - 10.06	15.85
Magnesium												
0" - 6"	30/30	1020 - 3590	Undefined	N/A	N/A	1646	1.37	1543 - 1969	1924	1555	1340 - 1860	2777
36" - 42"	30/30	2930 - 54100	Undefined	N/A	N/A	13848	2.43[h]	N/A	N/A	16300	8120 - 27700	N/A
48" - 54"	21/21	5540 - 44100	Normal	23951	11661	N/A	N/A	18644 - 29259	28340	27600	16300 - 29800	51599
Glaciofluvial	17/17	3370 - 42300	Normal	25215	11262	N/A	N/A	19425 - 31005	29983	27700	16500 - 32100	53211
Till	32/32	2930 - 44100	Lognormal	N/A	N/A	13245	2.25[h]	N/A	N/A	14300	8120 - 27100	N/A

Table 4-8. continued

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Manganese												
0" - 6"	30/30	189 - 4850	Lognormal	N/A	N/A	650	1.84	626 - 1035	983	562	481 - 785	1772
0" - 6" with suspected outlier deleted[j]	29/29	189 - 1500	Lognormal	N/A	N/A	606	1.63	571 - 840	809	543	456 - 785	1348
36" - 42"	30/30	251 - 1410	Lognormal	N/A	N/A	532	1.55	500 - 706	683	510	387 - 621	1099
48" - 54"	21/21	288 - 1750	Undefined	N/A	N/A	468	1.53	426 - 639	613	420	356 - 483	940
Glaciofluvial	17/17	301 - 1040	Undefined	N/A	N/A	436	1.43	391 - 569	548	406	352 - 472	781
Till	32/32	288 - 1750	Undefined	N/A	N/A	561	1.56	530 - 741	718	548	378 - 667	1170
Mercury												
0" - 6"	1/30[c]	0.30 - 0.30	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.07	N/A	N/A
36" - 42"	0/30[a]	Avg SQL = 0.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
48" - 54"	1/21[c]	0.29 - 0.29	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.06	N/A	N/A
Glaciofluvial	0/17[a]	Avg SQL = 0.11	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Till	1/32[c]	0.29 - 0.29	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.06	N/A	N/A
Molybdenum												
0" - 6"	0/30[a]	Avg SQL = 2.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36" - 42"	0/30[a]	Avg SQL = 2.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
48" - 54"	1/21[c]	2.70 - 2.70	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.1	N/A	N/A
Glaciofluvial	1/17[c]	2.70 - 2.70	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1.1	N/A	N/A
Till	0/32[a]	Avg SQL = 2.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

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Table 4-8. continued

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Nickel												
0" - 6"	29/30	5.80 - 22.70	Lognormal	N/A	N/A	9.66	1.60	9.10 - 13.12	12.67	9.35	7.30 - 11.90	20.87
36" - 42"	30/30	11.00 - 41.90	Lognormal	N/A	N/A	20.10	1.48	18.84 - 25.39	24.69	19.55	16.90 - 22.20	38.14
48" - 54"	21/21	8.50 - 32.40	Lognormal	N/A	N/A	16.58	1.39	15.17 - 20.61	19.99	16.30	13.50 - 19.60	28.37
Glaciofluvial	17/17	8.50 - 26.40	Lognormal	N/A	N/A	15.43	1.34	13.95 - 18.89	18.34	15.30	12.60 - 17.50	24.90
Till	32/32	10.50 - 41.90	Lognormal	N/A	N/A	21.22	1.42	19.96 - 25.89	25.28	19.90	17.20 - 24.90	37.89
Potassium												
0" - 6"	29/30	374 - 1590	Normal	742	297	N/A	N/A	631 - 853	834	663	561 - 816	1402
36" - 42"	30/30	349 - 2140	Lognormal	N/A	N/A	923	1.56	867 - 1226	1186	834	743 - 1160	1911
48" - 54"	21/21	340 - 2180	Lognormal	N/A	N/A	989	1.58	901 - 1400	1338	942	753 - 1430	2109
Glaciofluvial	17/17	349 - 2120	Lognormal	N/A	N/A	824	1.53	735 - 1167	1111	811	608 - 1090	1663
Till	32/32	587 - 2180	Undefined	N/A	N/A	1074	1.49	1012 - 1357	1321	1155	796 - 1310	2069
Selenium												
0" - 6"	1/30[c]	0.72 - 0.72	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.39	N/A	N/A
36" - 42"	0/30[a]	Avg SQL = 0.64	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
48" - 54"	0/21[a]	Avg SQL = 0.61	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glaciofluvial	0/17[a]	Avg SQL = 0.58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Till	0/32[a]	Avg SQL = 0.66	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4-8. continued

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Silicon												
0" - 6"	30/30	15.1 - 2230	Normal	1114	392	N/A	N/A	967 - 1260	1235	1085	927 - 1290	1984
0" - 6" with suspected outlier deleted[k]	29/29	480 - 2230	Lognormal	N/A	N/A	1105	1.34	681 - 1299	1273	1110	927 - 1310	1797
36" - 42"	30/30	449 - 1540	Lognormal	N/A	N/A	945	1.33	887 - 1103	1081	990	795 - 1080	1519
48" - 54"	21/21	467 - 1850	Lognormal	N/A	N/A	892	1.48	812 - 1172	1130	846	722 - 1270	1696
Glaciofluvial	17/17	539 - 1850	Lognormal	N/A	N/A	829	1.38	746 - 1052	1016	794	723 - 879	1412
Till	32/32	449 - 1540	Lognormal	N/A	N/A	1009	1.35	950 - 1186	1162	1050	951 - 1260	1654
Silver												
0" - 6"	0/30[a]	Avg SQL = 2.6	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36" - 42"	0/30[a]	Avg SQL = 2.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
48" - 54"	0/21[a]	Avg SQL = 2.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glaciofluvial	0/17[a]	Avg SQL = 2.2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Till	0/32[a]	Avg SQL = 2.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sodium												
0" - 6"	27/30	26.90 - 54.70	Normal	34.34	10.19	N/A	N/A	30.53 - 38.14	37.50	33.95	30.70 - 38.60	56.96
36" - 42"	30/30	53.80 - 305.00	Lognormal	N/A	N/A	118.78	1.51	111.45 - 154.07	149.32	109.50	103.00 - 138.00	234.92
48" - 54"	21/21	90.40 - 345.00	Undefined	N/A	N/A	129.00	1.34	118.38 - 155.24	151.31	129.00	108.00 - 135.00	209.19
Glaciofluvial	17/17	64.30 - 345.00	Undefined	N/A	N/A	118.71	1.40	106.68 - 152.12	146.70	111.00	102.00 - 131.00	205.85
Till	32/32	53.80 - 305.00	Lognormal	N/A	N/A	125.31	1.49	118.03 - 158.36	154.13	117.00	107.00 - 143.00	241.36

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Table 4-8. continued

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Thallium												
0" - 6"	1/30[c]	0.58 - 0.58	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.26	N/A	N/A
36" - 42"	3/30[c]	0.49 - 0.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23	N/A	N/A
48" - 54"	0/21[a]	Avg SQL = 0.43	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glaciofluvial	0/17[a]	Avg SQL = 0.42	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Till	3/32[c]	0.49 - 0.55	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23	N/A	N/A
Till with suspected outlier deleted[l]	1/30[c]	0.49 - 0.49	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.23	N/A	N/A
Vanadium												
0" - 6"	30/30	11.30 - 32.70	Lognormal	N/A	N/A	19.76	1.30	18.59 - 22.65	22.25	19.20	17.60 - 23.60	30.37
36" - 42"	30/30	8.70 - 44.50	Lognormal	N/A	N/A	18.00	1.61	16.98 - 24.66	23.78	15.10	13.60 - 25.50	39.49
48" - 54"	21/21	8.40 - 40.20	Undefined	N/A	N/A	15.82	1.62	14.43 - 22.89	21.83	13.30	11.40 - 24.10	34.97
Glaciofluvial	17/17	8.40 - 40.20	Lognormal	N/A	N/A	15.42	1.60	13.72 - 22.91	21.69	13.10	11.90 - 23.80	33.55
Till	32/32	10.40 - 44.50	Undefined	N/A	N/A	18.76	1.59	17.75 - 25.11	24.30	16.15	13.60 - 25.60	40.07
Zinc												
0" - 6"	30/30	29.40 - 70.00	Undefined	N/A	N/A	39.99	1.27	37.71 - 45.29	44.55	38.90	34.50 - 42.90	59.61
36" - 42"	30/30	27.30 - 101.00	Lognormal	N/A	N/A	49.30	1.35	46.27 - 58.37	57.11	48.00	40.20 - 53.90	81.20
48" - 54"	21/21	33.30 - 67.70	Lognormal	N/A	N/A	44.95	1.18	42.31 - 49.29	48.62	45.00	39.90 - 47.80	59.19
Glaciofluvial	17/17	35.40 - 69.40	Undefined	N/A	N/A	43.26	1.20	40.15 - 48.40	47.57	43.70	37.90 - 45.80	58.28
Till	32/32	33.30 - 101.00	Lognormal	N/A	N/A	51.08	1.30	48.22 - 58.36	57.50	48.50	42.20 - 53.90	78.65

Table 4-8. continued

[a] When all of the values in the data set were not detectable, one-half of the SQL was the best representative value for the mean and the SQL was the best representative value for the UTL.

[b] The Barium (0-6) result in sample number 61692 was identified as a statistical outlier and was excluded from this data set.

[c] When less than or equal to 10% of measured concentrations were above the SQL, only the range of detection and sample median were presented.

[d] Calculated geometric standard deviation was greater than 2.00. This was caused by the combination of only 12 values out of 30 above SQL and the maximum concentration of 1140 µg/g. Summary statistics for "0-6" without suspected outlier was used as the representative statistics for this data set.

[e] The Boron (0-6) result in sample number 61666 was identified as a statistical outlier and was excluded from this data set.

[f] The Cadmium (36-42) result in sample numbers 61697 and 61642 was identified as a statistical outlier and was excluded from this data set.

[g] The Cadmium (Till) result in sample numbers 61697 and 61642 was identified as a statistical outlier and was excluded from this data set.

[h] When the calculated geometric standard deviation was greater than 2.00, the median, 95% confidence interval on the median and maximum measured concentration for UTL were used as the best representative statistics for the data set.

[i] The Lead (0-6) result in sample number 61698 was identified as a statistical outlier and was excluded from this data set.

[j] The Manganese (0-6) result in sample number 61692 was identified as a statistical outlier and was excluded from this data set.

[k] The Silicon (0-6) result in sample number 61666 was identified as a statistical outlier and was excluded from this data set.

[l] The Thallium (Till) result in sample numbers 61709 and 61657 was identified as a statistical outlier and was excluded from this data set.

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Table 4-9: Summary Statistics for Radiological Constituents

(all values are reported in pCi/g)

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Actinium^{227}												
0" - 6"	1/30[a]	0.09 - 0.09	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.025	N/A	N/A
36" - 42"	2/30[a]	0.08 - 0.10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.020	N/A	N/A
48" - 54"	1/21[a]	0.06 - 0.06	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.020	N/A	N/A
Glaciofluvial	1/17[a]	0.08 - 0.08	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.020	N/A	N/A
Till	2/32[a]	0.06 - 0.10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.020	N/A	N/A
Cesium^{137}												
0" - 6"	30/30[b]	0.15 - 0.71	Lognormal	N/A	N/A	0.341	1.563	0.321 - 0.455	0.440	0.33	0.25 - 0.49	0.711
36" - 42"	0/30[b]	Avg SQL = 0.10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
48" - 54"	0/21[b]	Avg SQL = 0.10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glaciofluvial	0/17[b]	Avg SQL = 0.10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Till	0/32[b]	Avg SQL = 0.10	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Lead^{210}												
0" - 6"	30/30	0.53 - 1.30	Lognormal	N/A	N/A	0.904	1.264	0.853 - 1.019	1.003	0.89	0.84 - 1.03	1.330
36" - 42"	26/30	0.31 - 0.83	Undefined	N/A	N/A	0.473	1.681	0.448 - 0.680	0.652	0.55	0.48 - 0.63	1.112
48" - 54"	17/21	0.44 - 0.97	Undefined	N/A	N/A	0.446	1.768	0.410 - 0.718	0.676	0.52	0.46 - 0.63	1.139
Glaciofluvial	15/17	0.31 - 0.97	Lognormal	N/A	N/A	0.461	1.617	0.410 - 0.690	0.653	0.50	0.47 - 0.55	1.016
Till	26/32	0.31 - 0.83	Undefined	N/A	N/A	0.454	1.787	0.439 - 0.684	0.655	0.56	0.44 - 0.64	1.179

Table 4-9. (continued)

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Potassium[40]												
0" - 6"	30/30	13.10 - 21.40	Lognormal	N/A	N/A	16.129	1.130	15.538 - 17.023	16.888	15.80	15.40 - 16.60	19.713
36" - 42"	30/30	9.27 - 30.20	Lognormal	N/A	N/A	16.417	1.365	15.399 - 19.546	19.114	16.30	14.30 - 18.80	27.396
48" - 54"	21/21	8.60 - 31.00	Lognormal	N/A	N/A	16.420	1.402	15.008 - 20.603	19.969	16.10	14.20 - 20.20	28.634
Glaciofluvial	17/17	9.27 - 21.20	Normal	14.835	4.057	N/A	N/A	12.749 - 16.921	16.553	15.90	11.40 - 17.40	24.921
Till	32/32	8.60 - 31.00	Lognormal	N/A	N/A	18.087	1.359	17.031 - 21.351	20.911	17.10	15.70 - 22.40	29.944
Protactinium[231]												
0" - 6"	0/30[a]	Avg SQL = 0.31	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36" - 42"	0/30[a]	Avg SQL = 0.26	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
48" - 54"	0/21[a]	Avg SQL = 0.25	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glaciofluvial	0/17[a]	Avg SQL = 0.22	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Till	0/32[a]	Avg SQL = 0.28	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Radium[224]												
0" - 6"	30/30	0.54 - 0.93	Undefined	N/A	N/A	0.798	1.135	0.768 - 0.844	0.837	0.84	0.77 - 0.86	0.983
36" - 42"	30/30	0.30 - 1.07	Lognormal	N/A	N/A	0.589	1.418	0.552 - 0.721	0.703	0.58	0.51 - 0.68	1.046
48" - 54"	21/21	0.29 - 0.96	Lognormal	N/A	N/A	0.550	1.405	0.502 - 0.691	0.670	0.54	0.47 - 0.67	0.962
Glaciofluvial	17/17	0.29 - 0.87	Lognormal	N/A	N/A	0.491	1.392	0.441 - 0.627	0.605	0.52	0.38 - 0.59	0.846
Till	32/32	0.31 - 1.07	Lognormal	N/A	N/A	0.635	1.376	0.598 - 0.757	0.741	0.62	0.51 - 0.81	1.074

Table 4-9. (continued)

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Radium^{226}												
0" - 6"	30/30	0.85 - 1.48	Lognormal	N/A	N/A	1.168	1.141	1.122 - 1.239	1.228	1.19	1.12 - 1.24	1.450
36" - 42"	30/30	0.59 - 1.61	Undefined	N/A	N/A	0.901	1.307	0.848 - 1.038	1.019	0.83	0.77 - 0.94	1.400
48" - 54"	21/21	0.63 - 1.38	Undefined	N/A	N/A	0.841	1.209	0.786 - 0.935	0.921	0.76	0.76 - 0.91	1.148
Glaciofluvial	17/17	0.63 - 1.29	Undefined	N/A	N/A	0.823	1.216	0.761 - 0.931	0.914	0.77	0.75 - 0.89	1.136
Till	32/32	0.59 - 1.61	Undefined	N/A	N/A	0.916	1.293	0.865 - 1.046	1.028	0.85	0.78 - 0.94	1.397
Radium^{228}												
0" - 6"	30/30	0.80 - 1.27	Undefined	N/A	N/A	1.053	1.123	1.016 - 1.108	1.100	1.09	1.03 - 1.14	1.275
36" - 42"	30/30	0.40 - 1.37	Lognormal	N/A	N/A	0.755	1.432	0.707 - 0.931	0.907	0.73	0.67 - 0.86	1.363
48" - 54"	21/21	0.36 - 1.27	Lognormal	N/A	N/A	0.701	1.419	0.640 - 0.889	0.860	0.71	0.59 - 0.83	1.247
Glaciofluvial	17/17	0.40 - 1.16	Lognormal	N/A	N/A	0.630	1.394	0.566 - 0.806	0.777	0.68	0.46 - 0.75	1.089
Till	32/32	0.36 - 1.37	Lognormal	N/A	N/A	0.812	1.396	0.764 - 0.977	0.955	0.78	0.67 - 1.04	1.406
Ruthenium^{106}												
0" - 6"	0/30[b]	Avg SQL = 0.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
36" - 42"	0/30[b]	Avg SQL = 0.06	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
48" - 54"	0/21[b]	Avg SQL = 0.06	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Glaciofluvial	0/17[b]	Avg SQL = 0.06	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Till	0/32[b]	Avg SQL = 0.07	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 4-9. (continued)

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Thorium^{230}												
0" - 6"	29/30	0.90 - 2.01	Normal	1.385	0.356	N/A	N/A	1.253 - 1.518	1.496	1.42	1.25 - 1.57	2.175
36" - 42"	26/30	0.62 - 2.34	Normal	1.117	0.486	N/A	N/A	0.935 - 1.299	1.268	1.09	0.90 - 1.32	2.197
48" - 54"	19/21	0.75 - 2.02	Normal	1.152	0.422	N/A	N/A	0.960 - 1.344	1.311	1.13	1.02 - 1.29	2.153
Glaciofluvial	16/17	0.75 - 1.53	Normal	1.068	0.285	N/A	N/A	0.922 - 1.215	1.189	1.10	0.99 - 1.20	1.777
Till	27/32	0.62 - 2.34	Normal	1.175	0.537	N/A	N/A	0.981 - 1.368	1.336	1.20	0.96 - 1.45	2.356
Thorium^{232}												
0" - 6"	30/30	0.64 - 1.52	Lognormal	N/A	N/A	0.998	1.208	0.948 - 1.092	1.079	1.01	0.92 - 1.07	1.362
36" - 42"	20/30	0.68 - 1.35	Undefined	N/A	N/A	0.640	1.723	0.610 - 0.942	0.902	0.77	0.50 - 0.91	1.567
48" - 54"	16/21	0.63 - 1.30	Normal	0.731	0.307	N/A	N/A	0.591 - 0.871	0.846	0.71	0.63 - 0.86	1.458
Glaciofluvial	9/17	0.63 - 1.00	Undefined	N/A	N/A	0.501	1.675	0.446 - 0.793	0.743	0.63	0.30 - 0.74	1.169
Till	27/32	0.63 - 1.35	Normal	0.843	0.295	N/A	N/A	0.736 - 0.949	0.931	0.85	0.75 - 0.95	1.491
Total Thorium												
0" - 6"	N/A	N/A	N/A	N/A	N/A	9.073 mg/kg[c]	N/A	N/A	N/A	N/A	N/A	12.38 mg/kg[c]
36" - 42"	N/A	N/A	N/A	N/A	N/A	5.818 mg/kg[c]	N/A	N/A	N/A	N/A	N/A	14.24 mg/kg[c]
48" - 54"	N/A	N/A	N/A	6.646 mg/kg[c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	13.255 mg/kg[c]
Glaciofluvial	N/A	N/A	N/A	N/A	N/A	4.555 mg/kg[c]	N/A	N/A	N/A	N/A	N/A	10.627 mg/kg[c]
Till	N/A	N/A	N/A	7.664 mg/kg[c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	13.555 mg/kg[c]

Table 4-9. (continued)

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Uranium^{234}												
0" - 6"	30/30	0.67 - 1.31	Lognormal	N/A	N/A	0.979	1.157	0.938 - 1.046	1.036	0.99	0.91 - 1.07	1.244
36" - 42"	28/30	0.48 - 1.30	Normal	0.742	0.209	N/A	N/A	0.663 - 0.820	0.807	0.71	0.69 - 0.77	1.206
48" - 54"	19/21	0.50 - 0.93	Normal	0.674	0.163	N/A	N/A	0.600 - 0.748	0.735	0.70	0.61 - 0.74	1.061
Glaciofluvial	13/17	0.62 - 1.08	Undefined	N/A	N/A	0.601	1.517	0.536 - 0.842	0.802	0.70	0.62 - 0.73	1.192
Till	32/32	0.48 - 1.30	Lognormal	N/A	N/A	0.741	1.235	0.704 - 0.820	0.809	0.72	0.68 - 0.80	1.048
Uranium$^{235/236}$												
0" - 6"	27/30	0.03 - 0.20	Lognormal	N/A	N/A	0.066	1.638	0.062 - 0.092	0.088	0.07	0.05 - 0.08	0.148
36" - 42"	27/30	0.03 - 0.20	Lognormal	N/A	N/A	0.057	1.812	0.055 - 0.088	0.084	0.06	0.05 - 0.07	0.152
48" - 54"	19/21	0.03 - 0.15	Lognormal	N/A	N/A	0.057	1.617	0.052 - 0.082	0.08	0.05	0.04 - 0.08	0.125
Glaciofluvial	13/17	0.04 - 0.15	Lognormal	N/A	N/A	0.045	1.775	0.041 - 0.077	0.072	0.05	0.04 - 0.06	0.117
Till	31/32	0.03 - 0.20	Lognormal	N/A	N/A	0.064	1.661	0.061 - 0.090	0.086	0.06	0.05 - 0.08	0.147
Uranium^{238}												
0" - 6"	30/30	0.85 - 1.33	Lognormal	N/A	N/A	1.039	1.103	1.007 - 1.084	1.077	1.03	1.01 - 1.08	1.222
36" - 42"	29/30	0.62 - 1.23	Normal	0.832	0.198	N/A	N/A	0.758 - 0.906	0.894	0.79	0.74 - 0.92	1.272
48" - 54"	19/21	0.60 - 1.04	Undefined	N/A	N/A	0.723	1.373	0.662 - 0.891	0.865	0.82	0.70 - 0.84	1.218
Glaciofluvial	14/17	0.62 - 1.23	Undefined	N/A	N/A	0.665	1.504	0.594 - 0.925	0.882	0.74	0.68 - 0.83	1.302
Till	32/32	0.64 - 1.23	Lognormal	N/A	N/A	0.841	1.185	0.804 - 0.909	0.899	0.84	0.76 - 0.92	1.113

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Table 4-9. (continued)

Constituent	Frequency of Detection	Range of Detection	Distribution	Sample Arithmetic Mean	Sample Arithmetic Standard Deviation	Sample Geometric Mean	Sample Geometric Standard Deviation	95% Confidence Interval on the Sample Mean	Upper 95% One-sided Confidence Limit on the Sample Mean	Sample Median	95% Confidence Interval on the Sample Median	Upper 95% Tolerance Limit
Total Uranium												
0" - 6"	N/A	N/A	N/A	N/A	N/A	3.123 mg/kg[c]	N/A	N/A	N/A	N/A	N/A	3.706 mg/kg[c]
36" - 42"	N/A	N/A	N/A	2.503 mg/kg[c]	N/A	N/A	N/A	N/A	N/A	N/A	N/A	3.856 mg/kg[c]
48" - 54"	N/A	N/A	N/A	N/A	N/A	2.178 mg/kg[c]	N/A	N/A	N/A	N/A	N/A	3.683 mg/kg[c]
Glaciofluvial	N/A	N/A	N/A	N/A	N/A	2.000 mg/kg[c]	N/A	N/A	N/A	N/A	N/A	3.929 mg/kg[c]
Till	N/A	N/A	N/A	N/A	N/A	2.533 mg/kg[c]	N/A	N/A	N/A	N/A	N/A	3.381 mg/kg[c]

[a] When less than or equal to 10% of measured concentrations were above the SQL, only the range of detection and sample medial were presented.

[b] This radionuclide is a fission product and its presence in the environment is due only to atmospheric releases of radiation (e.g., weapons testing). This radionuclide is not naturally occurring and is only expected to be present at or near detectable activities in the surface soil.

[c] Individual activities of the three isotopes for uranium and thorium were converted to weight percents. The three isotope weight percents for each radionuclide were added to obtain total thorium or uranium.