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TITLE: **Post-Remediation Soil Sampling and Analysis for the Former Sodium Disposal Facility**

- APPROVALS -

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1. Introduction

The Former Sodium Disposal Facility (T886) at the Rockwell International Santa Susana Field Laboratory was used primarily for cleaning sodium heat transfer system components (pipes, valves, tanks) and for disposal of scrap sodium by reaction with water. However, during its use, small quantities of a variety of other materials were disposed of there, including radioactively contaminated components and material. As a result, small amounts of radioactive contamination became dispersed in the T886 pool, and in the lower basin and adjacent areas. The pool and related structure, and all the soil in the lower basin, were removed during a remediation project lasting from 1991 through 1994. At the completion of the radiological remediation, a final gamma radiation survey and a sampling of soil and rock were performed to demonstrate the satisfactory removal of the radioactive contamination. The gamma radiation survey was summarized in ETEC document number 886-ZR-0007 (Ref. 1).

Following removal of all potentially radioactively contaminated soil from the former Sodium Disposal Facility, the soil and rock samples were independently taken by ICF-Kaiser Environment and Energy Group. These samples were analyzed by Oak Ridge Institute for Science and Education (ORISE), and the results reported to the Radiation Protection and Health Physics Services Group (now Environmental Remediation) at Rocketdyne. This report summarizes those results and presents comparisons with local background values.

2. Summary and Conclusions

To confirm the satisfactory radiological remediation of this area, a sampling and analysis plan was developed by the Environment and Energy Group of ICF Kaiser Engineers (Ref. 2) . ICF Kaiser personnel collected 63 soil samples and 15 rock samples for analysis according to this plan. Figure 1 shows the layout of the Former Sodium Disposal Facility and its subdivision into grids to provide a basis for the sampling. (Figures and Tables follow the text of this report.)

The ICF Kaiser samples were sent to ORISE where they were individually analyzed by gamma spectrometry, and analyzed by various radiochemistry procedures in composited groups. Sample material is available for confirmatory analyses by the State of California Department of Health Services - Radiologic Health Branch.

The gamma spectrometry showed low concentrations of Cs-137, the primary radioactive contaminant at the Former Sodium Disposal Facility, and normal amounts of natural K-40, and the thorium and uranium decay chains. The Cs-137 concentrations are similar to, though in some instances somewhat greater than, local background surface soil concentrations due to global fallout from nuclear weapon testing. The radiochemistry showed low concentrations of Sr-90, similar to the Cs-137 concentrations, and somewhat higher than local background surface soil concentrations. Radiochemistry with alpha spectrometry for thorium and uranium showed concentrations that agreed well with values expected for naturally occurring minerals, and in agreement with the daughter activities found by gamma spectrometry. This comparison shows that the thorium and uranium activities are a natural occurrence.

Gamma spectrometry of the rock samples showed natural concentrations of K-40 and the thorium and uranium decay chains, in agreement with the concentrations found in the soil, but no Cs-137. Radiochemistry showed natural equilibrium in the thorium chain but some

disequilibrium in the uranium chain, with the Th-230 activity (and its daughters) exceeding that expected from the parent uranium activities. This is commonly found in geological materials.

Radiochemistry with alpha spectrometry for plutonium (Pu-238, Pu-239/240) showed no concentrations in soil or in rock that differed statistically from zero.

The small amounts of Sr-90 and Cs-137, which may represent residue from the contaminated soil that was removed, are well below proposed guidelines for residual radioactivity in soil, for release without radiological restrictions (Ref. 3). No other indications of possible remaining contamination were found.

No samples indicated the presence of significant levels of radioactive contaminants. All results were well below proposed acceptable limits for radioactive contamination in soil. The results of this sampling and analysis program confirm that the area is acceptable for release for use without radiological restriction.

3. Sampling

For the purpose of providing a uniform basis for sampling the Former Sodium Disposal Facility area, four regions were established, relating to the history of the facility. These regions were subdivided into 50-foot square grids, and sample locations were selected within the grids by use of random numbers.

Surface soil samples were collected by hand, with a trowel, providing somewhat more than 1 kg of soil for each sample. Soil samples were placed in jars for transport to the ORISE laboratory. Subsurface samples were collected at a depth of about 4 feet below the surface by use of a hand auger. Bedrock samples were broken after core-drilling from the local rock.

Sample locations were identified, relative to the grid shown in Figure 1, by use of a 12-character code. The first digit indicates the region (1-4), the next 2 digits indicate the block number for that region, the next 2 digits give the distance in feet to the north from the southeast corner of the block, the next 2 digits give the distance in feet to the west from the same corner, and the next digit (0 or 1) indicates a surface sample (0) or a 4-foot subsurface sample (1). The type of sample is indicated by S for soil and B for bedrock. The samples taken for radionuclide analysis were further identified by RN. Scheduled samples, as distinct from QC samples, were identified by a final 0.

After the initial gamma spectrometry had been reported for all the individual samples, portions of selected samples were grouped together at the ORISE laboratory to form composite samples for the radiochemistry analyses. This was done to use the analytical funding as effectively as possible, since gamma spectrometry is relatively inexpensive, compared to analyses requiring chemical separation.

The composite groups were selected by first associating the gamma spectrometry results for each sample with the region, and then combining nearby samples with similar radiological characteristics, as determined from the gamma spectrometry. Some samples were kept separate for individual analysis. The sample groupings are shown on the layout map of the area in Figure 2.

4. Analysis

Samples were analyzed at ORISE in Oak Ridge, Tennessee, under contract to DOE/OAK. The gamma spectrometry used a high-purity germanium detector with a computer based multichannel analyzer. The standard Canberra software for interpretation of photopeaks was used. The uncertainties reported with the results are determined by the computer processing and are specified at the 2-sigma level.

Radiochemistry was done to quantify Sr-90 and the requested alpha emitters. Chemical separation provides a strontium precipitate, beta counting serves as the determination of the activity. Similarly chemical separation provides separate deposits for thorium, uranium, and plutonium. Alpha spectrometry is used to determine the individual isotopic activity for each element. Uncertainties for the radiochemical results are also reported at the 2-sigma level.

5. Results

The results of the ORISE analyses are listed in Tables 1A, 1B, and 1C. These tables provide the sample location code number, as described above, and the activity concentration and 2-sigma uncertainty, in pCi/g. All scheduled samples are included here, with the results for 3 field duplicate soil samples. Blank entries in the uncertainty (unc) column indicate that the activity for that radionuclide was not detected, and so one-half of the Minimum Detectable Activity (MDA) has been entered as the result for that sample. Table 1A lists all sample results obtained by gamma spectrometry. Table 1B lists the results obtained by radiochemistry. Table 1C lists the MDA values for all the radionuclide analyses that were performed.

The groups of individual samples that were composited for the radiochemistry analyses are listed in Table 2, with the associated Lab ID, Lab composite ID, and the designated composite number.

6. Interpretation

Individual results from the analysis of soil and rock are presented as cumulative probability plots in Figures 3a through 3q. In these plots, measured values are shown with a small or large error bar associated with the data symbol. The error bars indicate the 2-sigma uncertainty estimated for the result. Non-detected results, set to one-half the MDA, are shown without an error bar. In a cumulative probability plot, data with a normal (or Gaussian) distribution fall along a straight line. The plot shows, as a diagonal line, the theoretical Gaussian distribution calculated from the arithmetic mean and standard deviation of the dataset.

Most of the radionuclides detected show a distribution that is close to Gaussian. The distribution for Cs-137 in soil (Figure 3b) shows several values that are somewhat higher than expected, but not entirely outside the range of environmental fallout activity in surface soil. Only 3 samples, at 0.57, 0.30, and 0.30 pCi/g, are above the upper 95% bound for local background of 0.27 pCi/g. The highest value, 0.57, corresponded to the sample with the highest Sr-90 result. All results are well below the proposed SSFL site limit for Cs-137 in soil, 8.6 pCi/g (Ref. 3). This limit was determined by a pathways analysis using the DOE code RESRAD Version 5.61, for a maximum annual dose of 10 mrem in a residential setting.

The results for Sr-90 in soil (Figure 3i) also show some elevated values. Of the 19 composite sample analyses performed, 14 were reported at levels that were below the MDA. Only 4 composite soil samples, at 0.57, 0.49, 0.40, and 0.26 pCi/g, are above MDA for this analysis. The

highest value, 0.57, corresponded to the sample with the highest Cs-137 result, also 0.57 pCi/g. One composite rock sample, at 0.28 pCi/g, was above the MDA of 0.27. All results are well below the proposed SSFL site limit for Sr-90 in soil, 24 pCi/g. This limit was determined by the same pathways analysis.

The distribution for U-235, in both soil and rock (Figure 3h), as determined by gamma spectrometry, is distorted by the many non-detected values. There is no indication of contamination in these results, and higher quality values determined by radiochemistry with alpha spectrometry (Figure 3n) confirm this conclusion.

The analyses for plutonium, both Pu-238 and Pu-239 (including Pu-240), show no results that indicate contamination. While the analyses for Pu-238, which is found in global fallout, showed 6 (out of 19) results above the MDA, none of the analyses for Pu-239, a suspect SSFL contaminant, were above the MDA. The reported values result from random variability in the background of the analyses.

The determination of background distributions of the radionuclides reported here, for soil, is based on two sets of data covering large local areas. One collection is from the McLaren-Hart Multimedia Study of the Brandeis-Bardin Institute and Santa Monica Mountains Conservancy properties near SSFL (Ref. 4), as supplemented by some recent samples collected offsite by Rocketdyne. (This set is identified as "... in Background Soil".) The other consists of results from the Rocketdyne Area IV Radiological Characterization Study (Ref. 3), using only those results that are clearly unaffected by contamination. (This set is identified as "... in Area IV Soil (background)".) These measured background distributions, representative of the local area, are shown in Figures 4a through 4k.

For comparison, the average value and 2-sigma uncertainty for each radionuclide measured in soil from the Former Sodium Disposal Facility are listed below, with the corresponding values from the two background sets.

Radionuclide	Former Sodium Disposal Facility	Background Soil	Area IV Soil
K-40	21.7 ± 3.14	21.9 ± 3.44	19.0 ± 4.72
Sr-90	0.13 ± 0.29	0.047 ± 0.080	0.040 ± 0.080
Cs-137	0.069 ± 0.189	0.103 ± 0.166	0.079 ± 0.141
Th-228	1.43 ± 0.35	0.98 ± 0.95	1.00 ± 0.53
Th-230	1.21 ± 0.26	0.28 ± 0.57	0.82 ± 0.46
Th-232	1.34 ± 0.35	0.37 ± 0.83	0.99 ± 0.51
U-234	0.96 ± 0.27	0.35 ± 0.84	0.77 ± 0.35
U-235	0.044 ± 0.024	0.018 ± 0.045	0.042 ± 0.022
U-238	0.95 ± 0.26	0.36 ± 0.79	0.78 ± 0.33
Pu-238	0.027 ± 0.040	-----	0.0006 ± 0.0052
Pu-239	0.009 ± 0.043	-----	0.003 ± 0.007

While there are some variations from background, some above, some below, the averages look quite similar.

Further evidence that the thorium and uranium activity detected in the Former Sodium Disposal Facility soil is natural, can be seen in comparisons of the daughter activities. Thorium and uranium are naturally occurring radioactive elements that slowly decay to stable isotopes of lead. The sequence of radionuclides in the major decay chains is shown below, with those radionuclides that were detected by the present analyses shown in boldface:

thorium chain	---- uranium chain ---- (U-238)	(U-235)
Th-232	**U-238**	**U-235**
Ra-228	**Th-234**	Th-231
Ac-228	Pa-234	Pa-231
Th-228	**U-234**	Ac-227
Ra-224	**Th-230**	Th-227
Rn-220	Ra-226	Ra-223
Po-216	Rn-222	Rn-219
Pb-212	Po-218	Po-215
Bi-212	**Pb-214**	Pb-211
Po-212	**Bi-214**	Bi-211
Pb-208 (stable)	Po-214	Po-211
	Pb-210	Pb-207 (stable)
	Bi-210	
	Po-210	
	Pb-206 (stable)	

In each chain, one longer-lived radionuclide acts as a "bottleneck" to the development of equilibrium activity after chemical purification of the element. Ra-228, with a half-life of 5.76 years, delays full development of equilibrium activity in the thorium chain by about 25 years. Th-230, with a half-life of 75,000 years, delays development of the uranium chain by 300,000 years. Several of these daughters (and the U-235 "cousin" to U-238) were measured in the soil from the Former Sodium Disposal Facility. The activities detected are shown in Figure 5. The straight diagonal lines show the theoretical variation of the daughter activity with the parent. The good agreement of the measured values with the theoretical variation shows that these activities are natural.

7. Quality Assurance

Several sets of measurements were done to provide quality control checks on the analytical procedure. These measurements were directed towards demonstrating the precision and accuracy of the analytical results. The QC samples consisted of field duplicates (which were reported in the main section of this report, but are also discussed here), laboratory replicate analyses, matrix spikes (laboratory control samples), and blind spikes. The Data Quality Objectives are considered to be satisfied if the observed differences are less than 3 times the estimated standard deviation of the difference (Ref. 4). (Standard laboratory reporting provides the uncertainties (unc) as 2 times the estimated standard deviation of the result. For the QC comparisons, the derived uncertainty must be multiplied by 1.5 to obtain the 3-sigma value.)

Duplicate soil samples were made from 3 original samples: 21346220, 30113170, and 42455090. The original samples were individually mixed, and "split" samples were taken from

the bulk material. These samples then proceeded through the balance of the sampling and analysis as though they were independent samples. The results are compared in Table 3. These results show good agreement, with the differences between separate paired soil samples generally being less than the estimated uncertainty. Of 31 comparisons, 5 failed to satisfy the 3-sigma test. Of these, 4 were among the alpha spectrometry analyses, which are sensitive to non-uniformity in the soil.

Laboratory duplicate analyses were done extensively for the gamma spectrometry, less so for the more complicated radiochemistry analyses. These results are shown in Table 4. The comparison is made by calculating the relative difference between the results of the two analyses, and the estimated uncertainty for this relative difference. For a perfect comparison, the relative difference would be zero. Because of random variations, some deviations from zero will occur. These should generally be less than the uncertainty. Of 79 comparisons, 15 failed the 3-sigma test. Two of these failures were for uranium in one of the blind laboratory spike samples, and may have resulted from lack of homogeneity.

Laboratory matrix spikes were prepared for gamma spectrometry by adding a calibrated solution of Cs-137 to selected soil samples. These results are shown as the first 9 entries in Table 5A. A "recovery" value of 1.000 indicates perfect detection of the added spike activity. Of the 9 ORISE-spiked samples, all results are within the required range of 3 times the estimated standard deviation of the difference.

Blind spikes were obtained through a commercial laboratory, by adding calibrated solutions of Sr-90, Cs-137, Th, U, and Pu-239 to 3 selected soil samples. These results are shown as the last 3 entries for Table 5A and all the entries in Table 5B. (The calibration sheets for these blind spikes are presented in the Appendix.) Gamma spectrometry showed the required agreement for 2 of the 3 comparisons. The radiochemistry showed disagreement for 14 of the 32 comparisons. In some of these cases, the differences may reflect the difficulty in making a bulk sample that is adequately homogeneous on the small scale of the analytical aliquots. (Gamma spectrometry measures the radioactivity in a large sample, 600-1000 grams, averaging throughout its volume, while the radiochemical procedures use relatively small aliquots, 3-5 grams, for processing and analysis.)

The results of the QC tests are summarized below as percentages of comparisons satisfying the 3-sigma test.

	Field Duplicates	Lab Duplicates	Matrix Spikes	Blind Spikes	Aggregate Total
K-40	3/3	9/10	---	---	12/13
Sr-90	1/1	1/1	---	2/4	4/6
Cs-137	3/3	10/10	9/9	2/3	24/25
Pb-212	3/3	6/10	---	---	9/13
Pb-214	3/3	3/10	---	---	6/13
Bi-214	3/3	10/10	---	---	13/13
Ac-228	2/3	10/10	---	---	12/13
Th-228	0/1	1/1	---	2/4	3/6
Th-230	1/3	1/1	---	---	2/4
Th-232	0/1	1/1	---	2/4	3/6
Th-234	3/3	9/10	---	---	12/13
U-234	0/1	0/1	---	0/4	0/6
U-235	1/1	1/1	---	4/4	4/6
U-238	0/1	0/1	---	1/4	1/6
Pu-238	1/1	1/1	---	4/4	6/6
Pu-239	1/1	1/1	---	3/4	5/6

The overall score for these comparisons is 74%.

8. Documentation

Backup documentation for this sampling and analysis project is stored in the Former Sodium Disposal Facility (T886) decommissioning file.

9. References

1. "Post-Remediation Ambient Gamma Radiological Survey of the Former Sodium Disposal Facility", 886-ZR-0007, F. C. Dahl, 12/13/94.

2. "Sampling and Analysis Workplan -- Former Sodium Disposal Facility, Santa Susana Field Laboratory", SSFL 95-01, ICF Kaiser Engineers, Environment and Energy Group, June 29, 1995.

3. "Proposed Sitewide Release Criteria for Remediation of facilities at the SSFL", N001SRR140127, B. M. Oliver and R. J. Tuttle, 3/11/96.

4. "Area IV Radiological Characterization Survey, Draft Final Report", Volume 1, A4CM-ZR-0011, P. D. Rutherford, March 15, 1996.

5. "Multi-Media Sampling Report for the Brandeis-Bardin Institute and the Santa Monica Mountains Conservancy", McLaren/Hart Environmental Engineering Corporation, March 10, 1993.

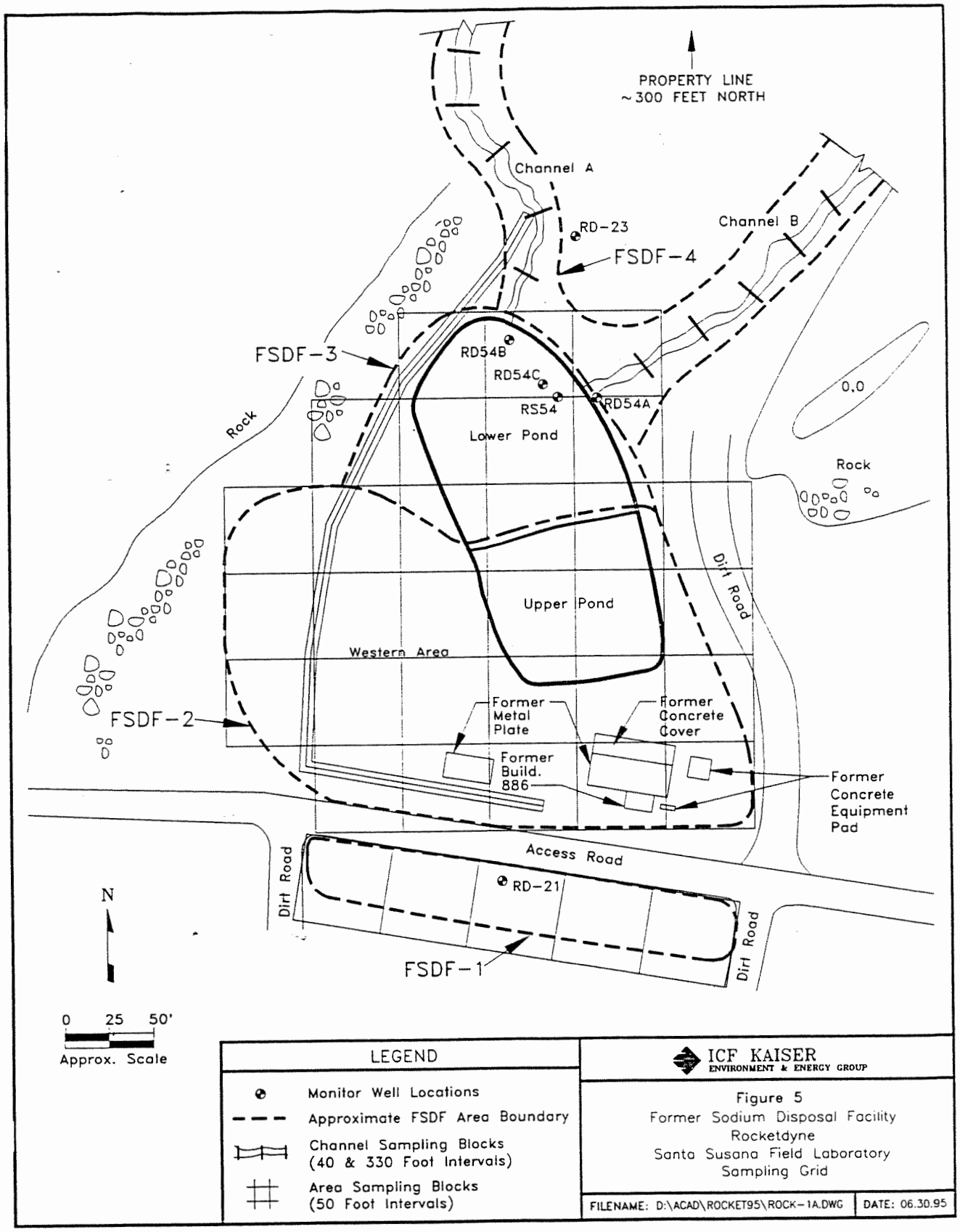


Figure 1. Layout of Former Sodium Disposal Facility for sampling.

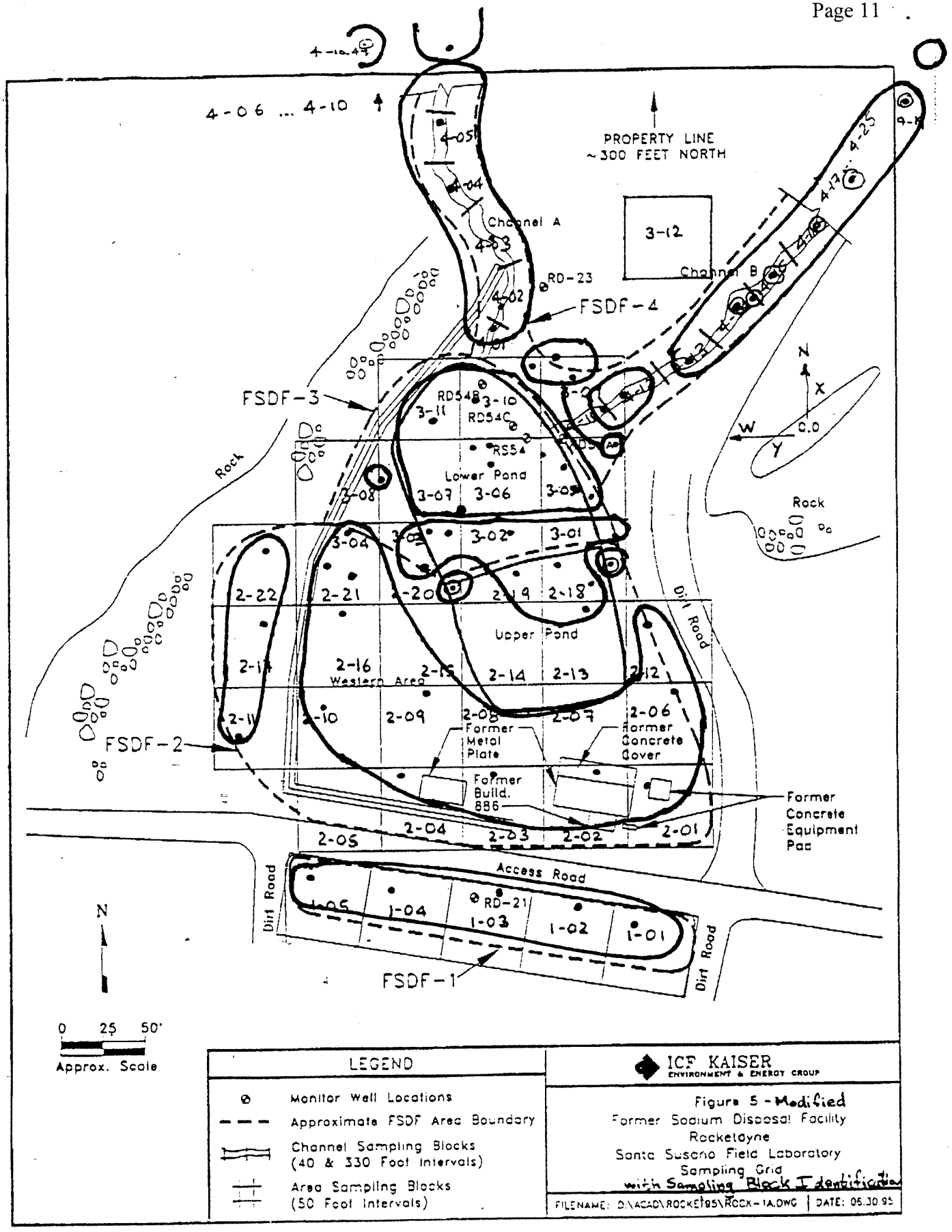
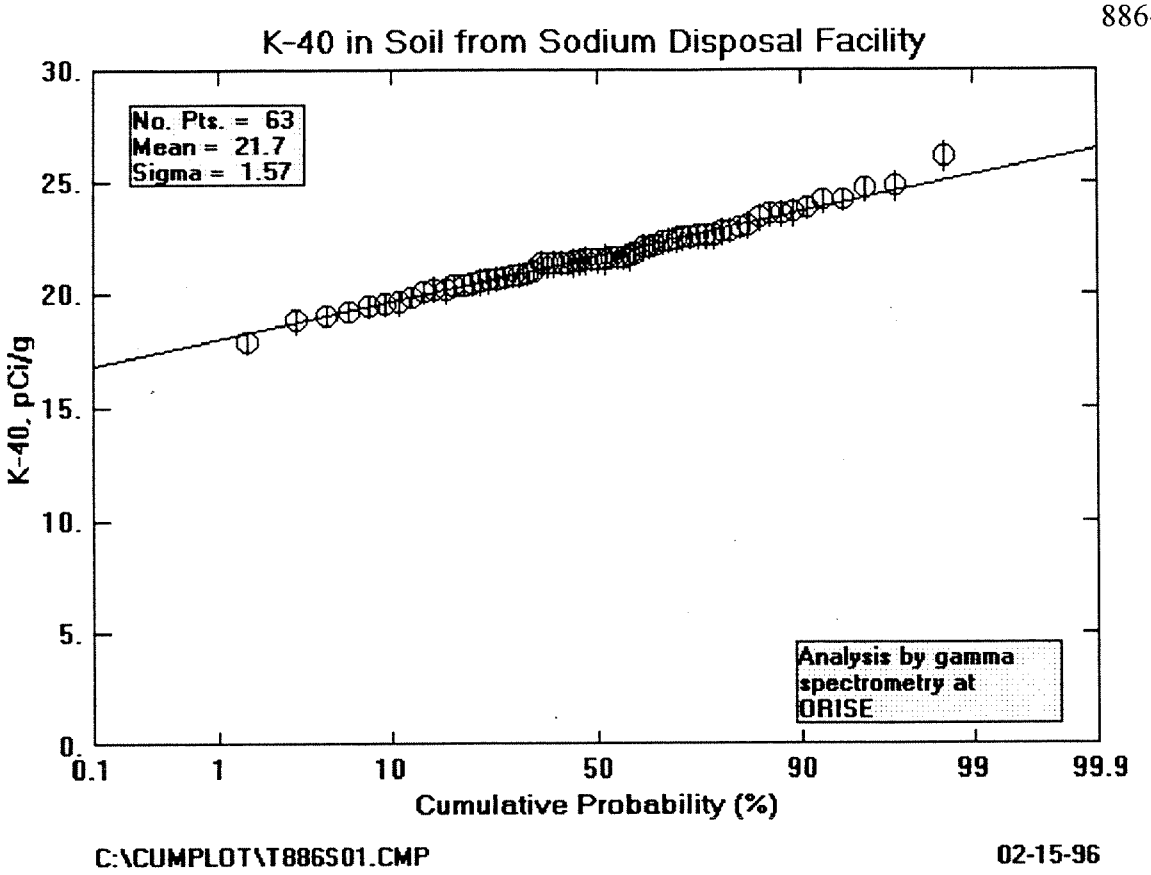


Figure 2. Locations of samples grouped for composite analysis.



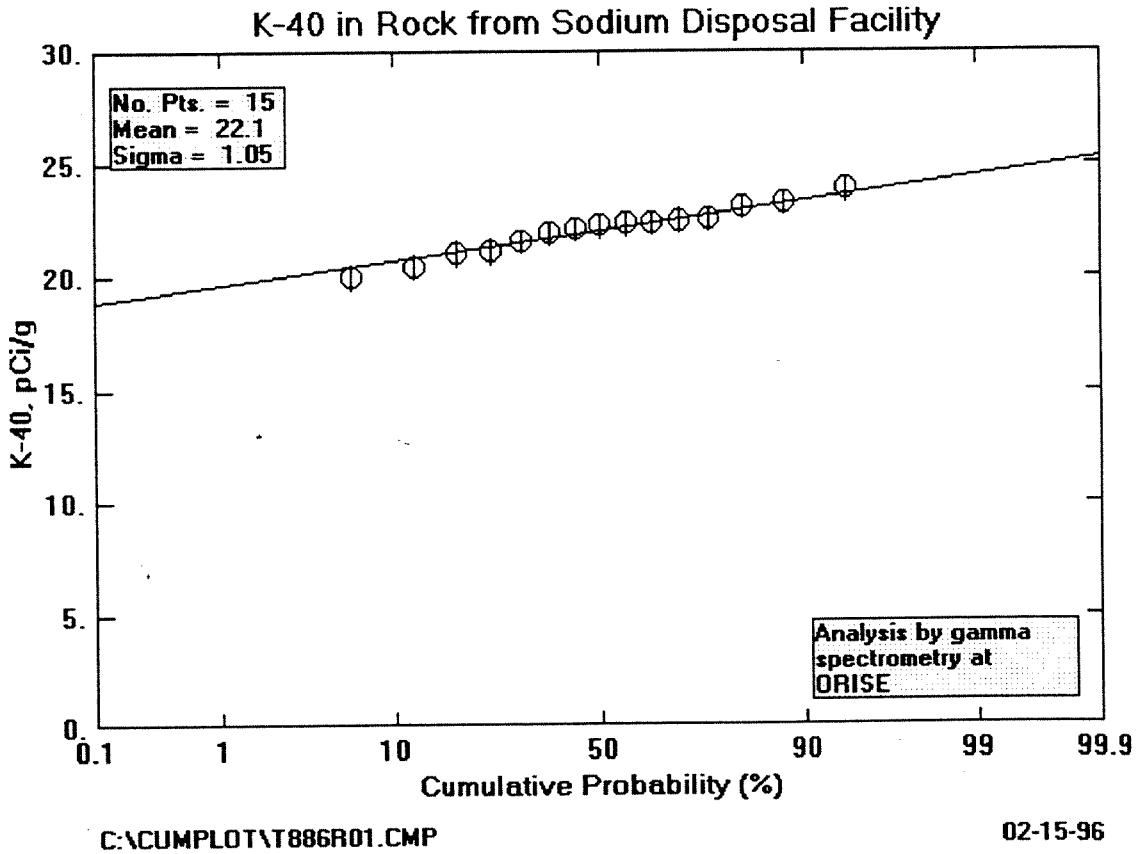
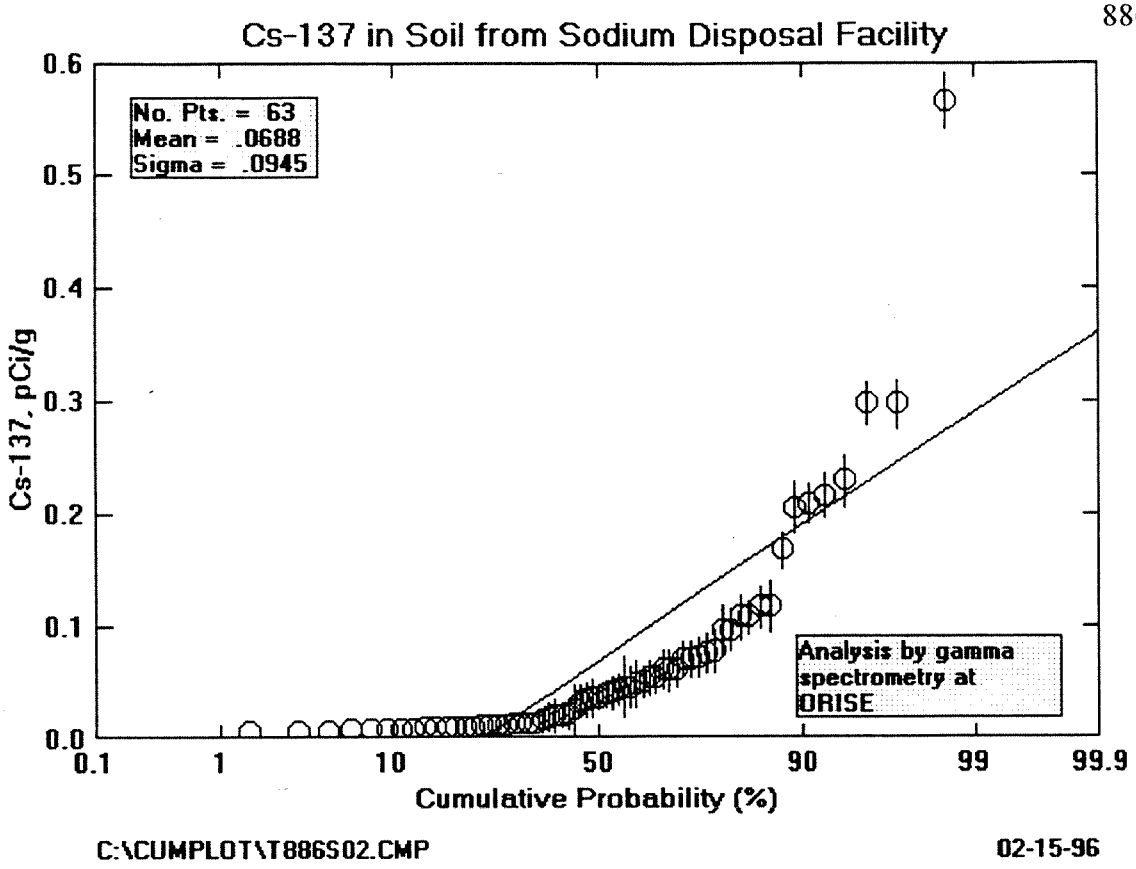


Figure 3a. Distribution of K-40 in Soil and Rock at the Former Sodium Disposal Facility.



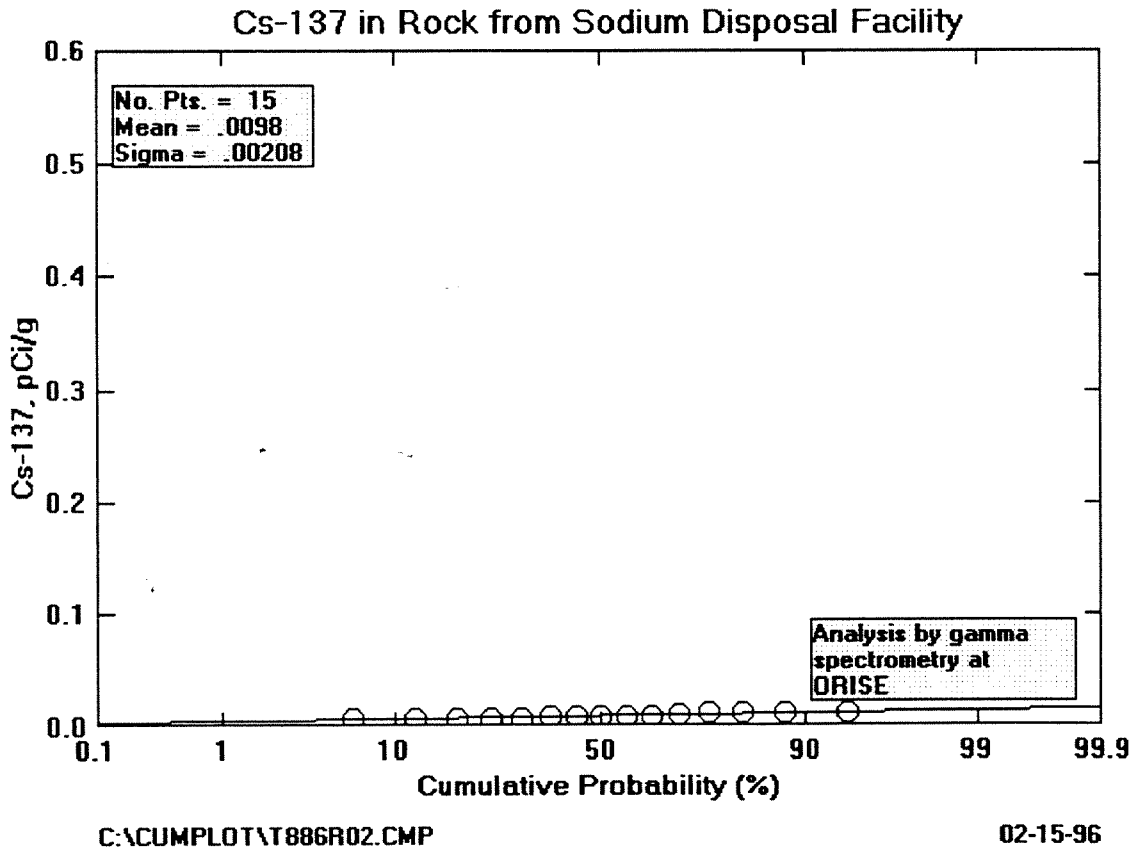
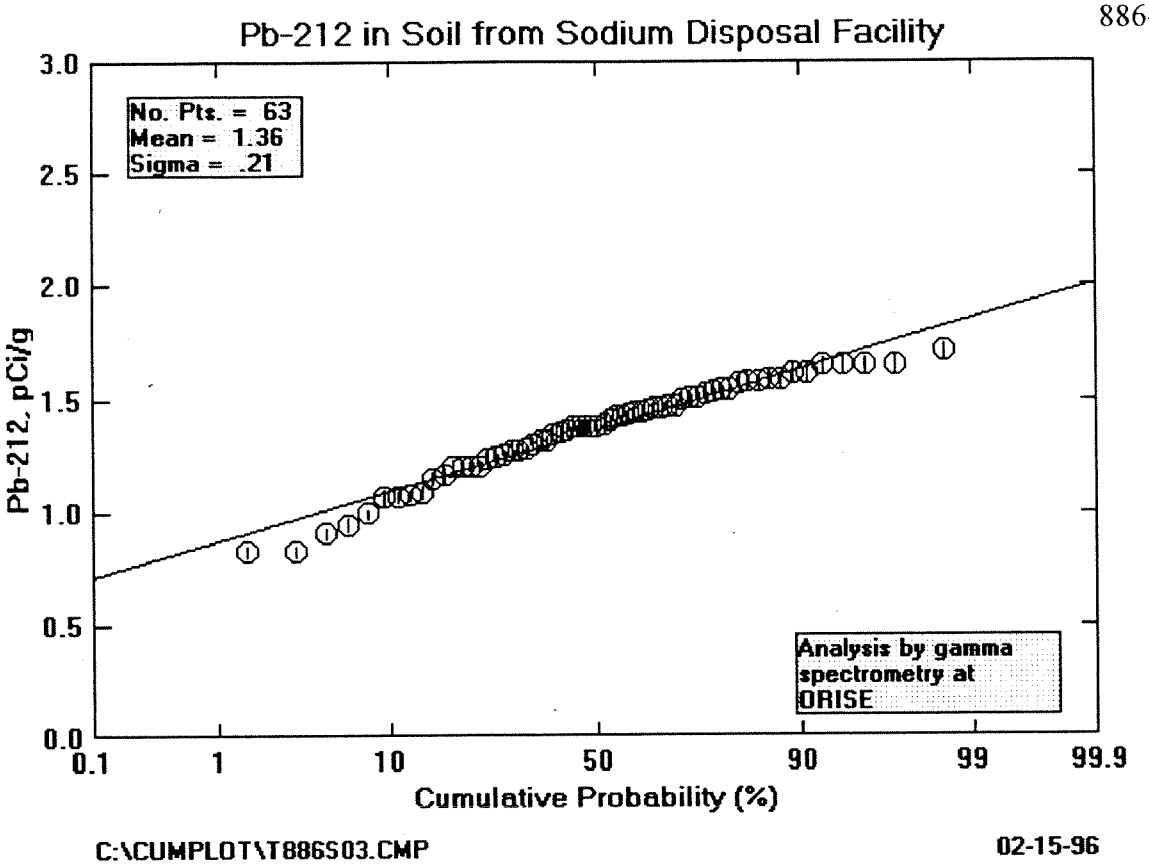


Figure 3b. Distribution of Cs-137 in Soil and Rock at the Former Sodium Disposal Facility.



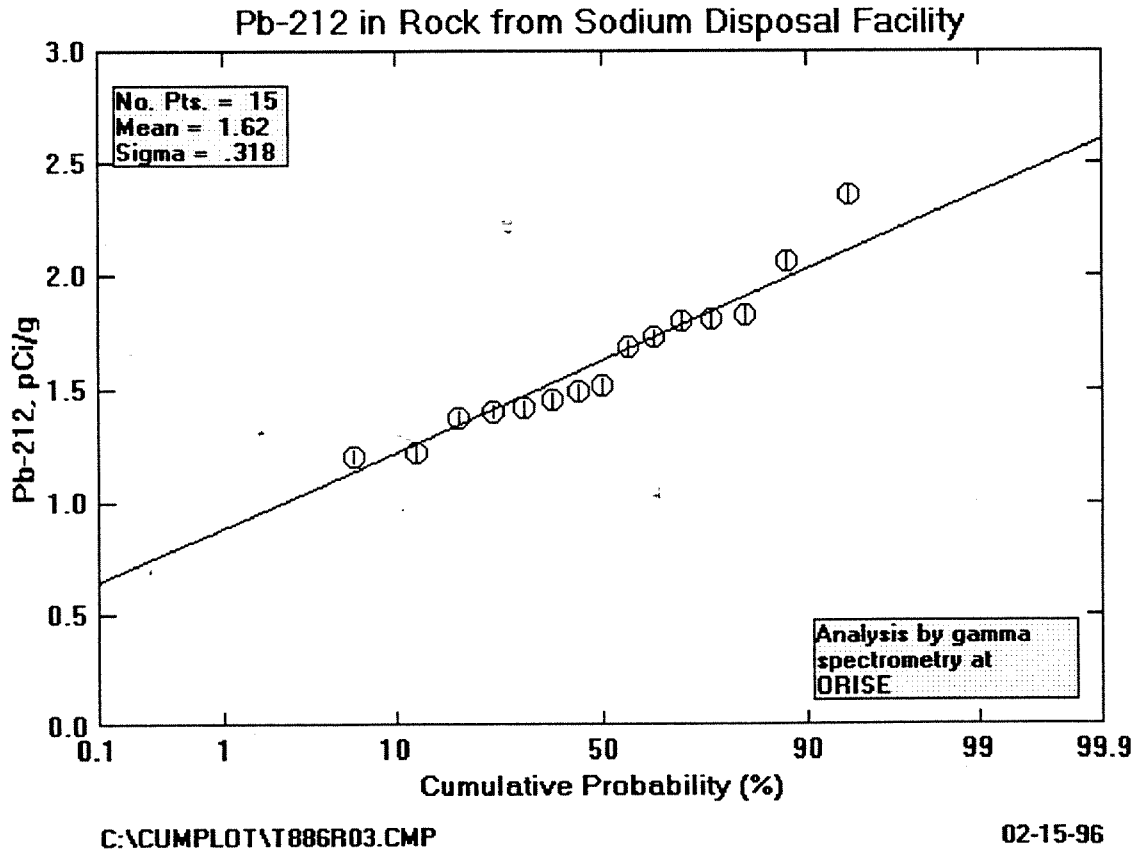
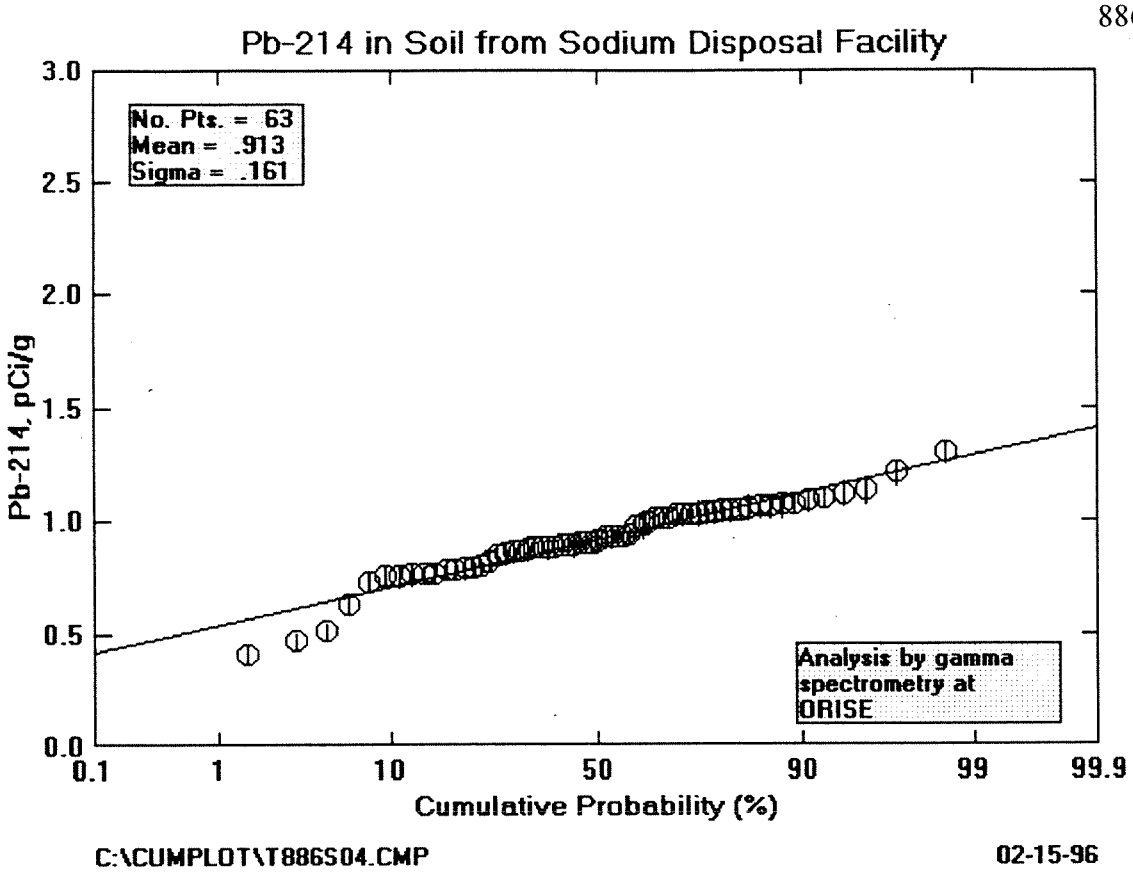


Figure 3c. Distribution of Pb-212 in Soil and Rock at the Former Sodium Disposal Facility.



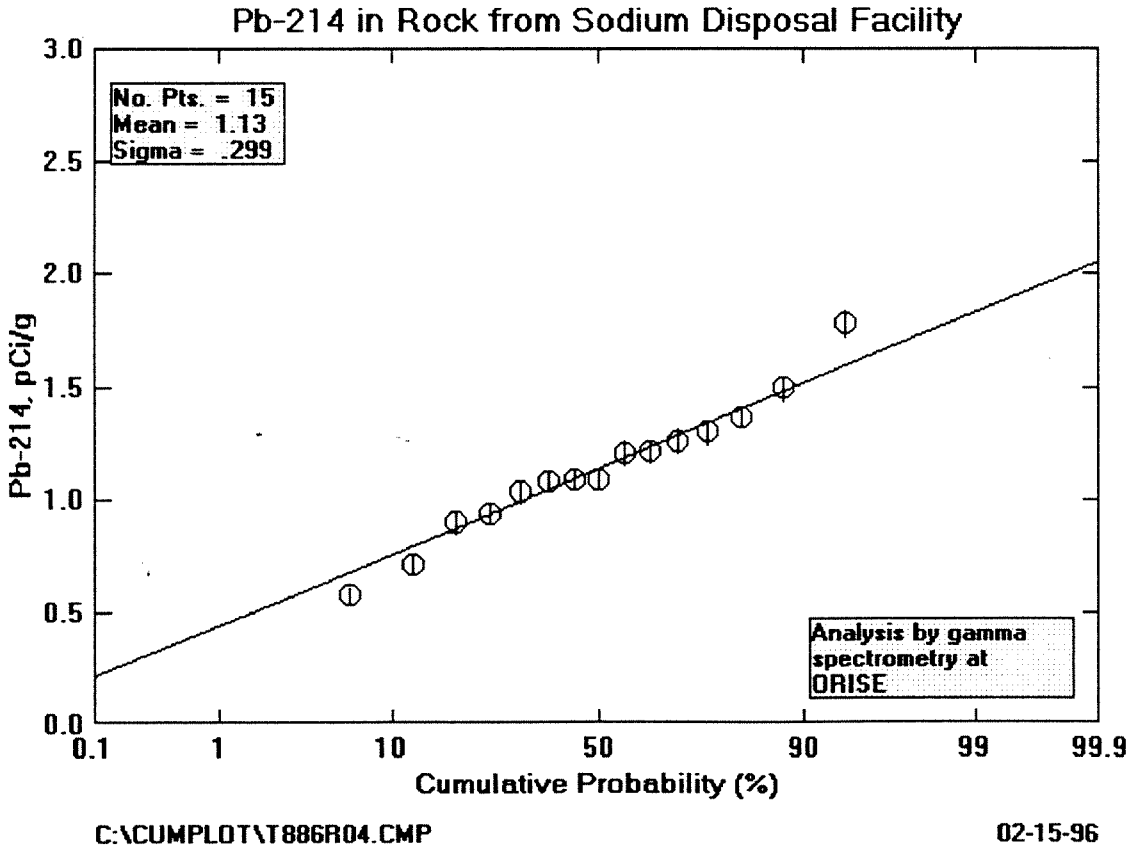
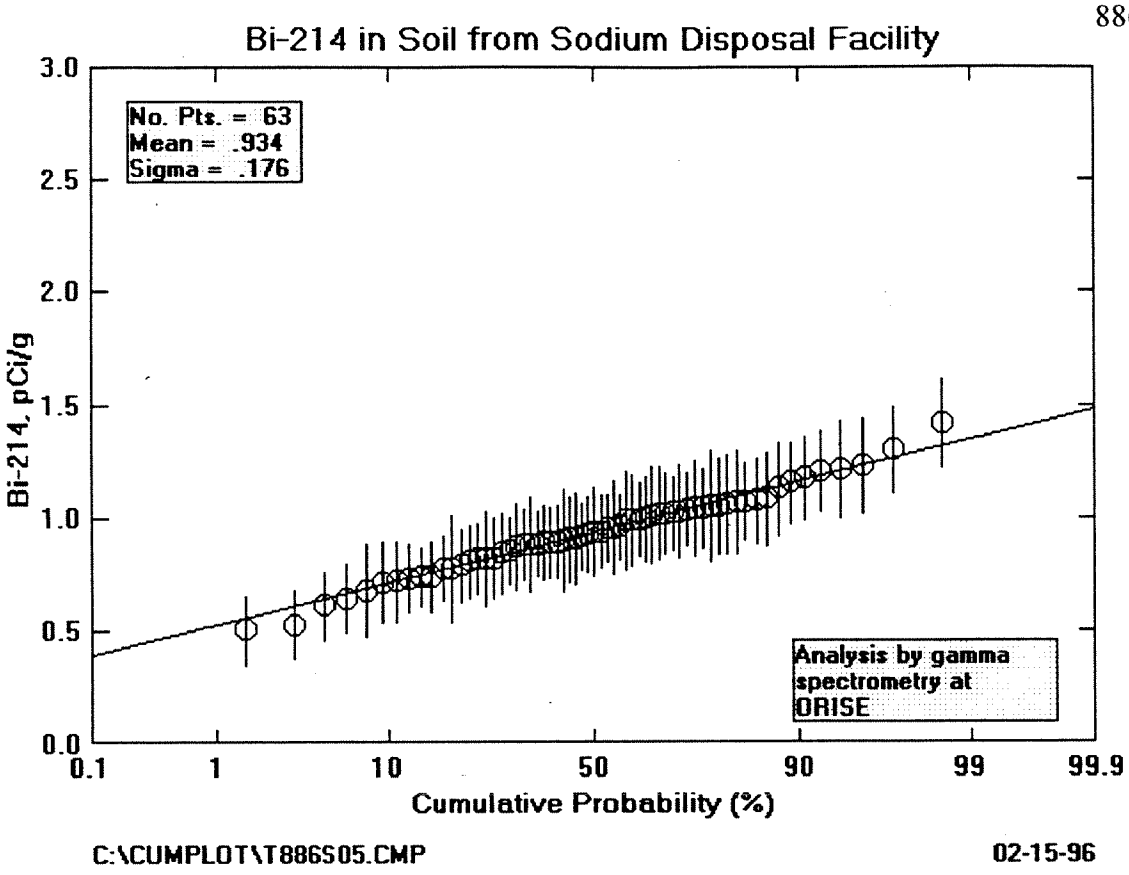


Figure 3d. Distribution of Pb-214 in Soil and Rock at the Former Sodium Disposal Facility.



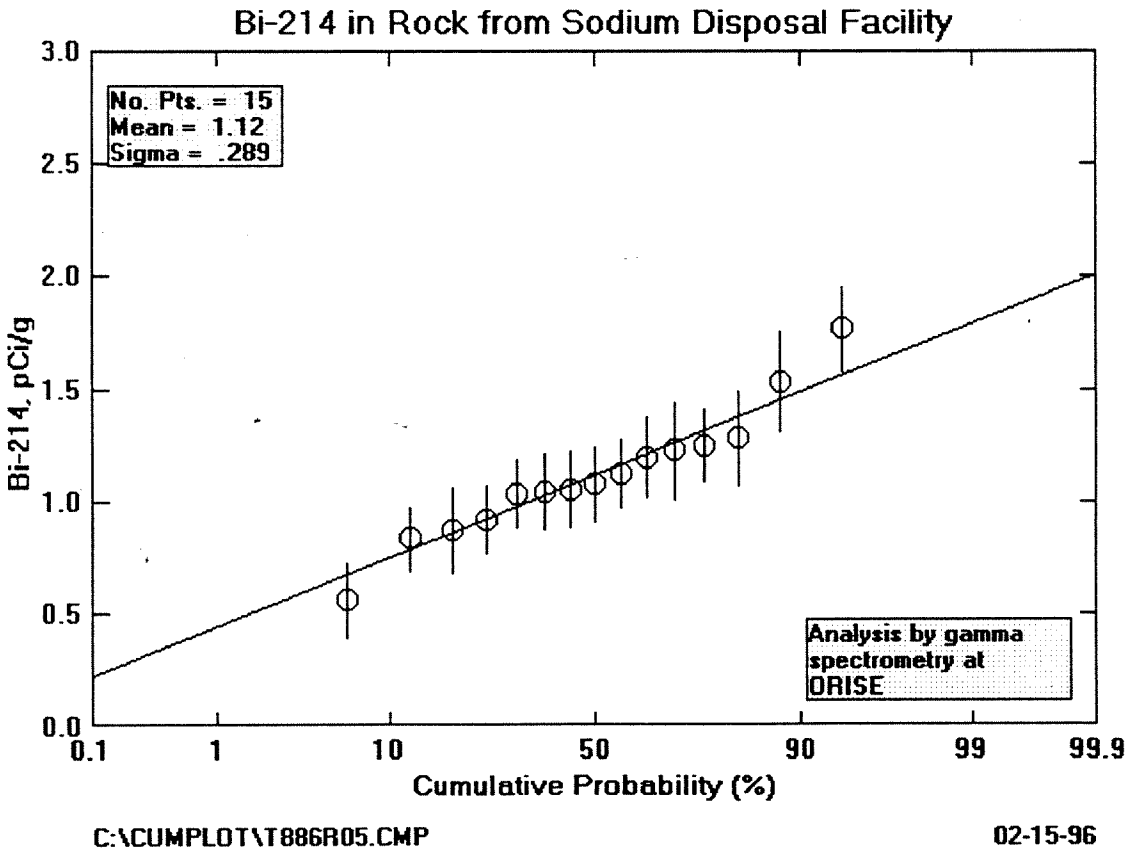
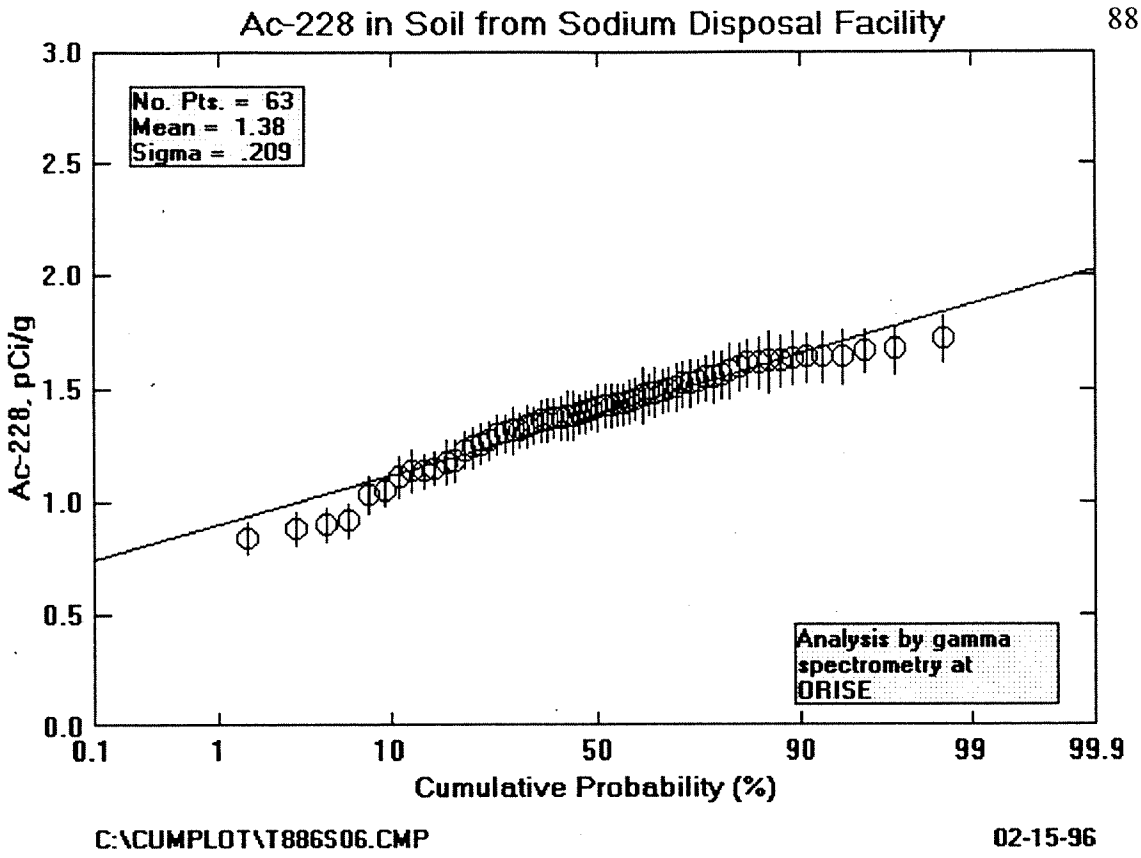


Figure 3e. Distribution of Bi-214 in Soil and Rock at the Former Sodium Disposal Facility.



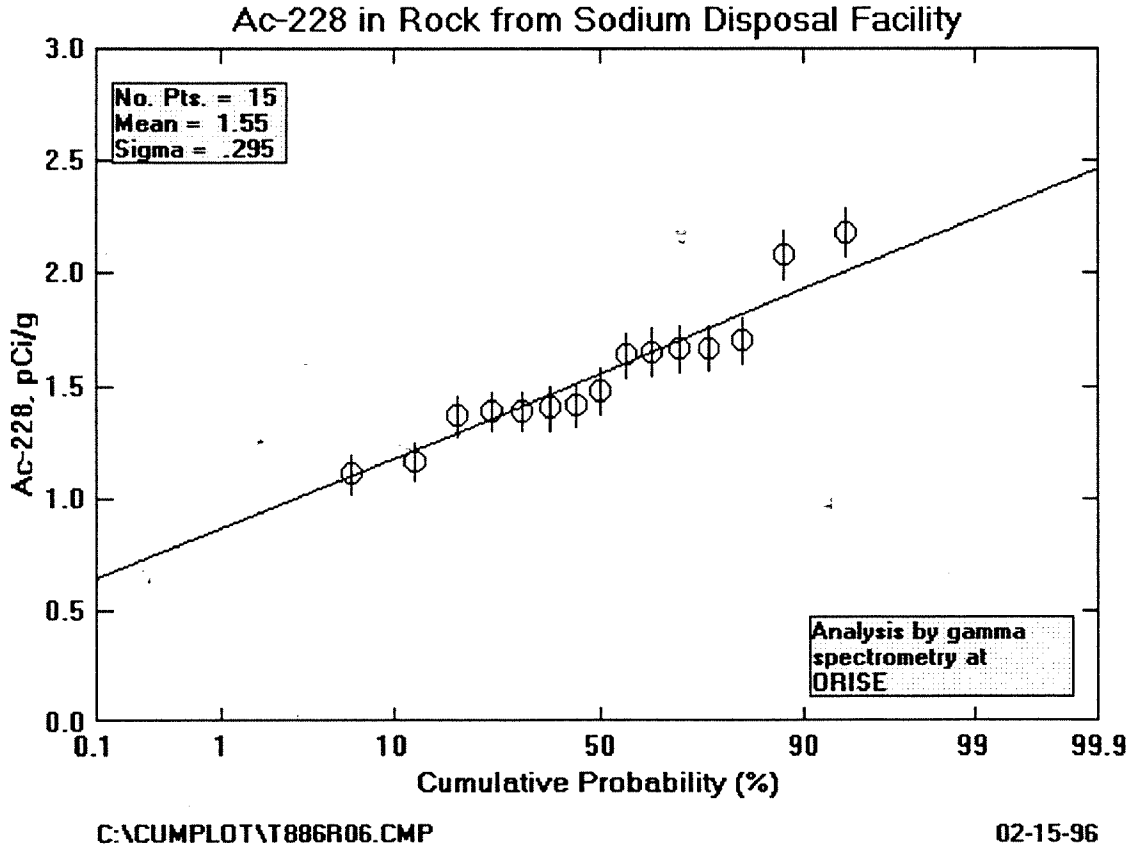
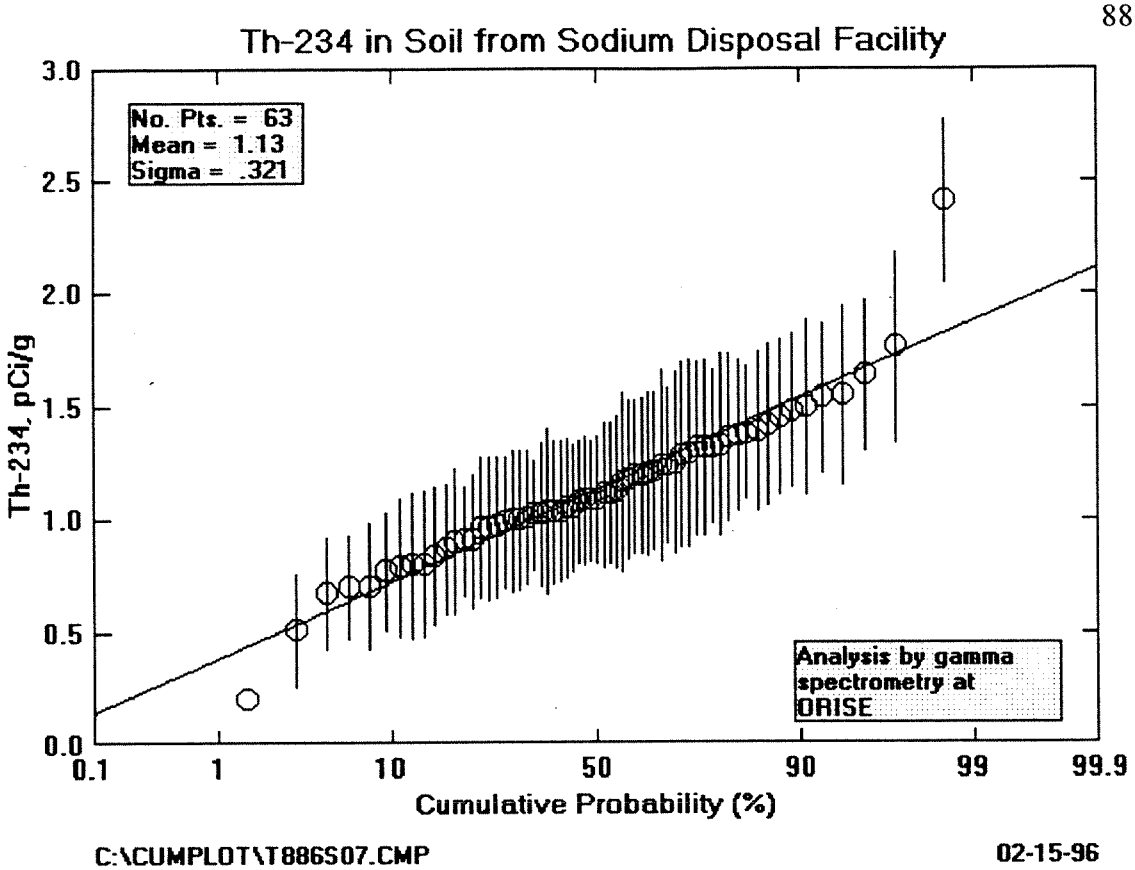


Figure 3f. Distribution of Ac-228 in Soil and Rock at the Former Sodium Disposal Facility.



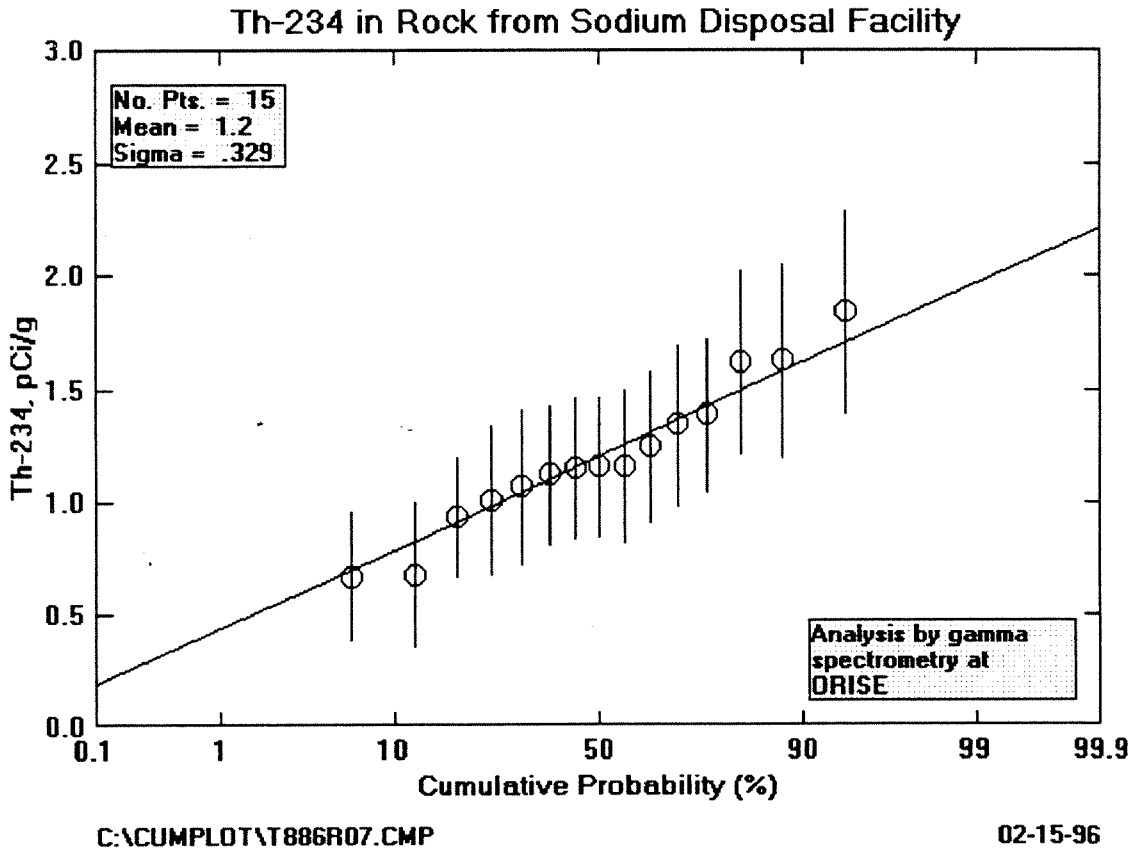
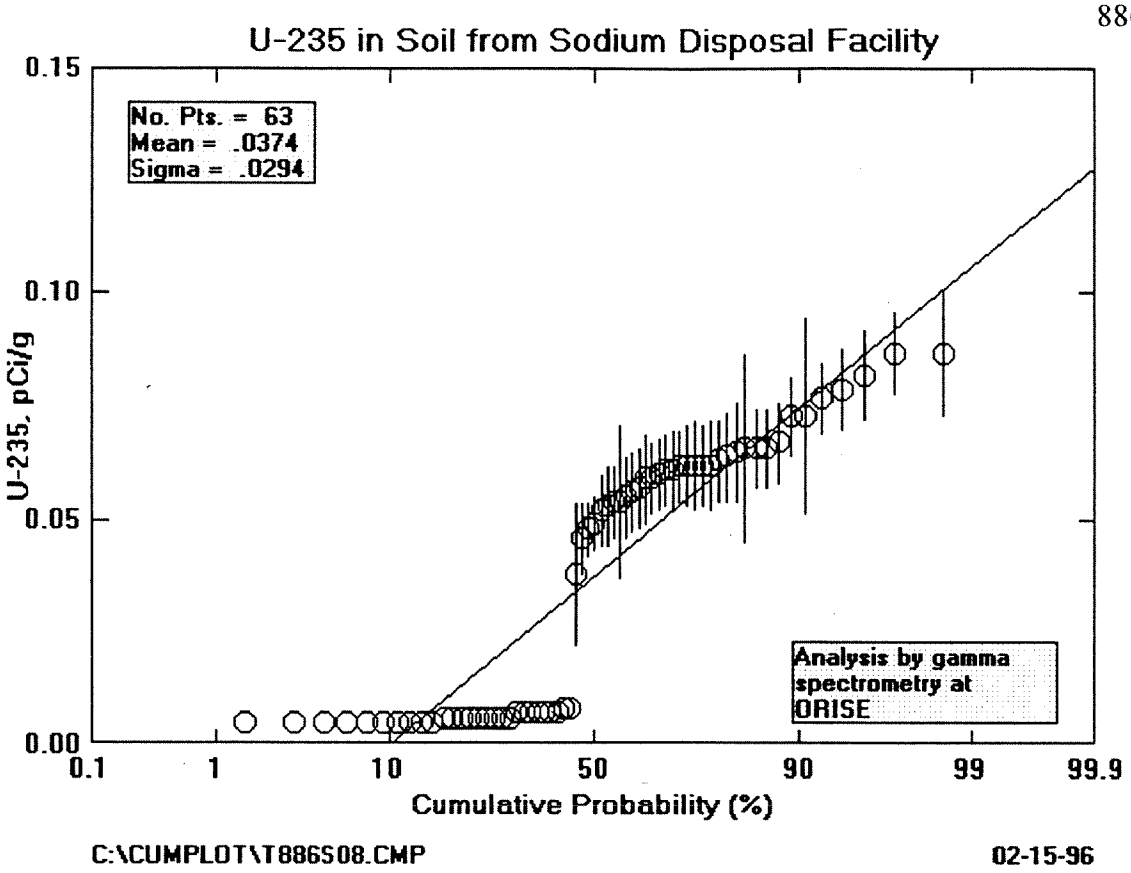


Figure 3g. Distribution of Th-234 in Soil and Rock at the Former Sodium Disposal Facility.



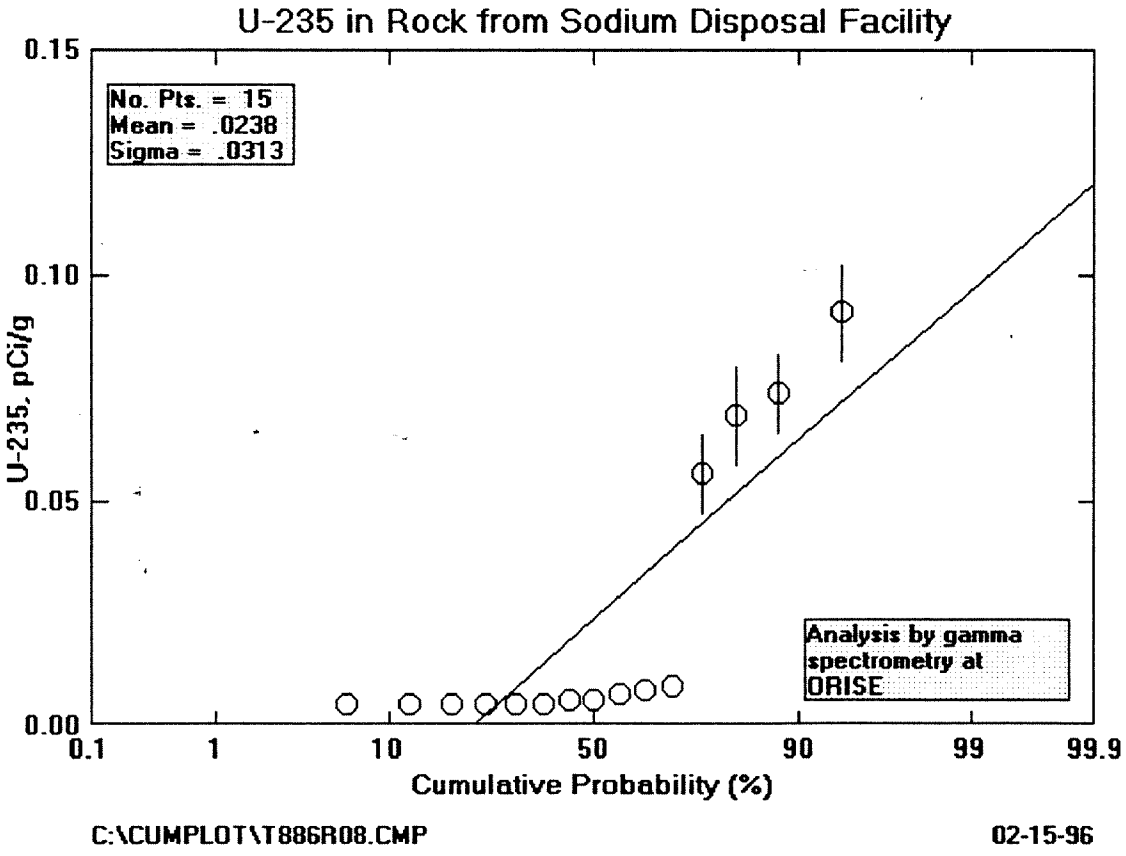
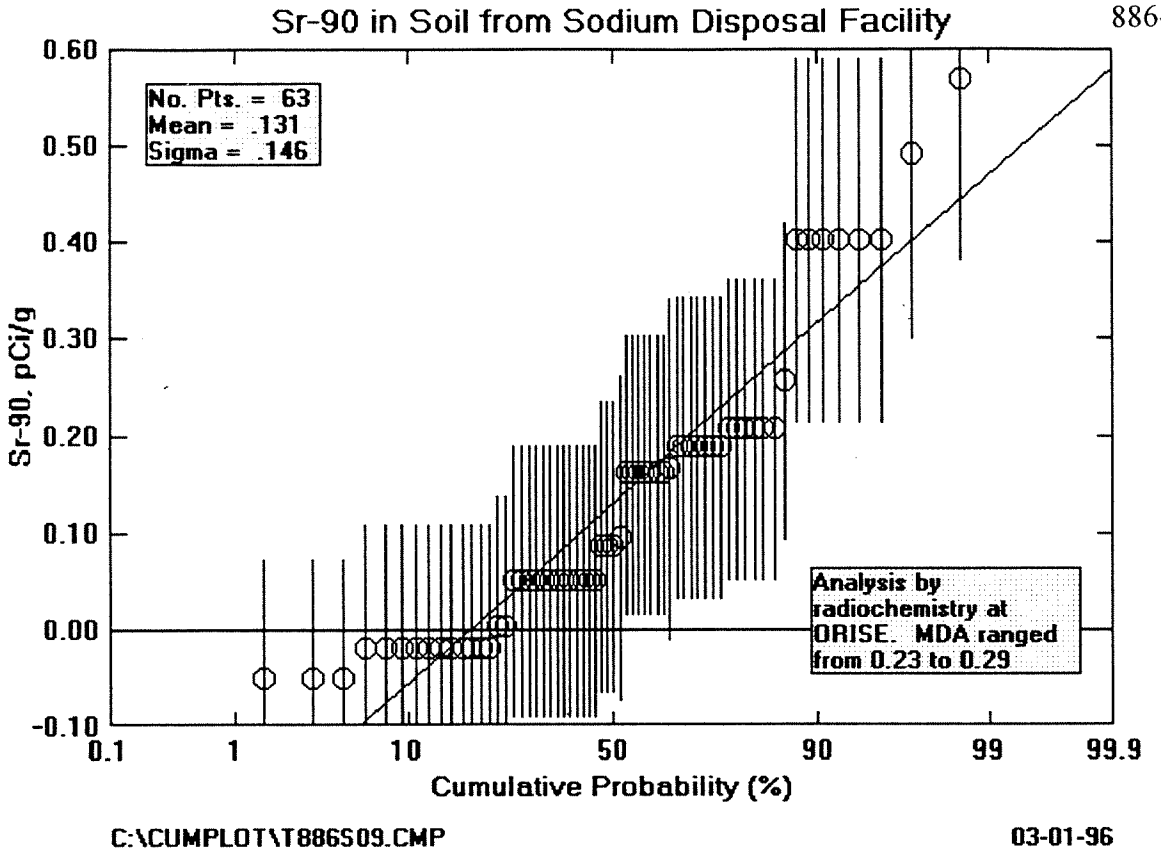


Figure 3h. Distribution of U-235 in Soil and Rock at the Former Sodium Disposal Facility.



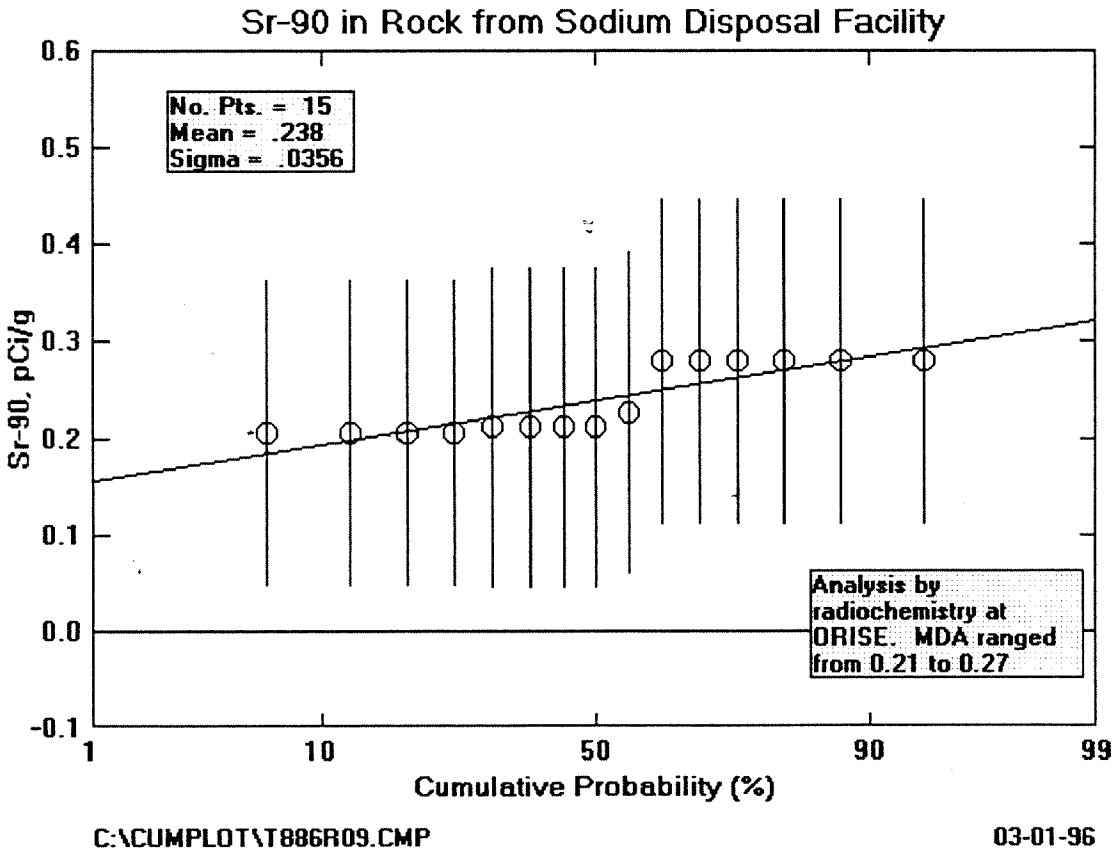
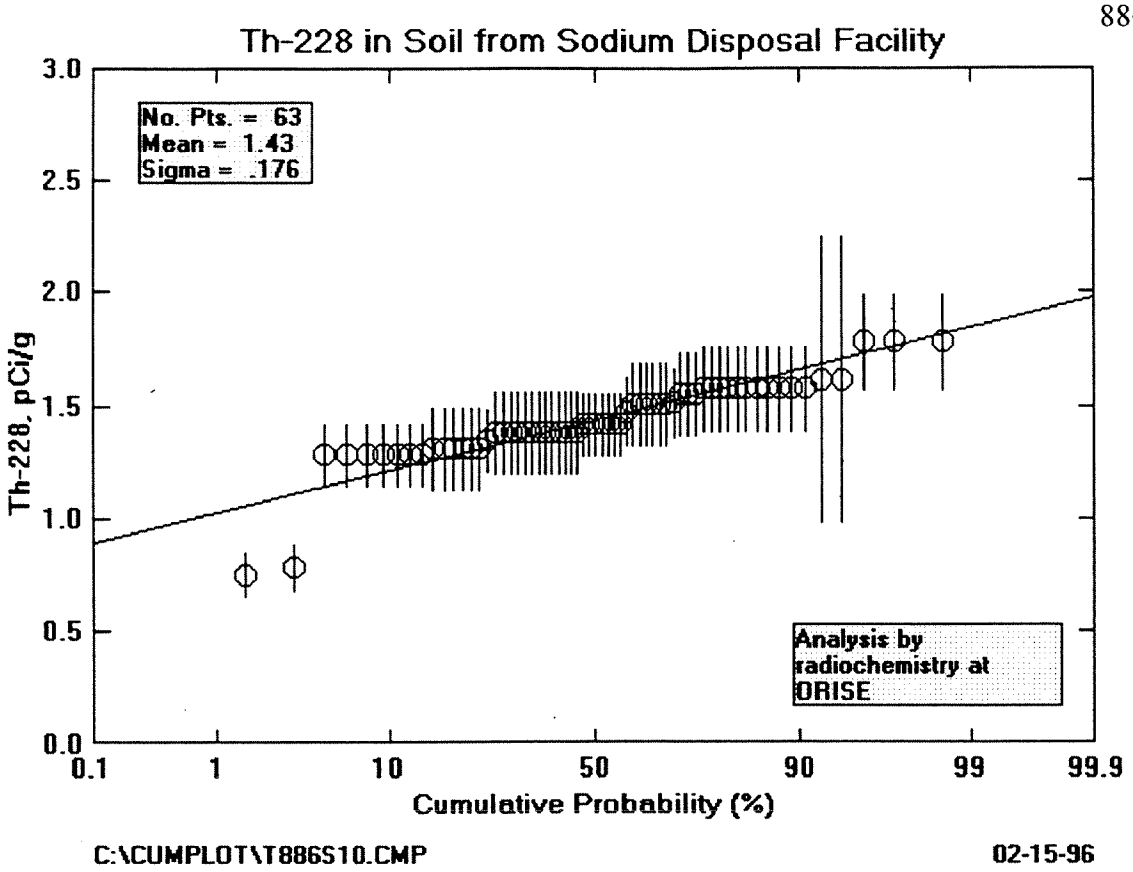


Figure 3i. Distribution of Sr-90 in Soil and Rock at the Former Sodium Disposal Facility.



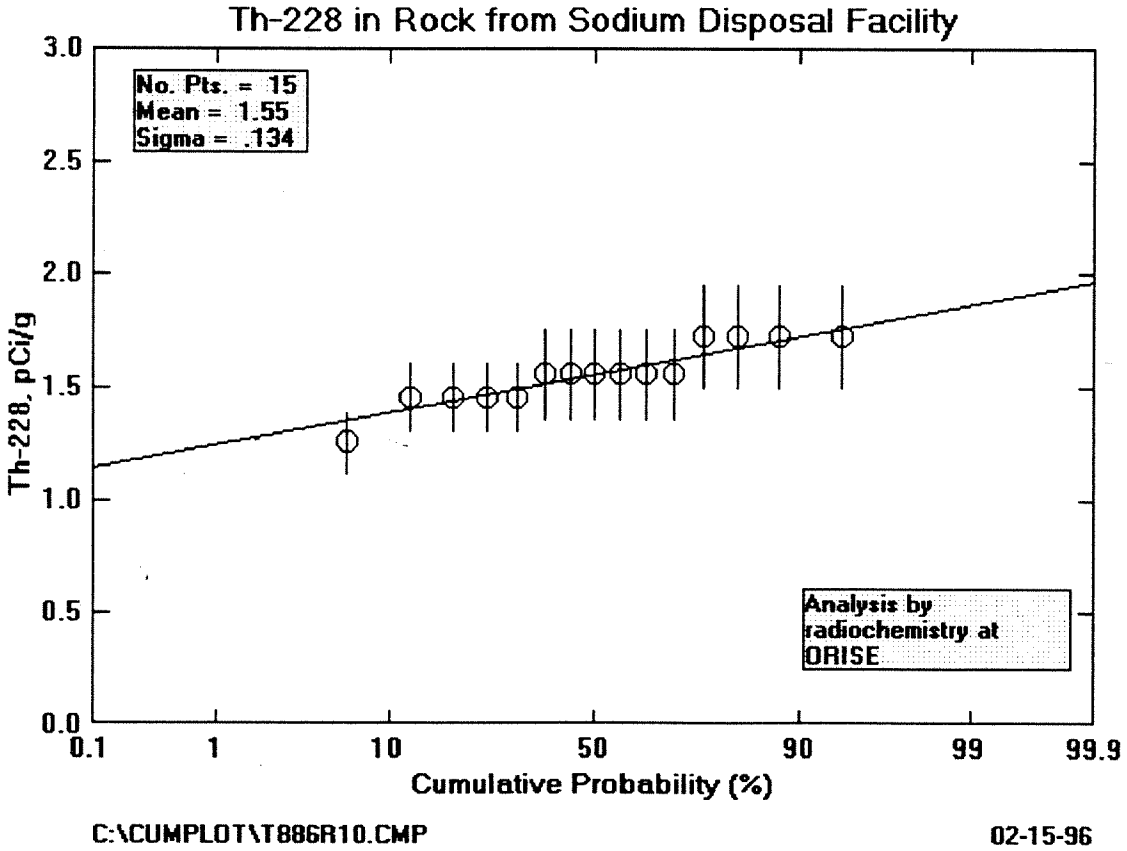
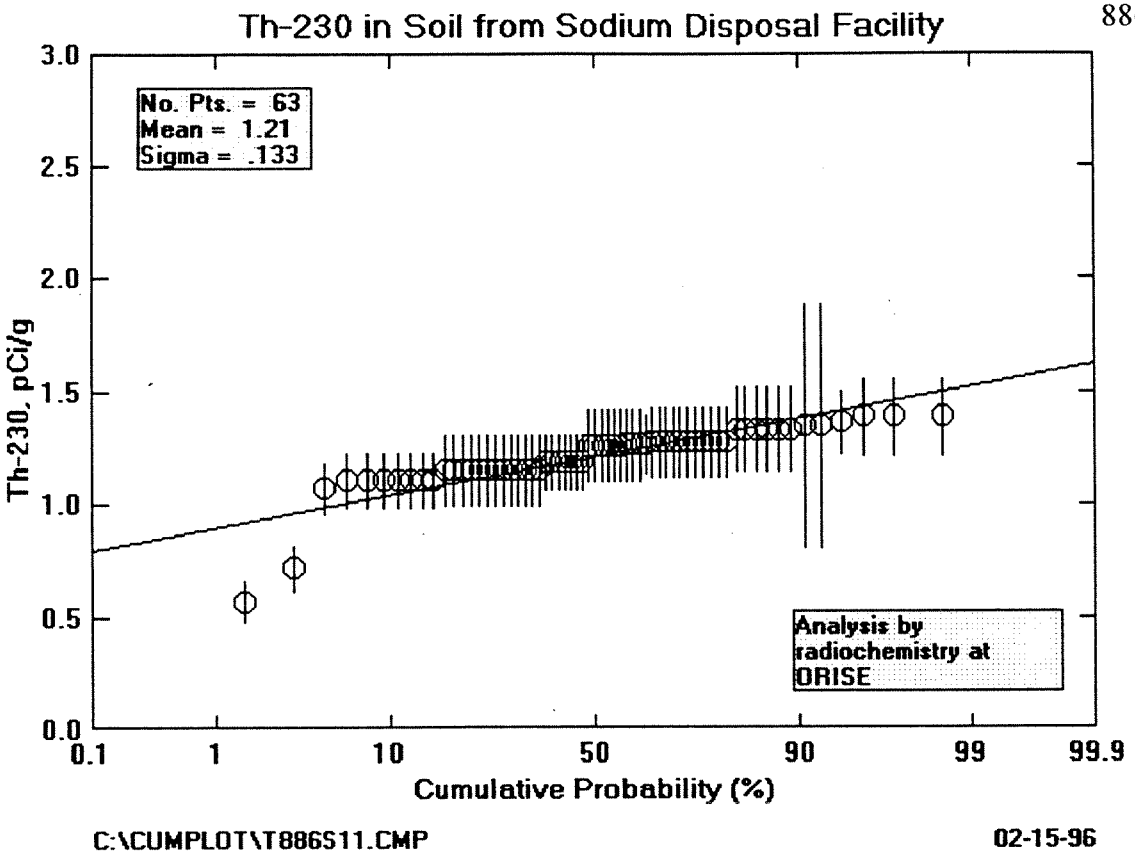


Figure 3j. Distribution of Th-228 in Soil and Rock at the Former Sodium Disposal Facility.



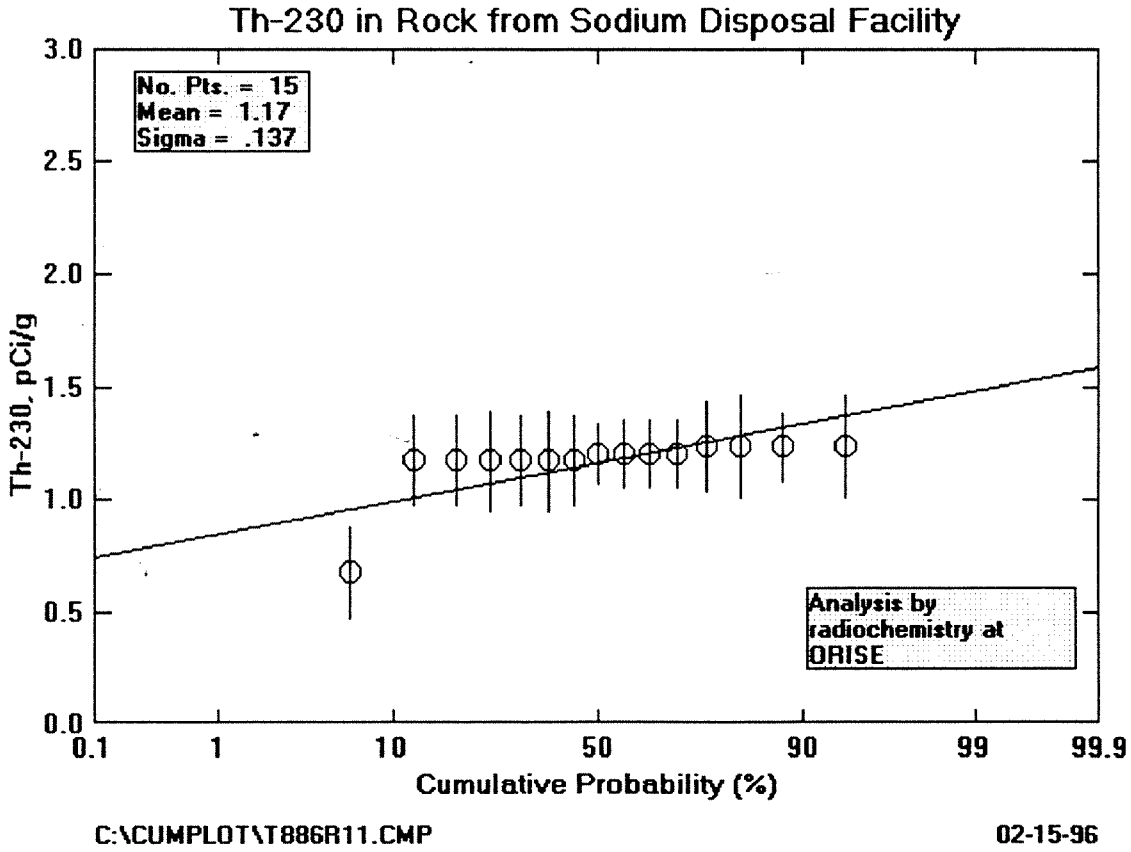
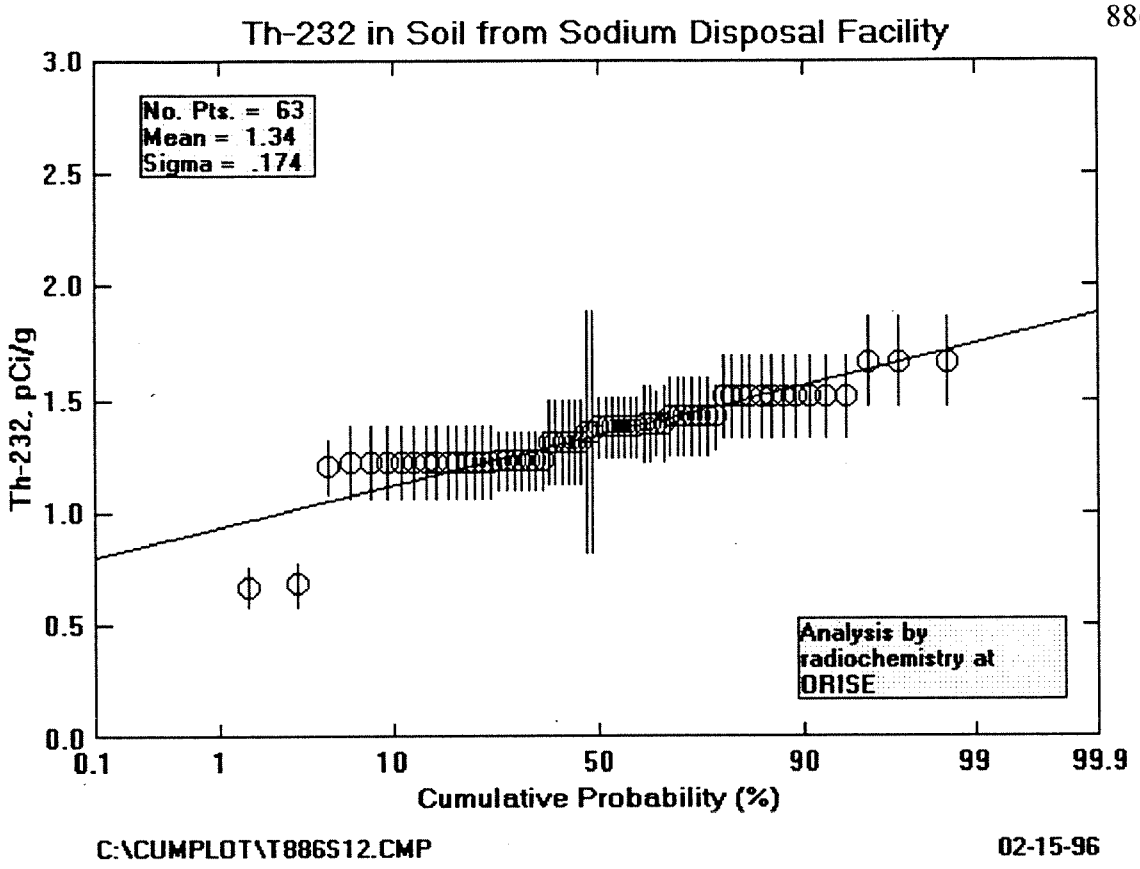


Figure 3k. Distribution of Th-230 in Soil and Rock at the Former Sodium Disposal Facility.



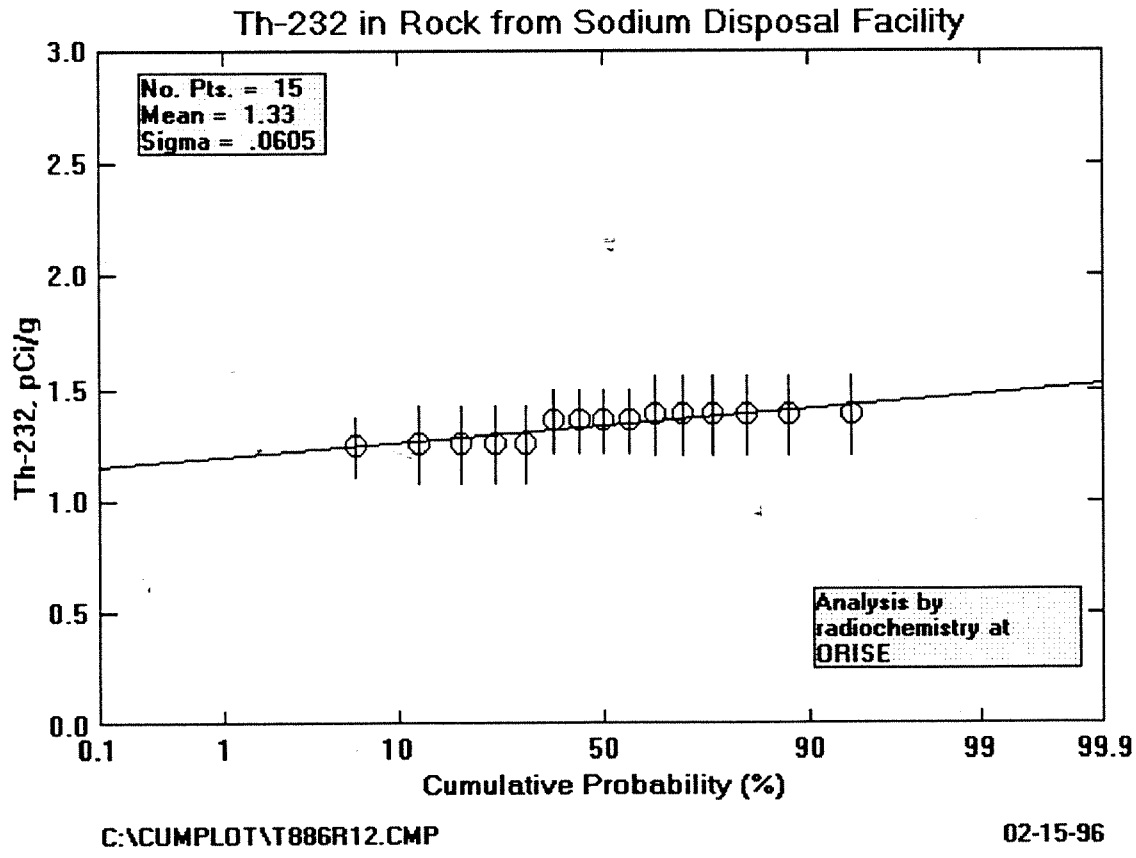
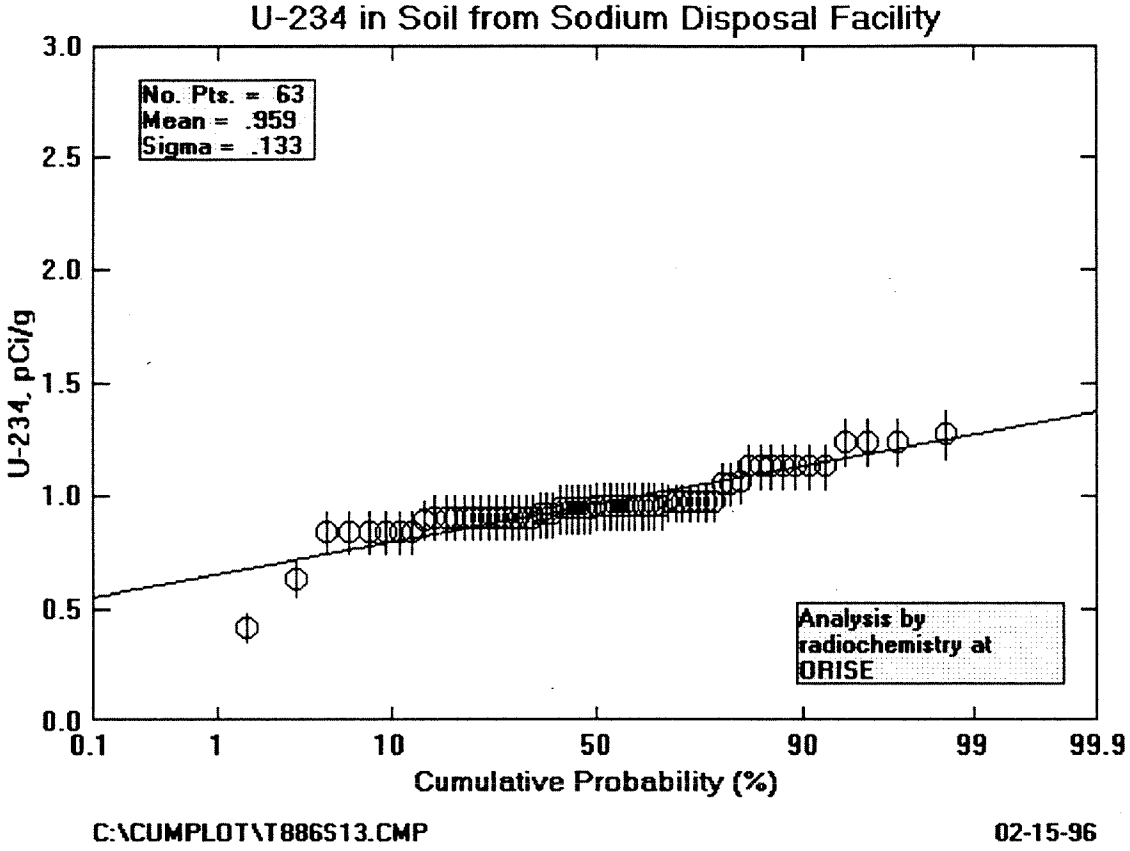


Figure 31. Distribution of Th-232 in Soil and Rock at the Former Sodium Disposal Facility.



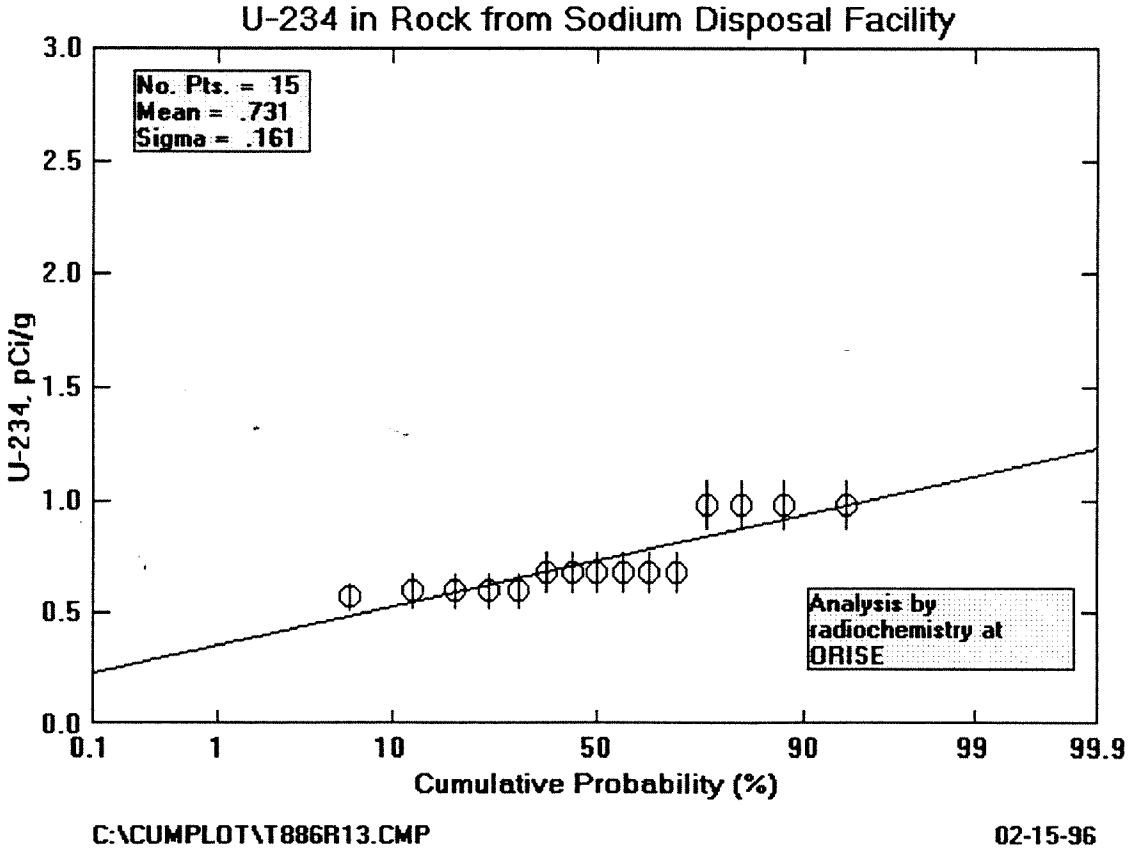
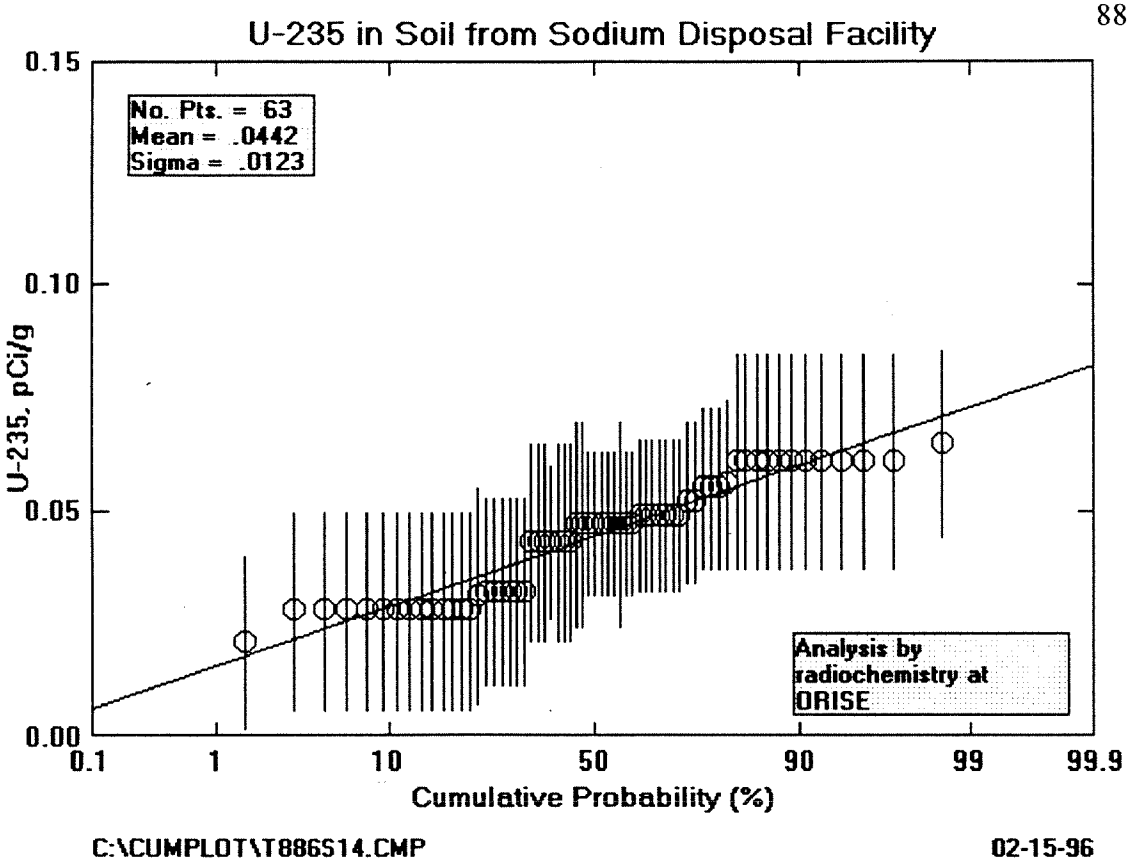


Figure 3m. Distribution of U-234 in Soil and Rock at the Former Sodium Disposal Facility.



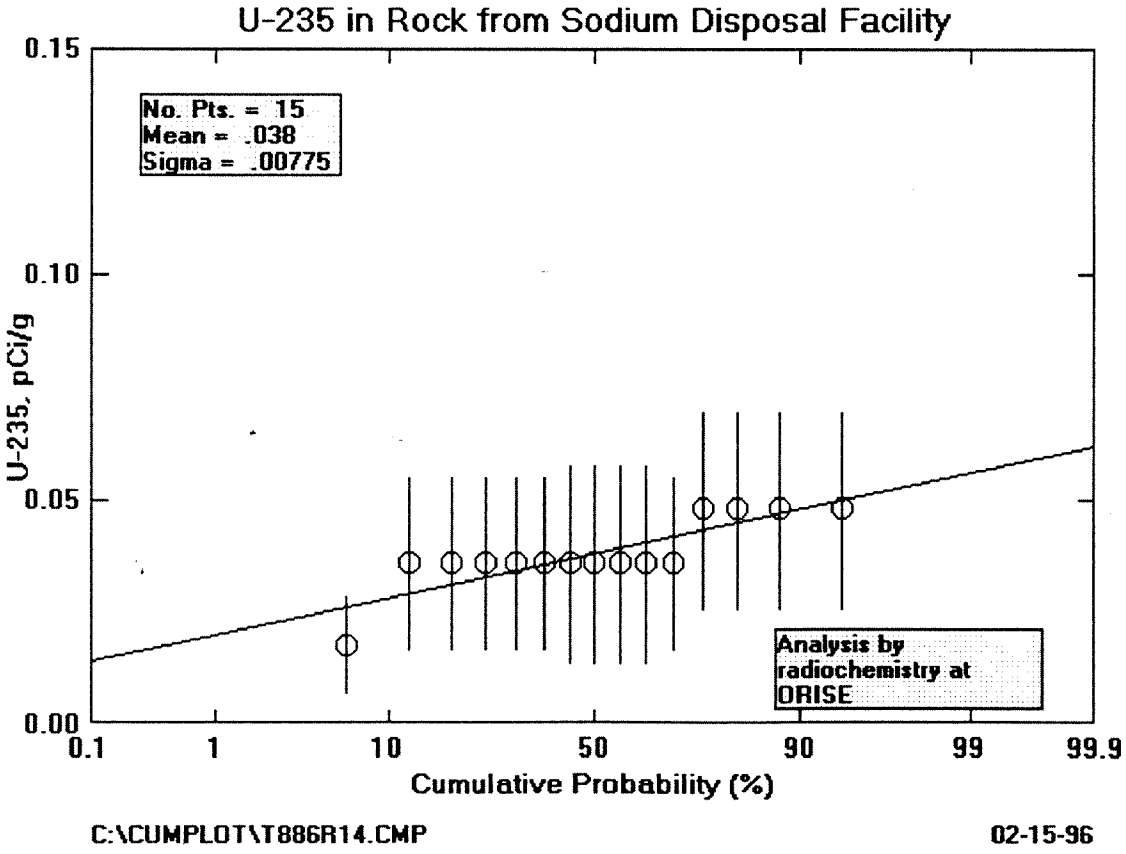
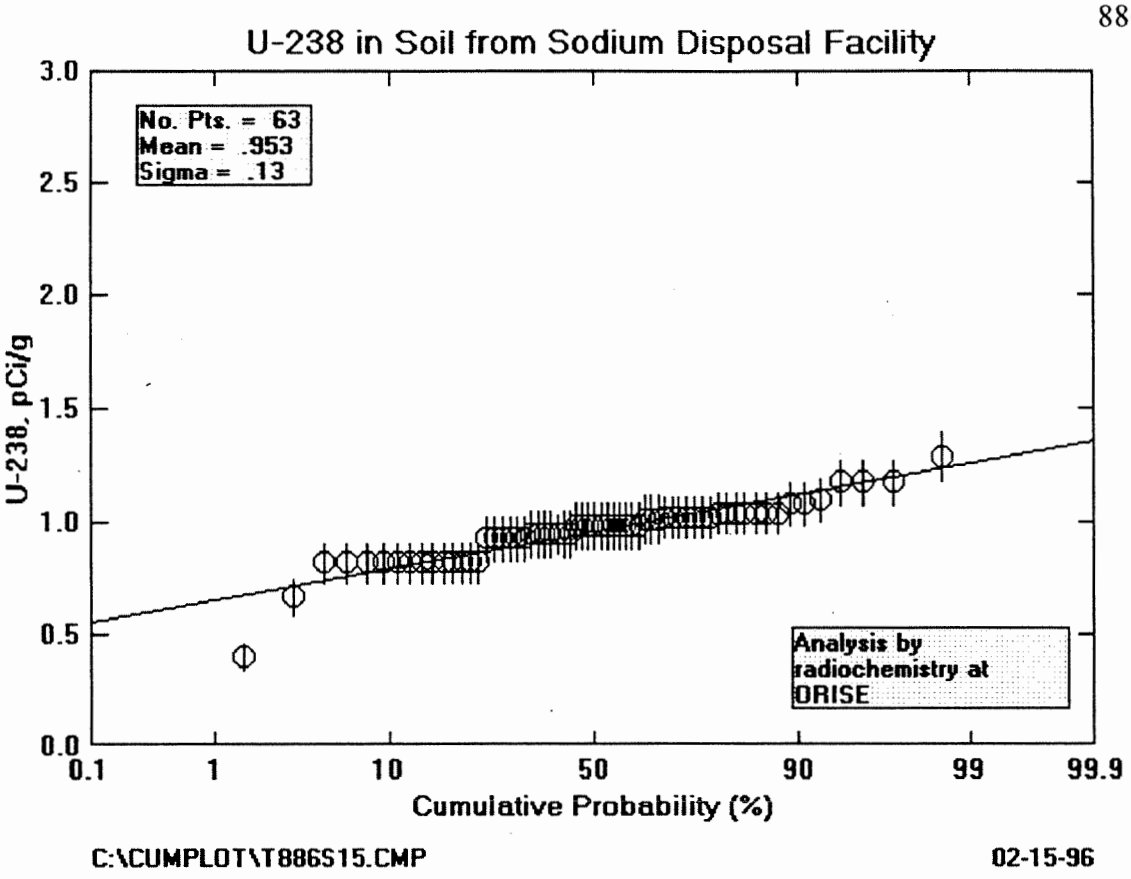


Figure 3n. Distribution of U-235 in Soil and Rock at the Former Sodium Disposal Facility.



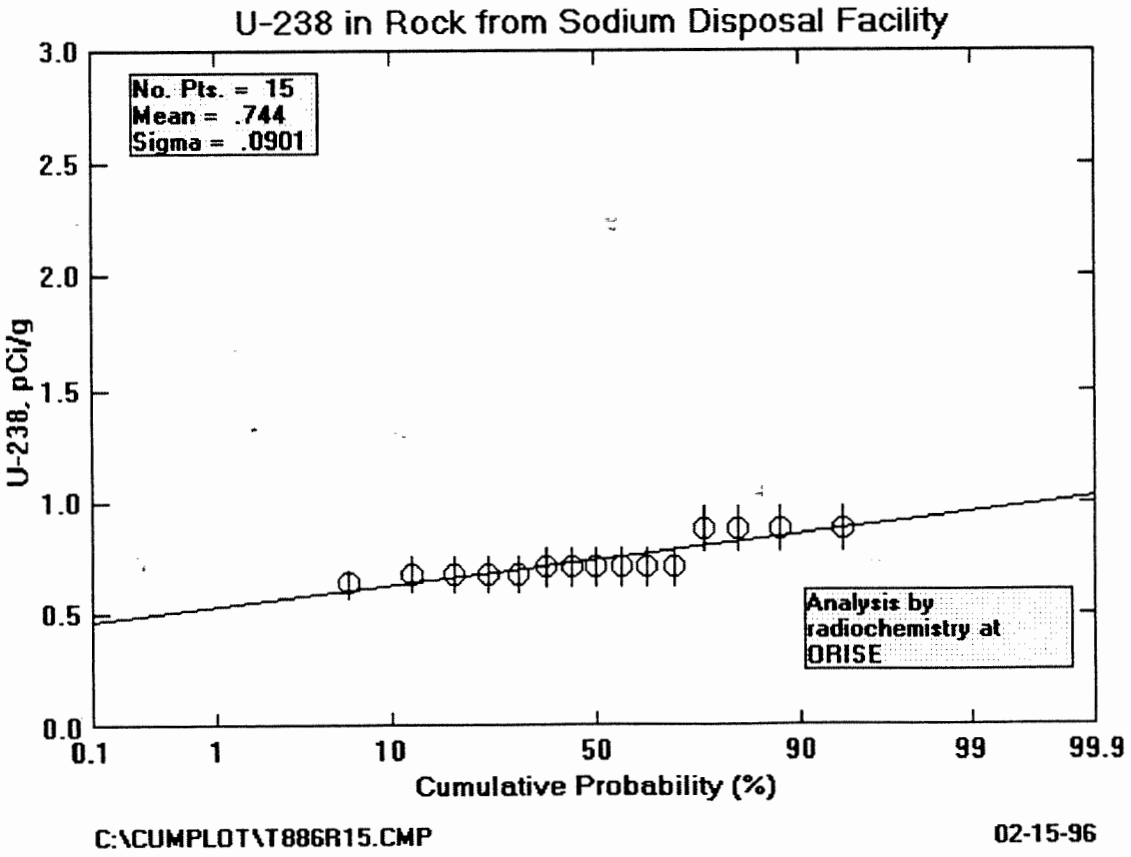
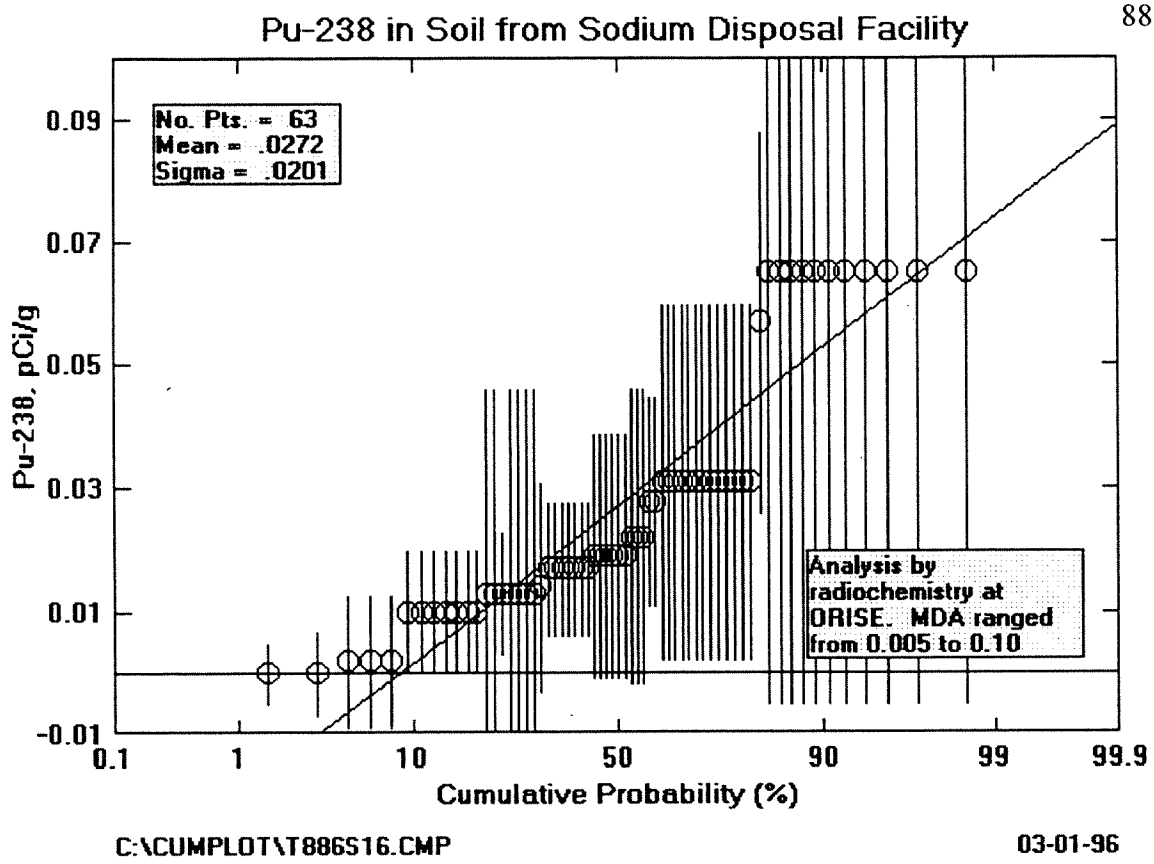


Figure 3o. Distribution of U-238 in Soil and Rock at the Former Sodium Disposal Facility.



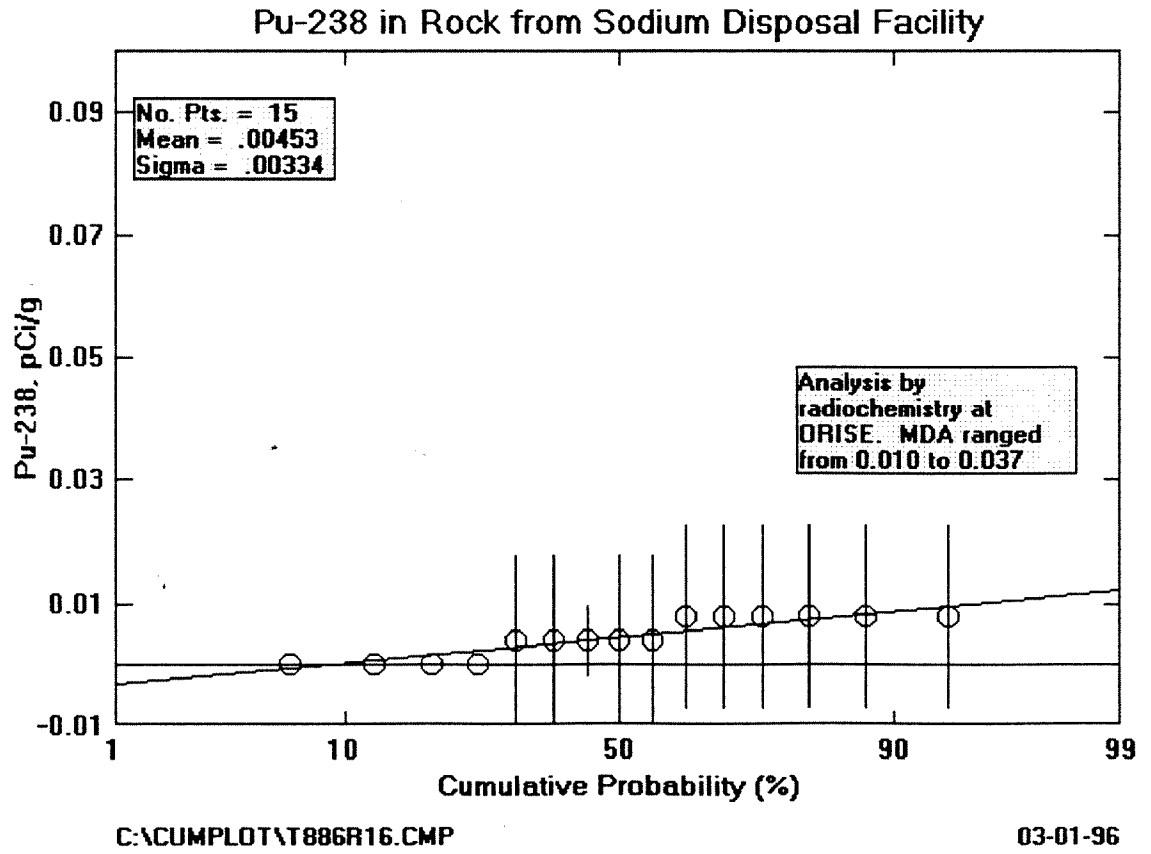
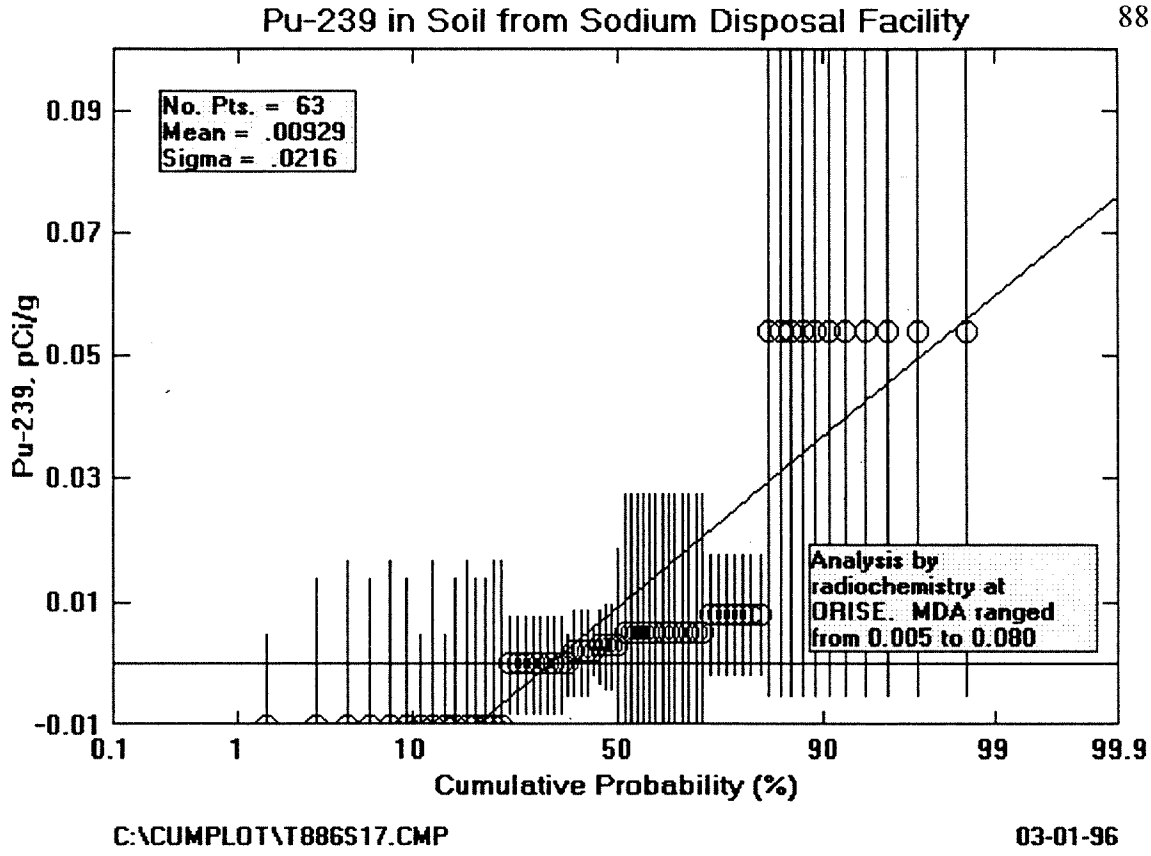


Figure 3p. Distribution of Pu-238 in Soil and Rock at the Former Sodium Disposal Facility.



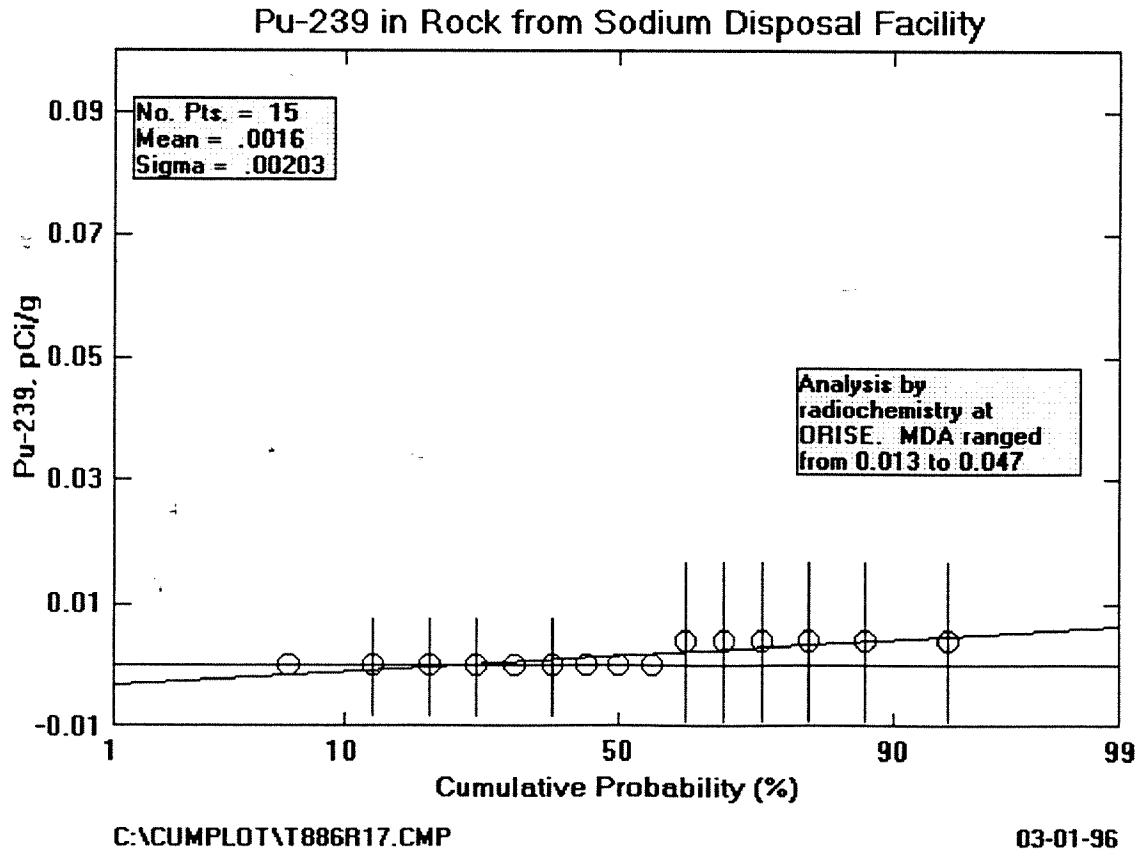
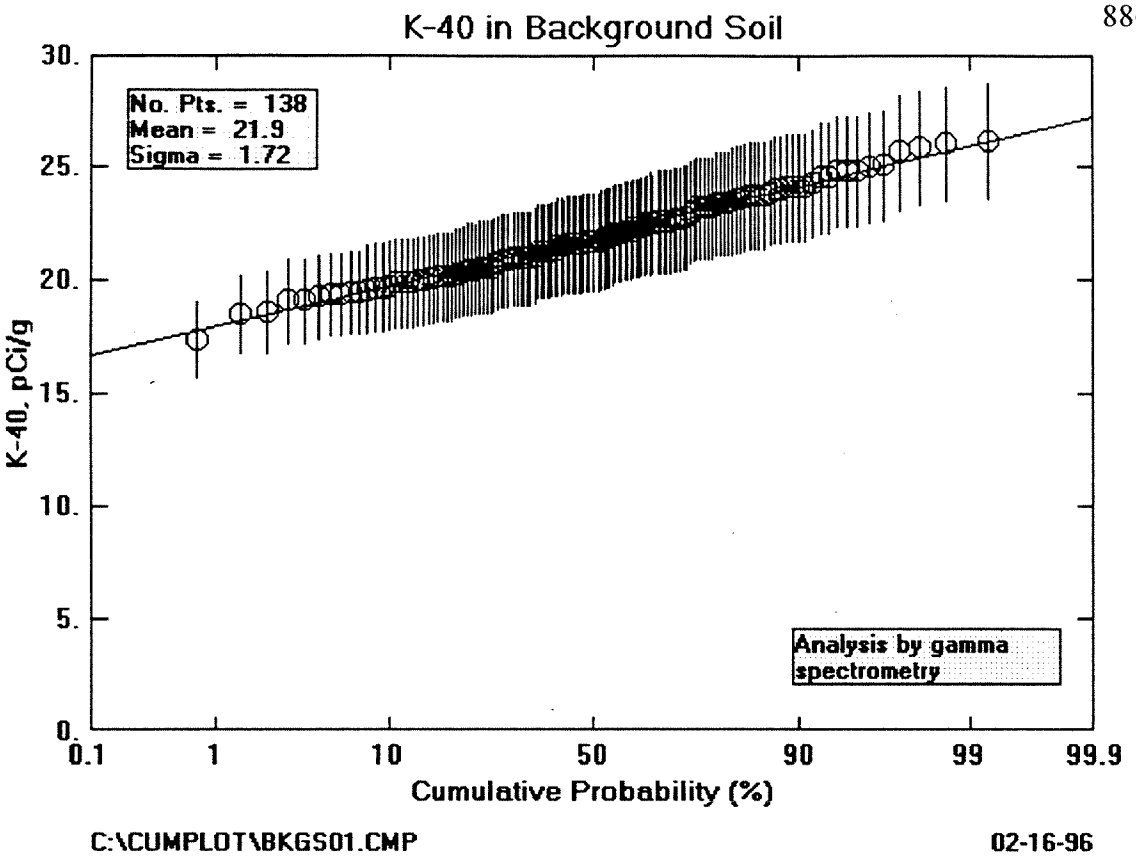


Figure 3q. Distribution of Pu-239 in Soil and Rock at the Former Sodium Disposal Facility.



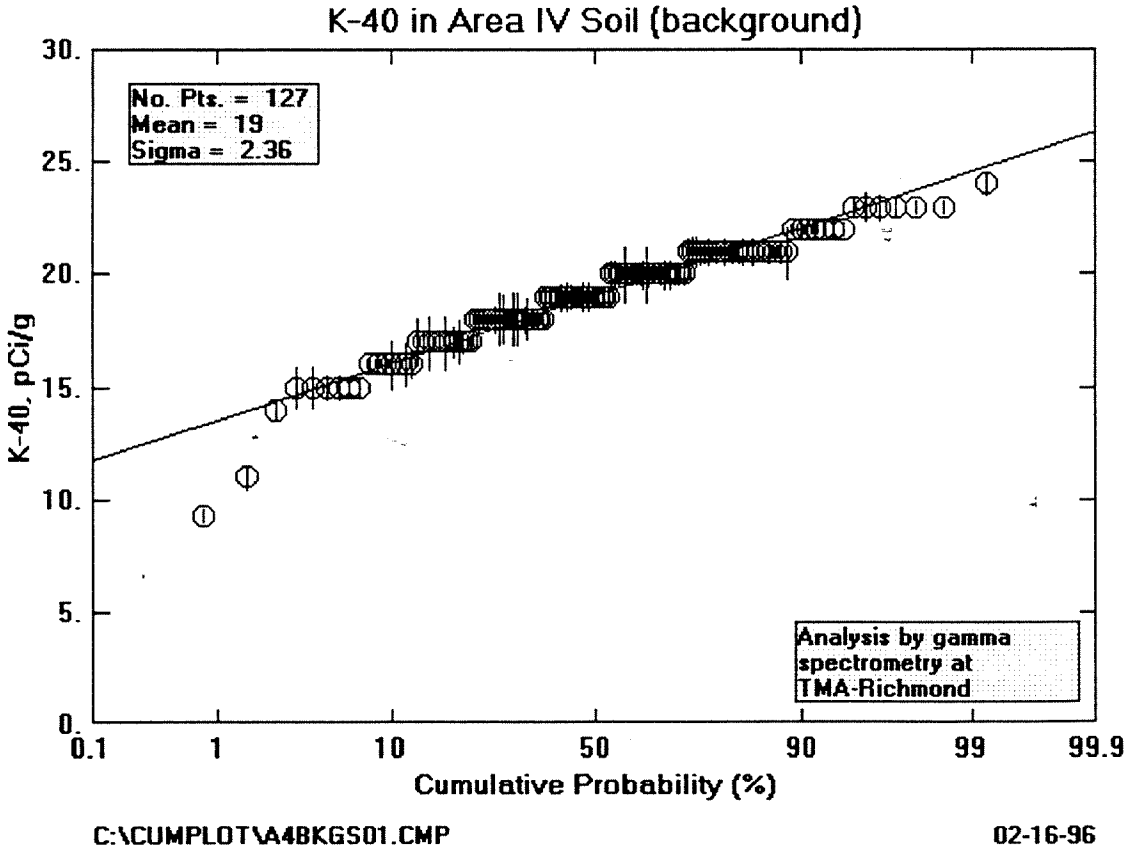
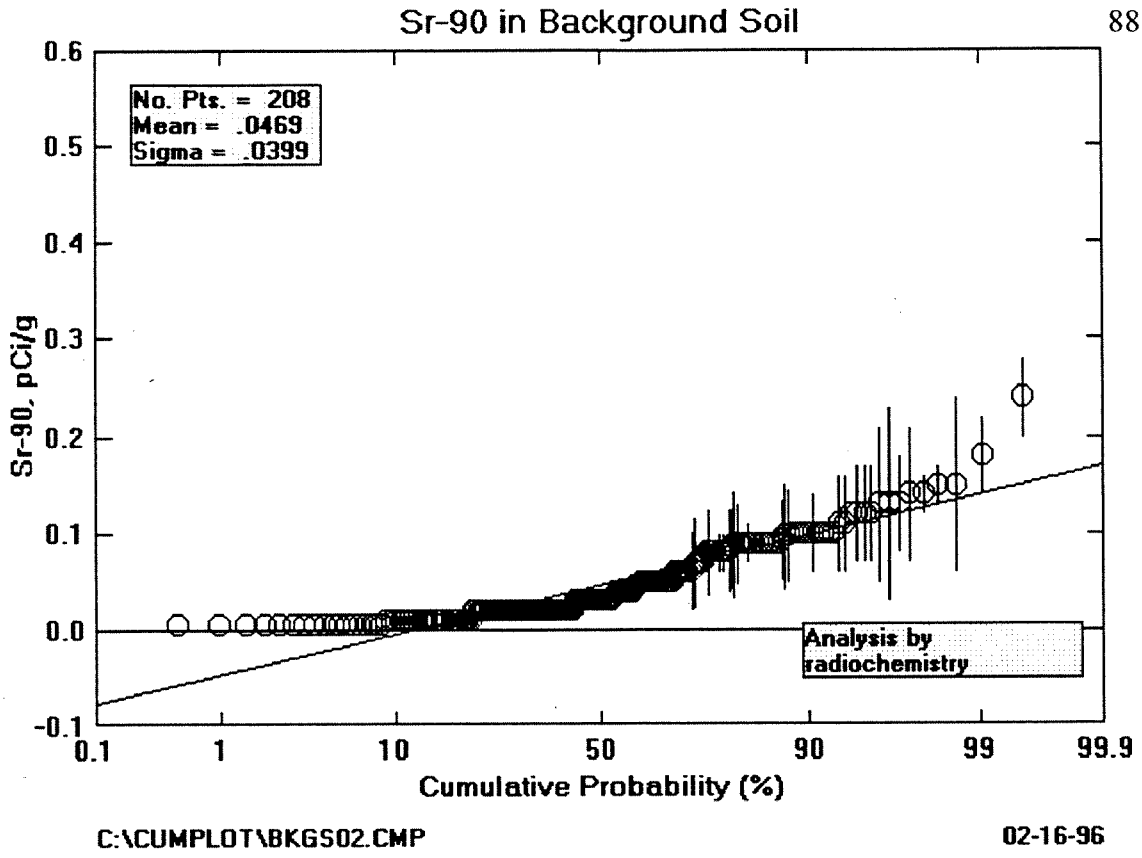


Figure 4a. Distribution of K-40 in Background Soil.



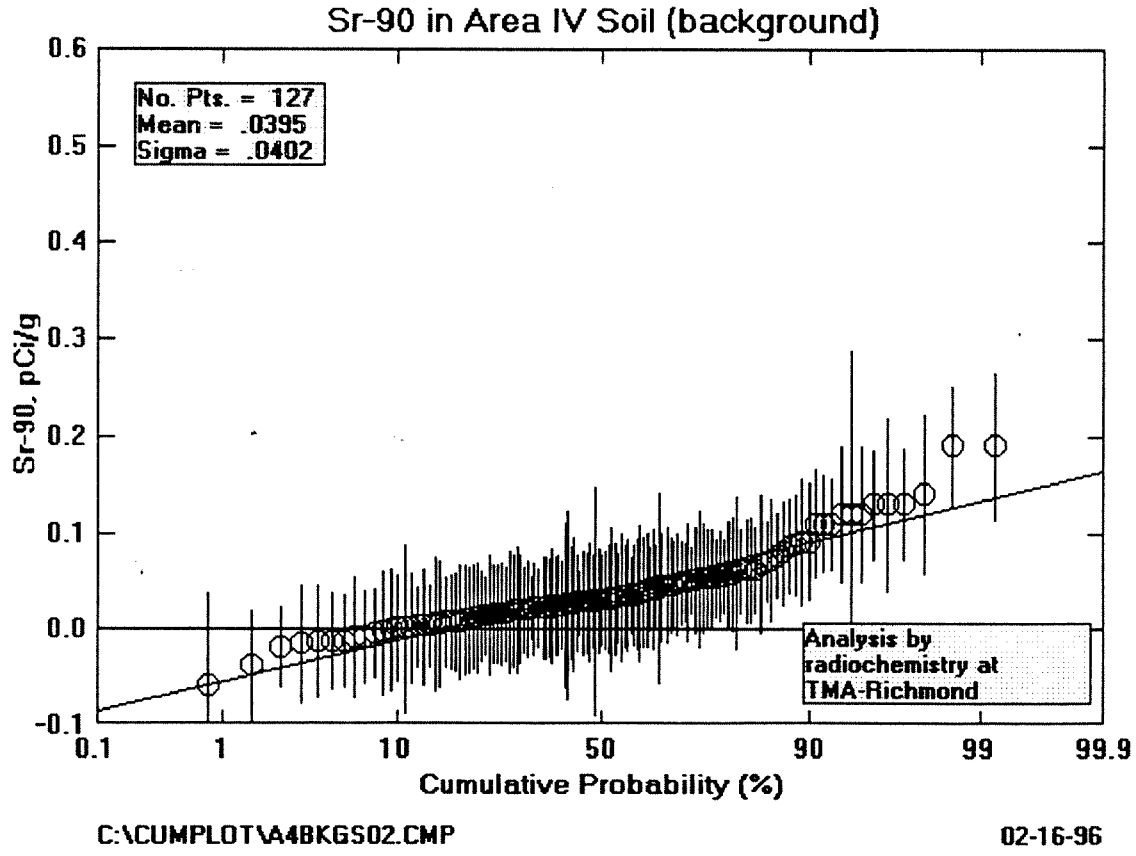
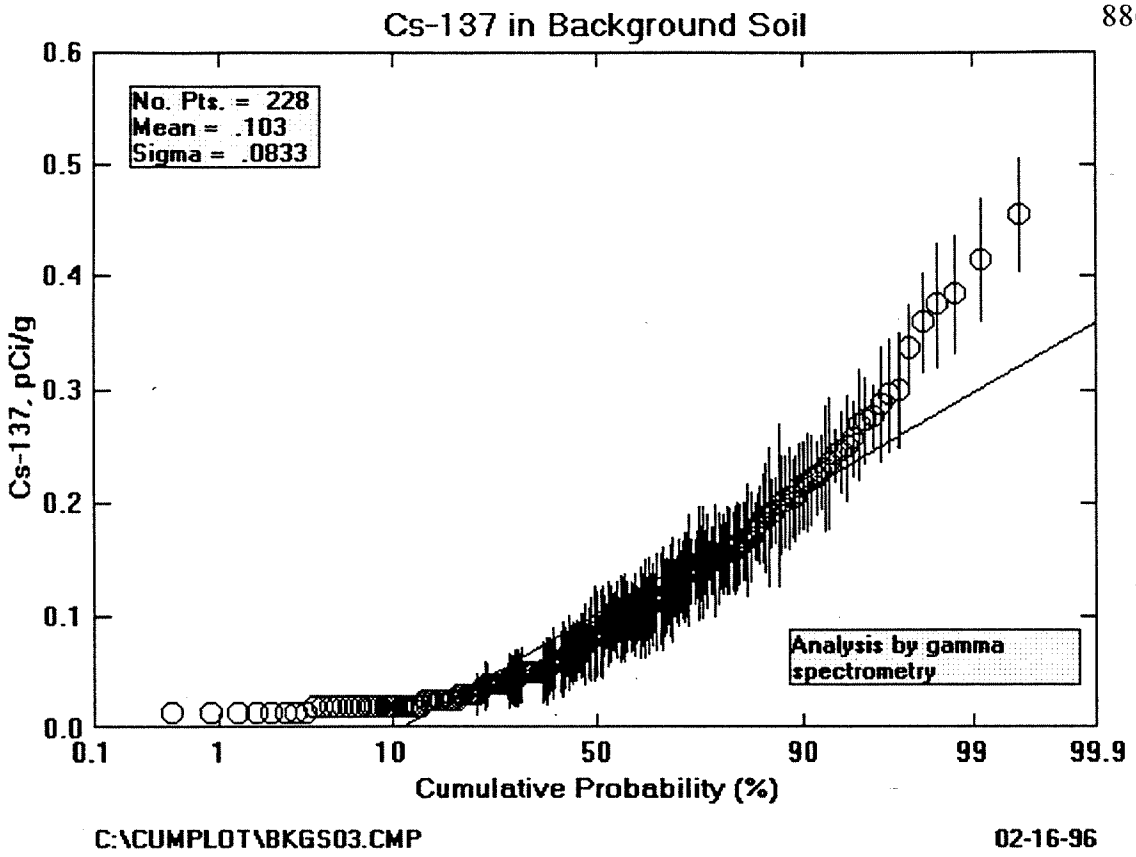


Figure 4b. Distribution of Sr-90 in Background Soil.



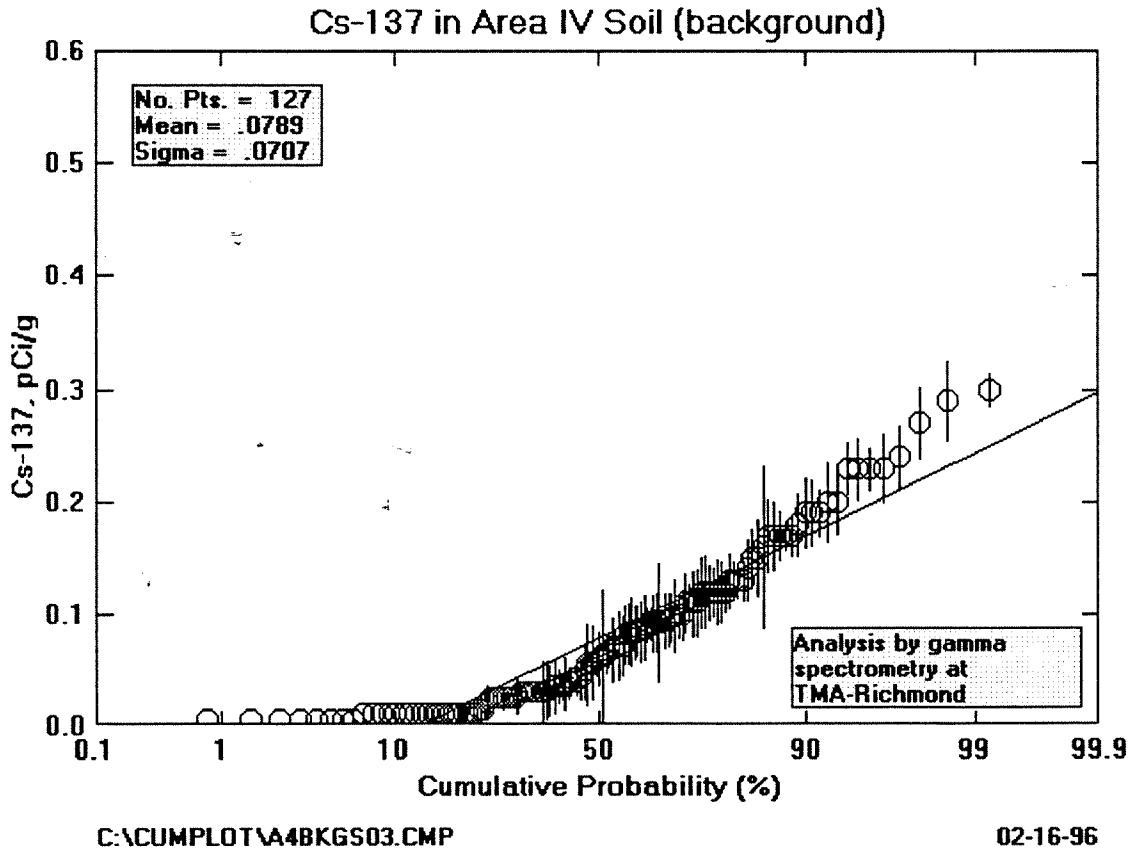
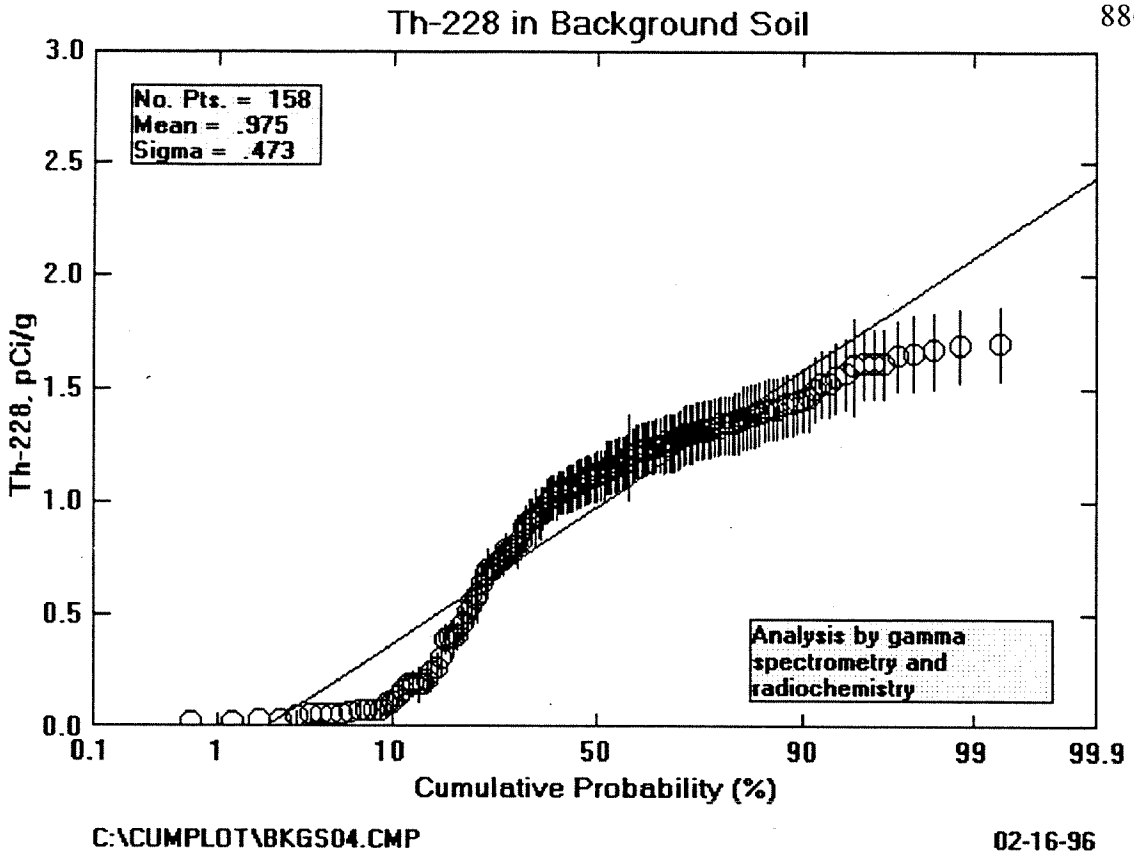


Figure 4c. Distribution of Cs-137 in Background Soil.



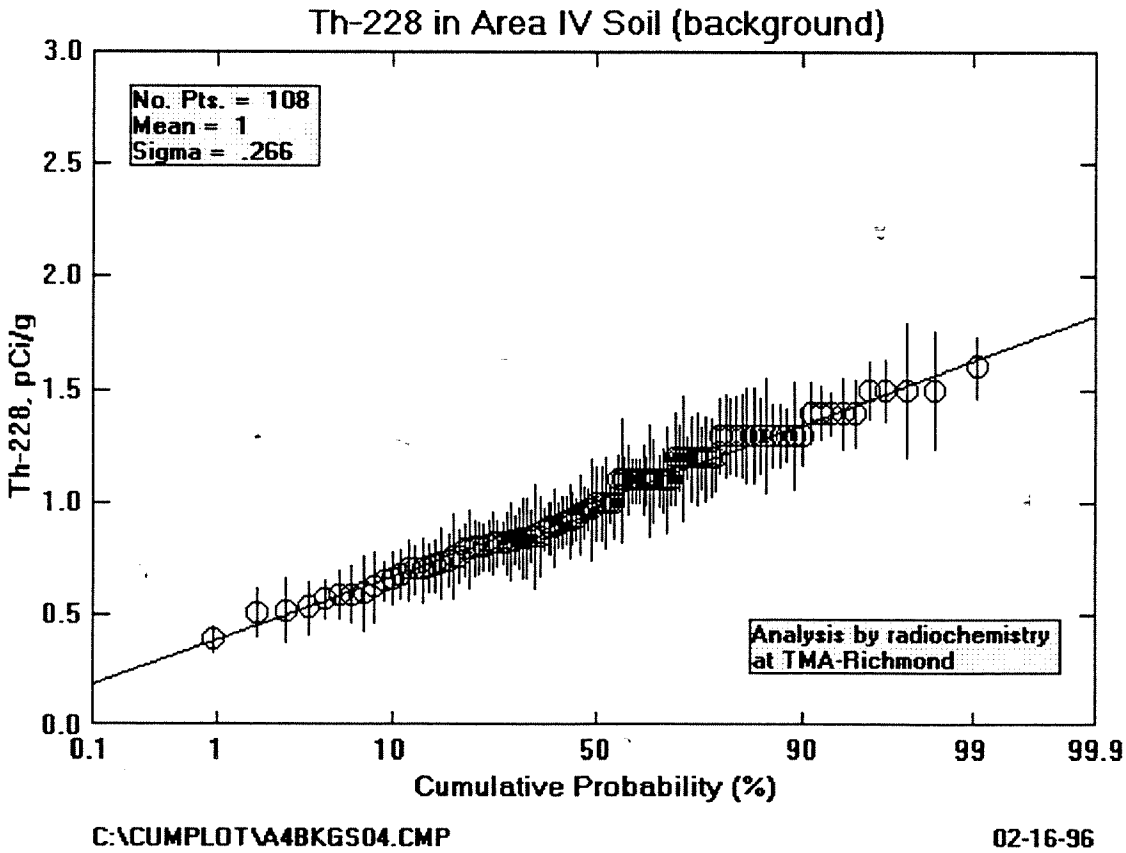
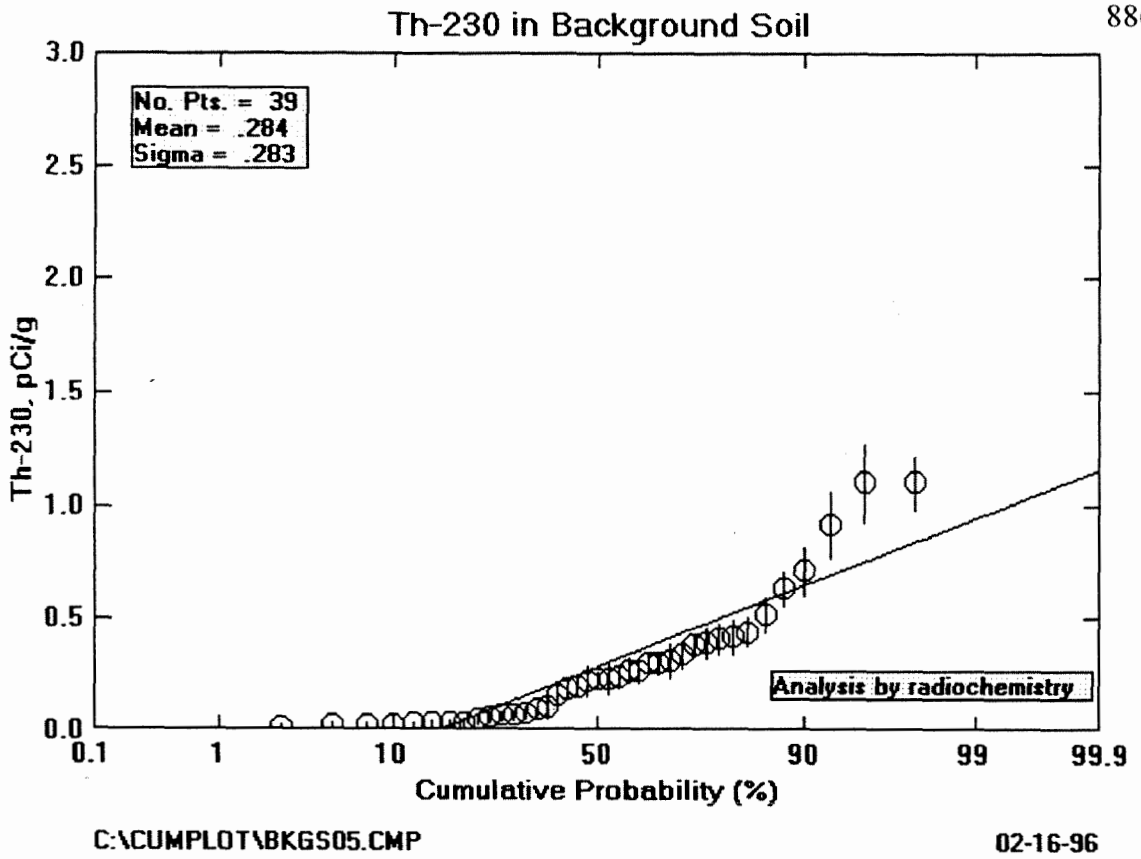


Figure 4d. Distribution of Th-228 in Background Soil.



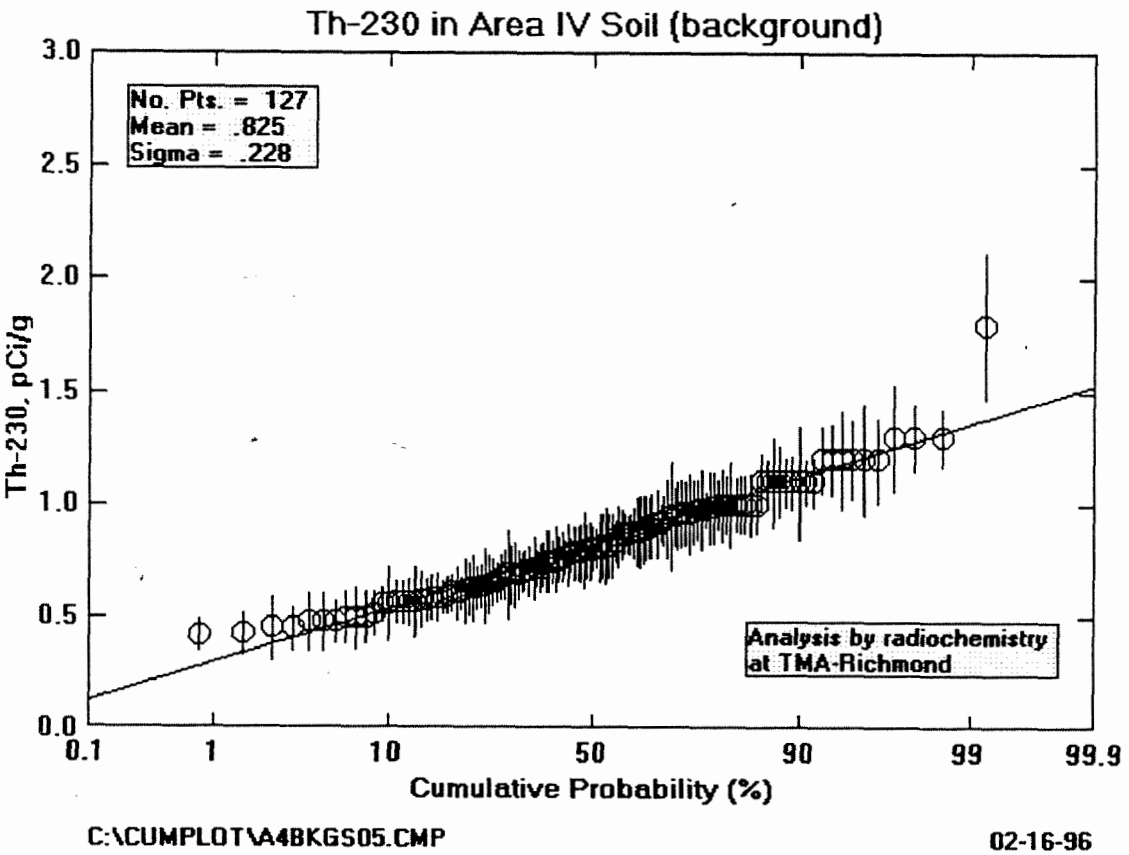
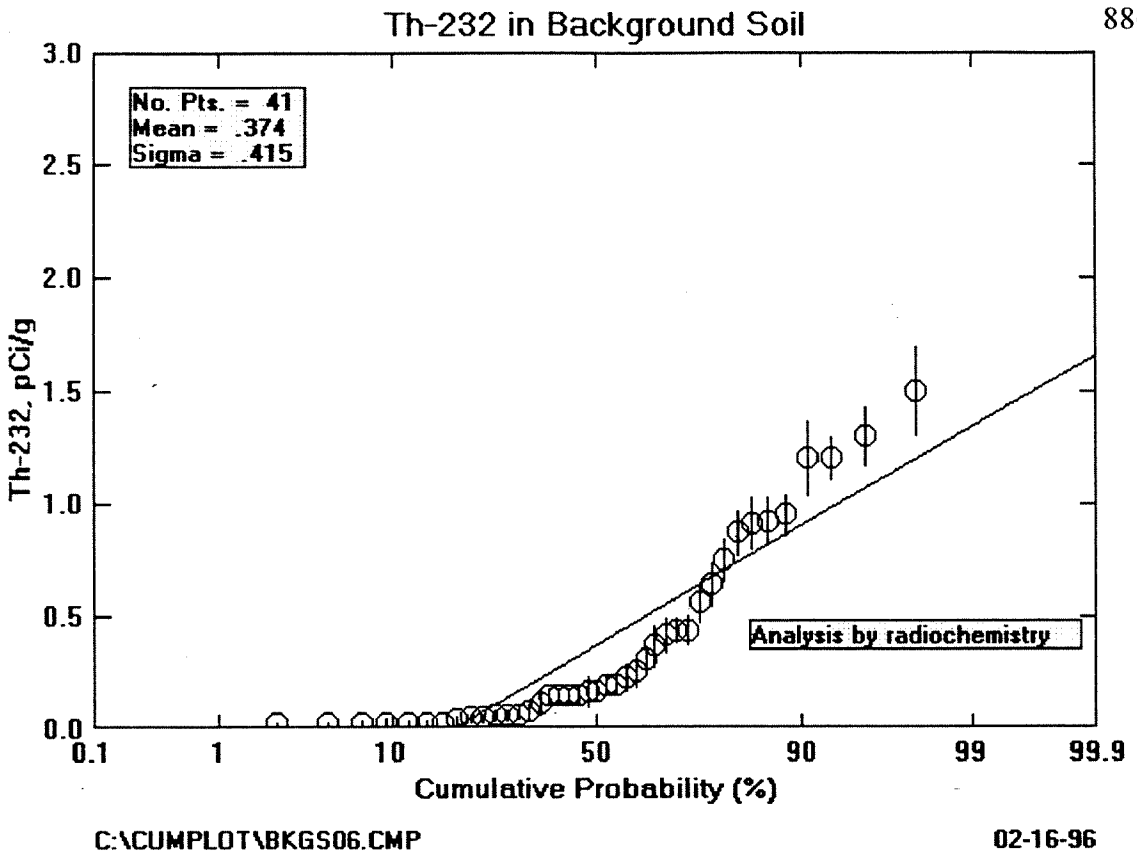


Figure 4e. Distribution of Th-230 in Background Soil.



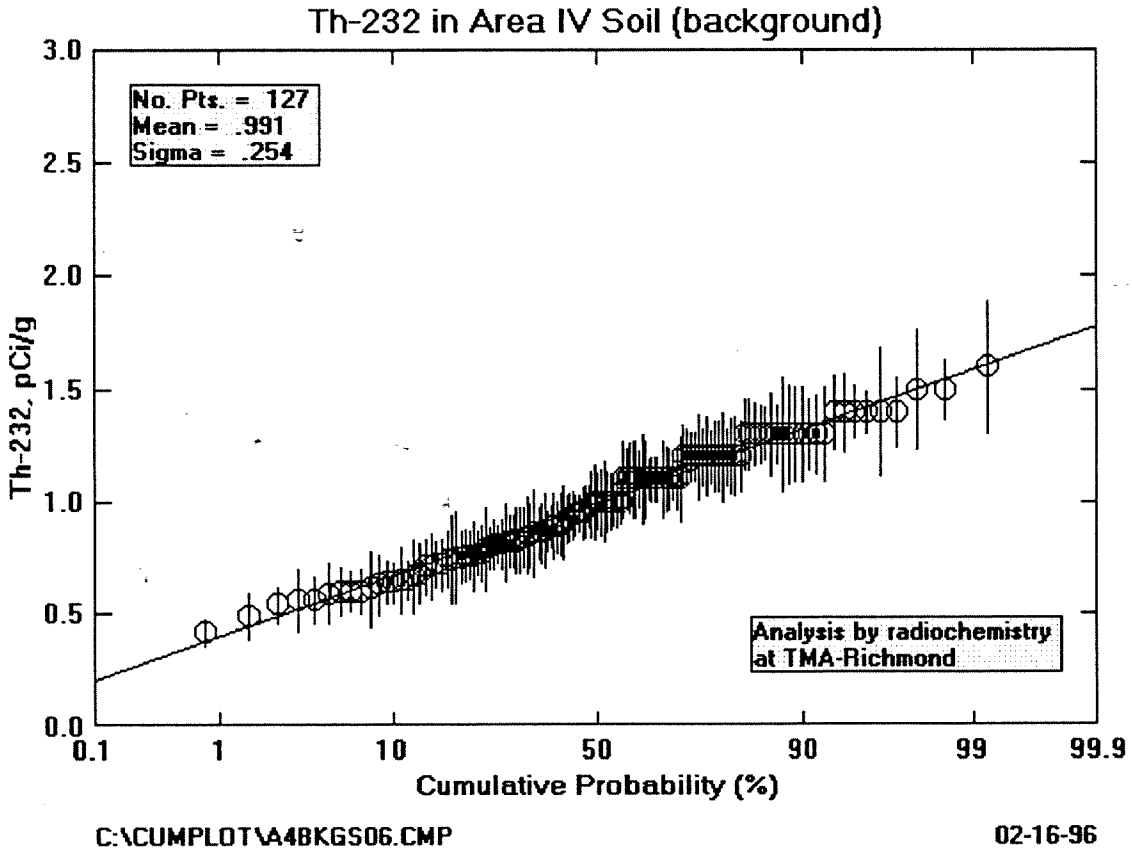
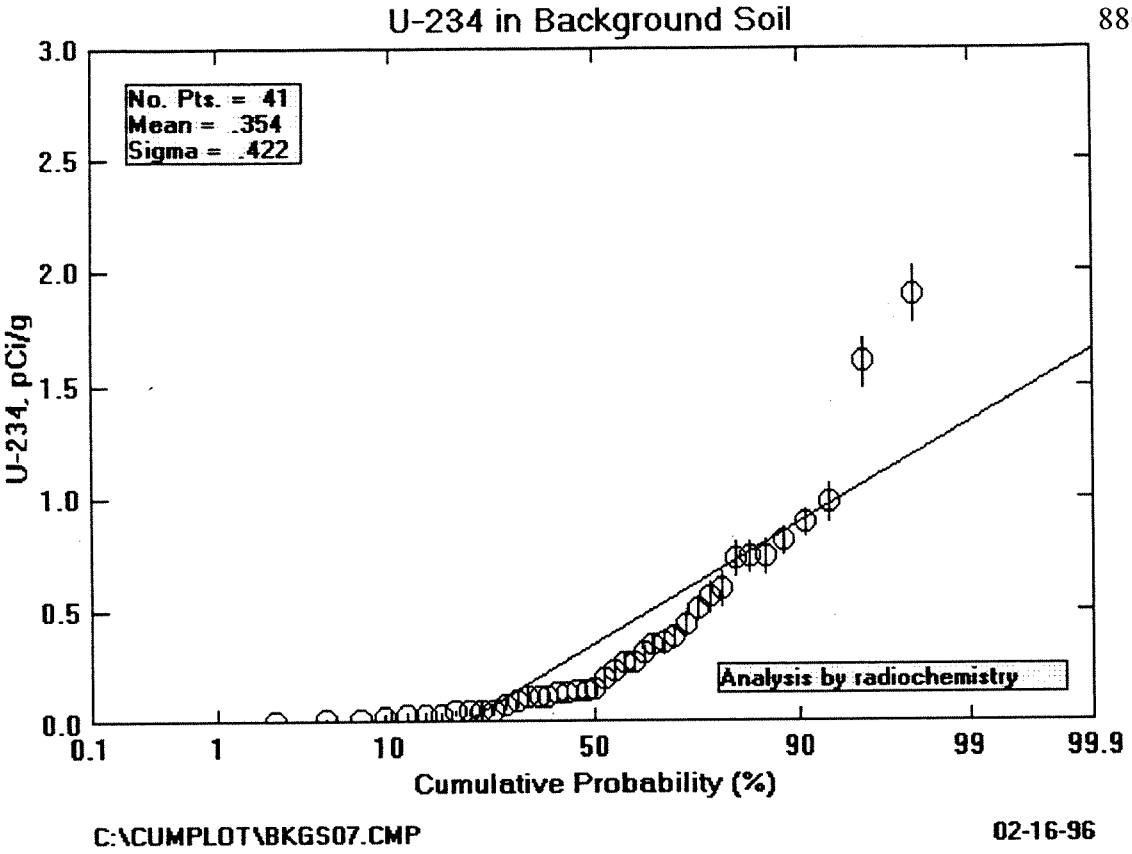


Figure 4f. Distribution of Th-232 in Background Soil.



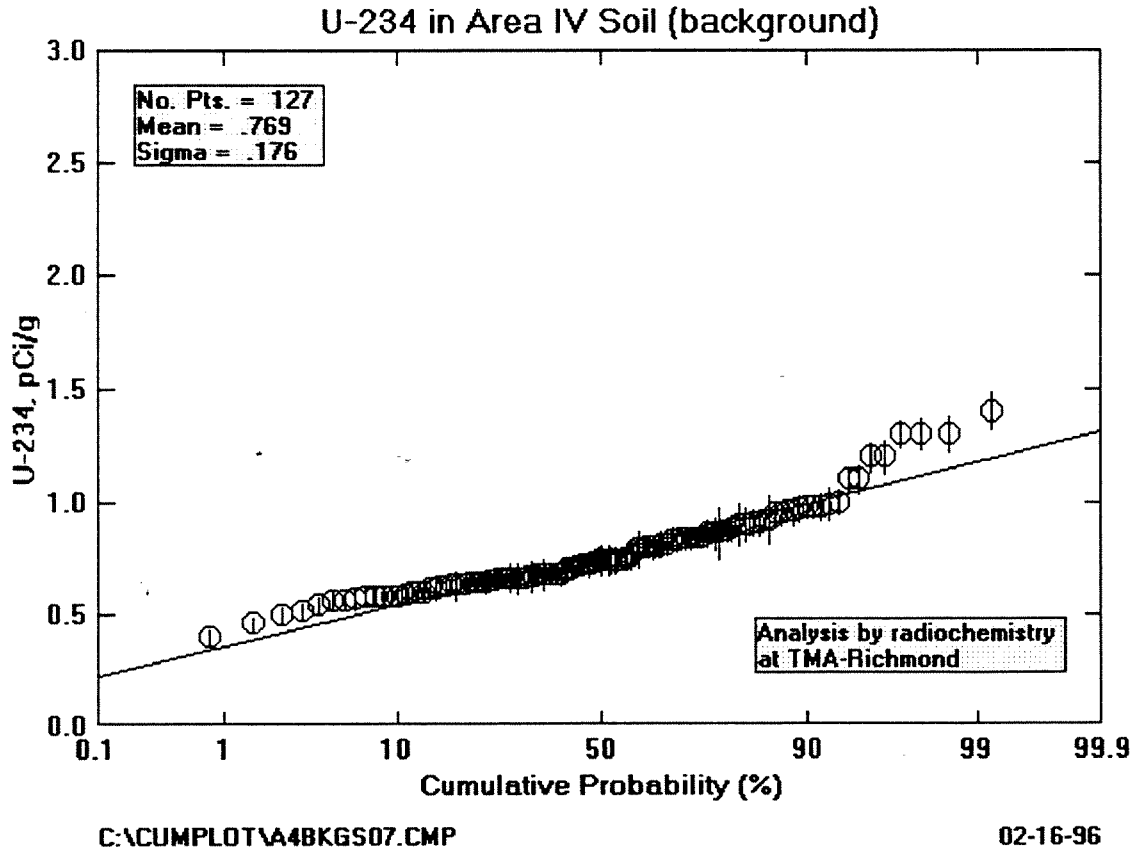
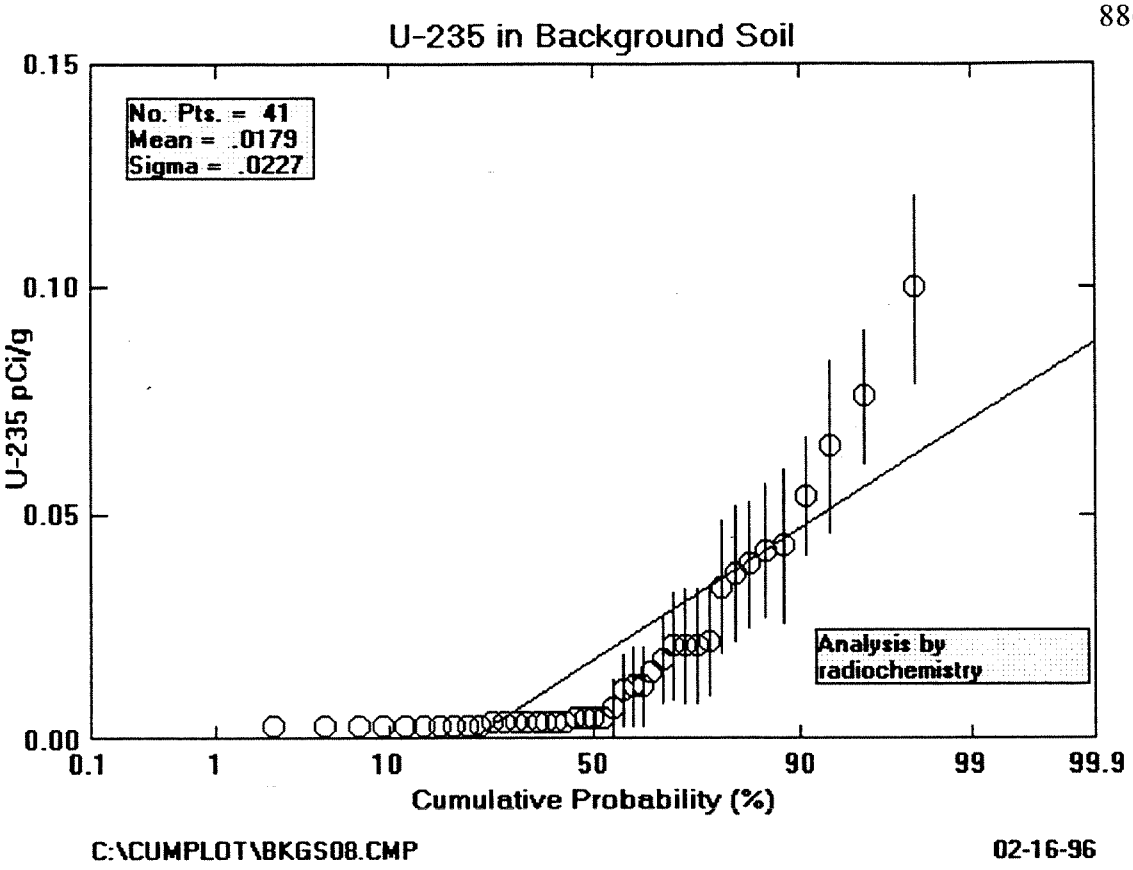


Figure 4g. Distribution of U-234 in Background Soil.



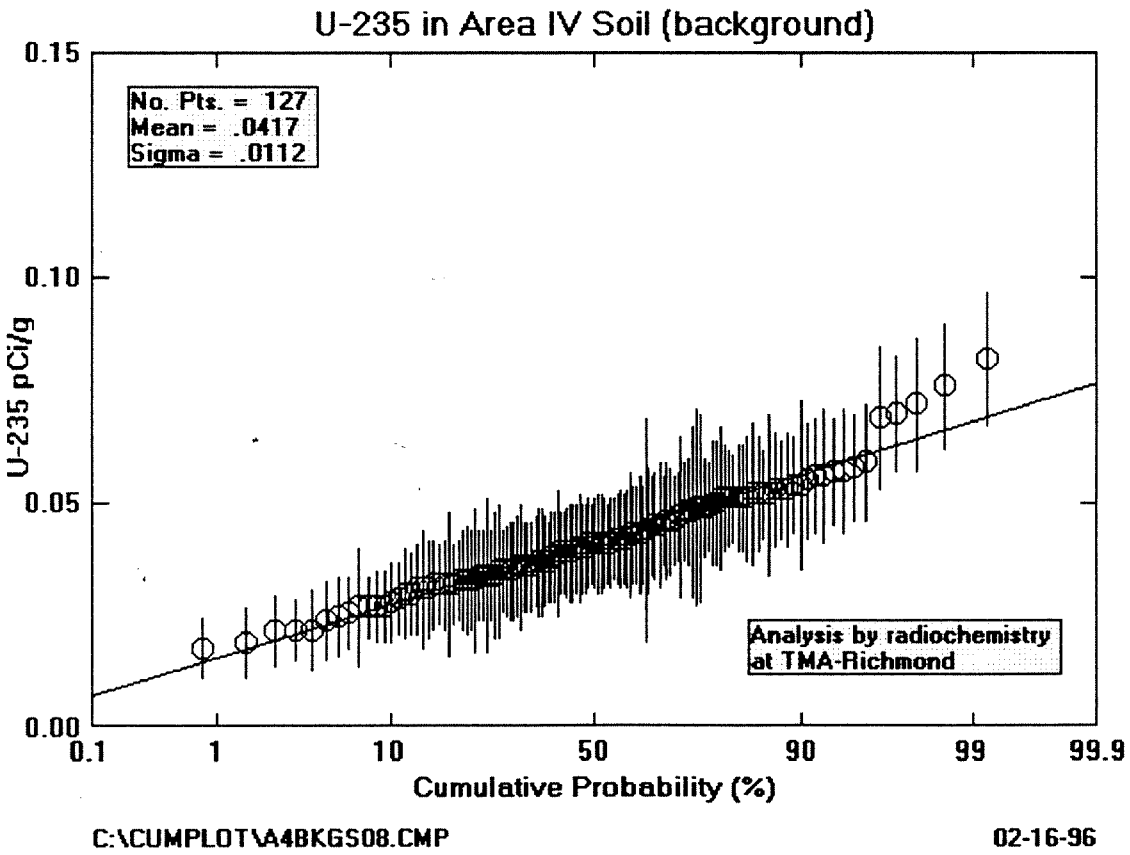
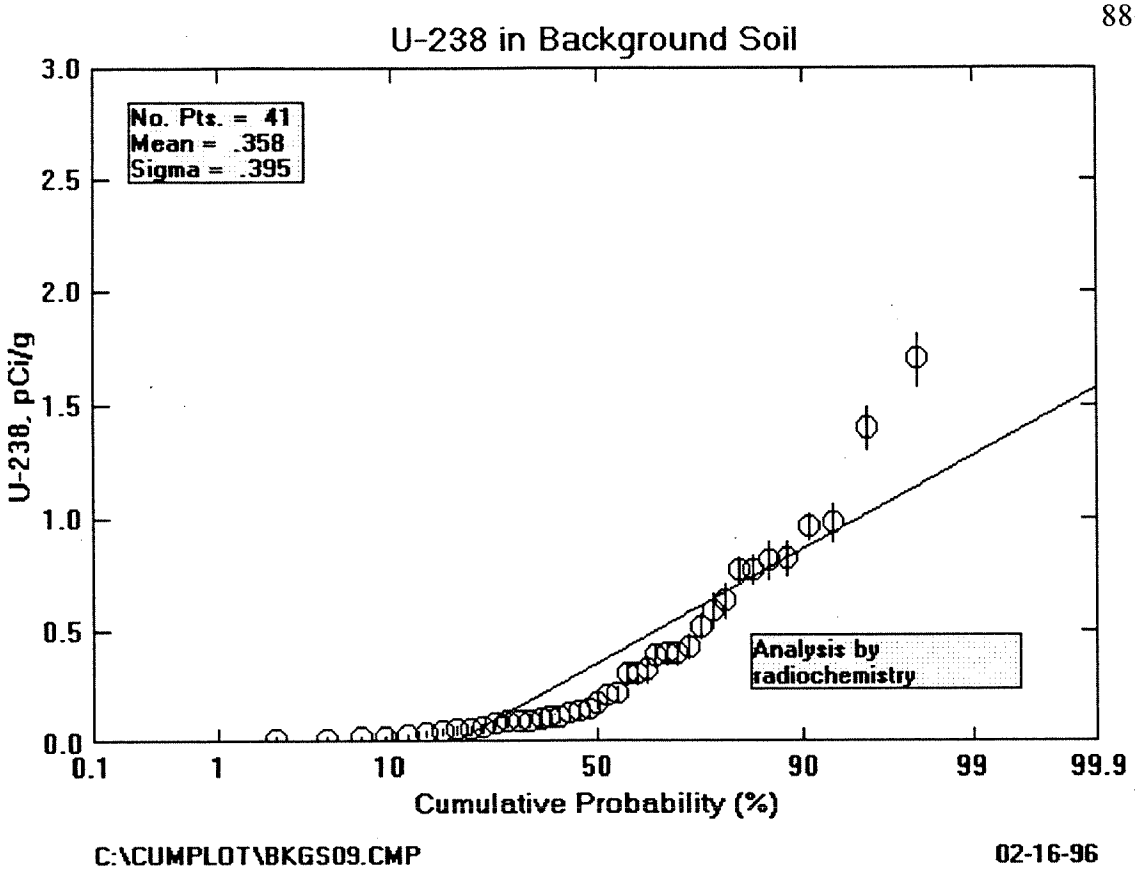


Figure 4h. Distribution of U-235 in Background Soil.



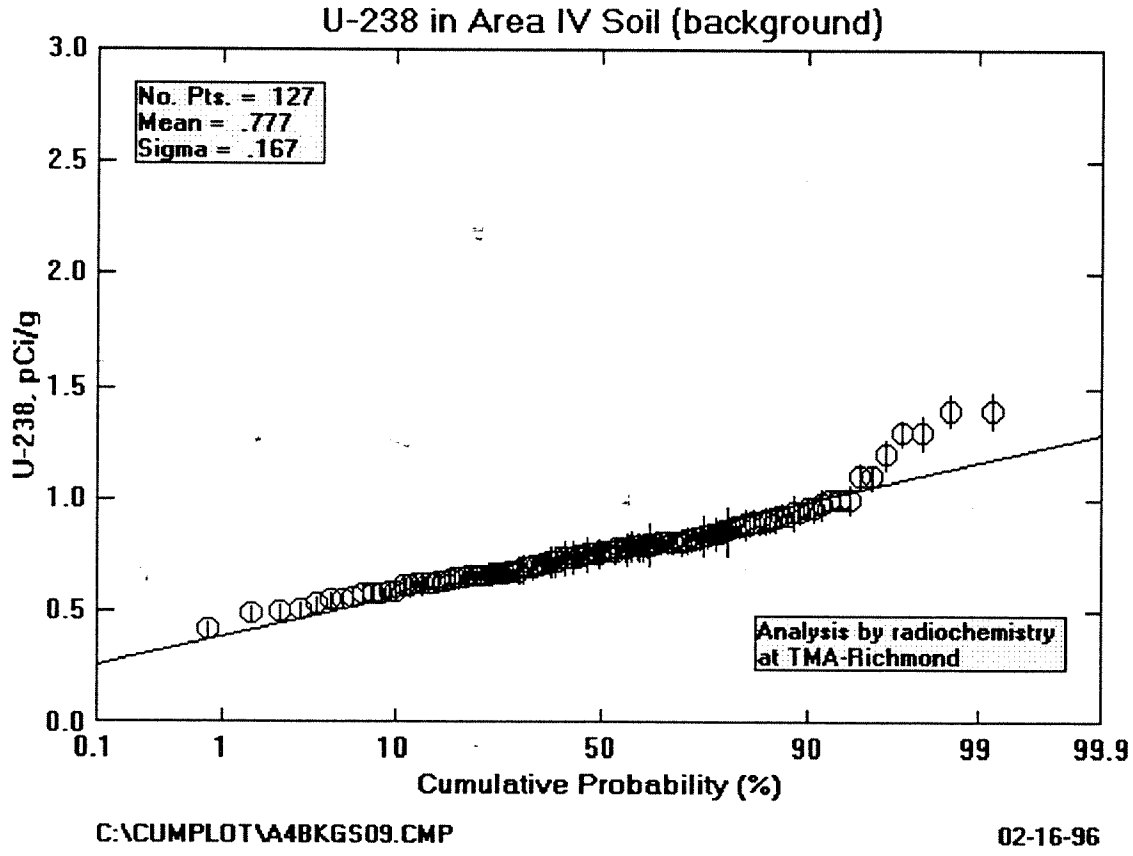


Figure 4i. Distribution of U-238 in Background Soil.

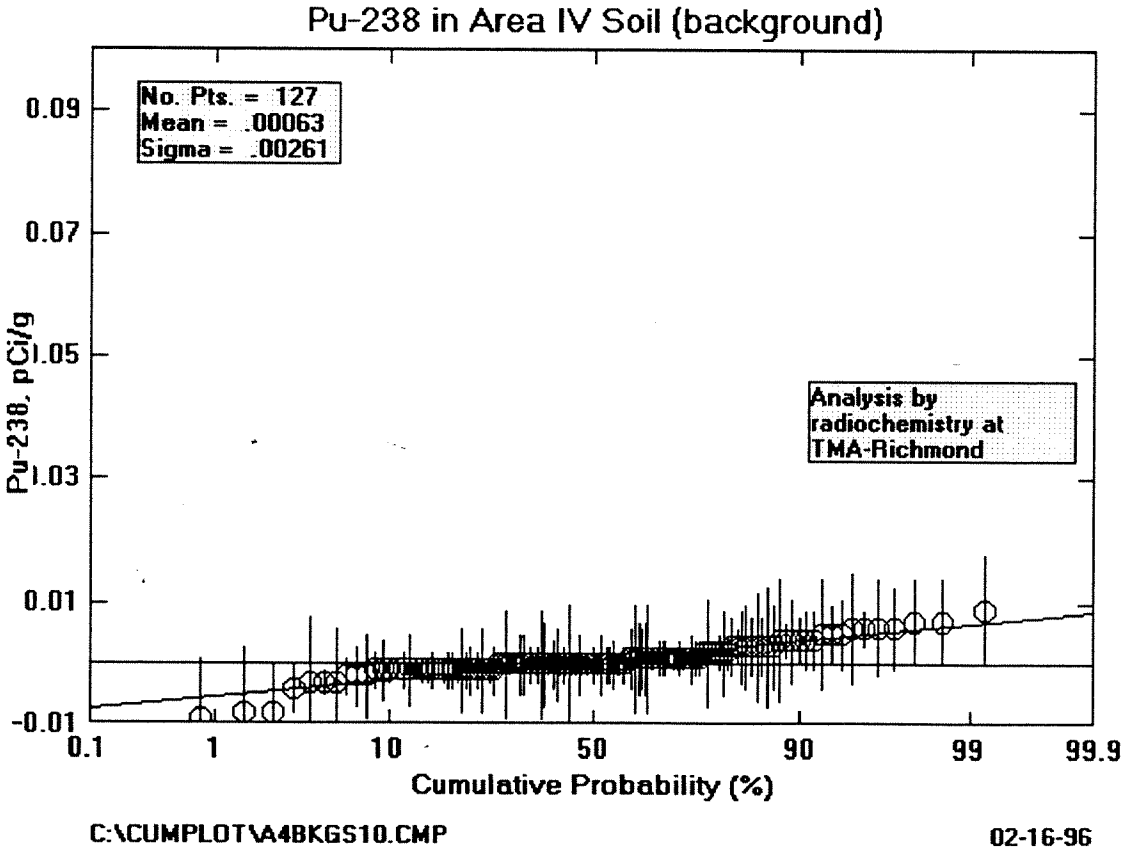


Figure 4j. Distribution of Pu-238 in Background Soil.

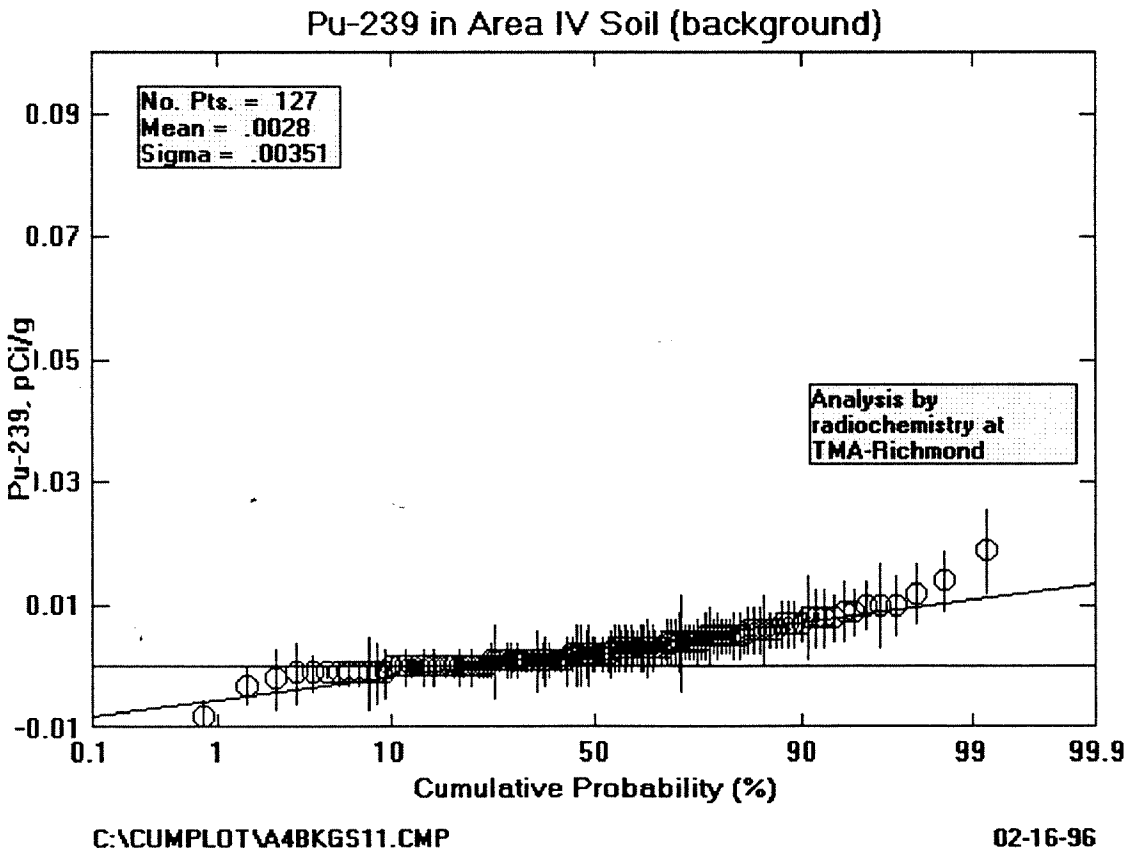
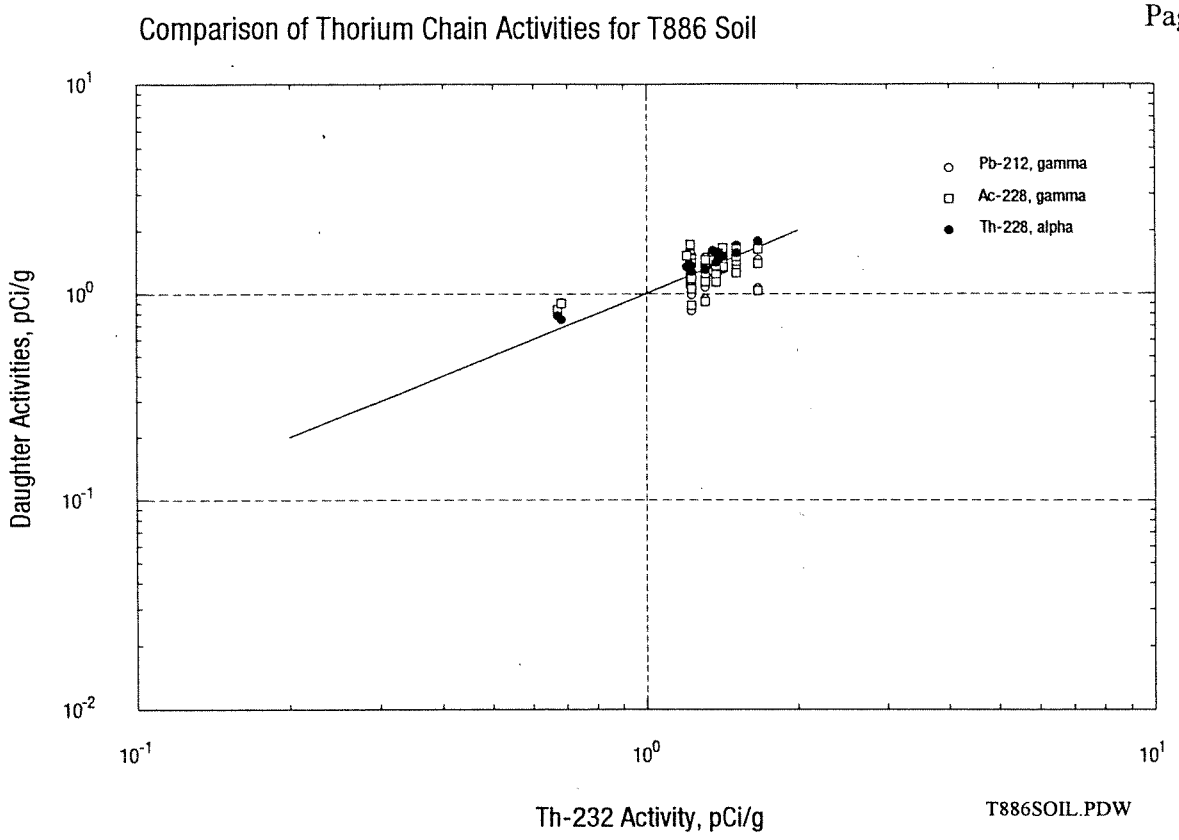


Figure 4k. Distribution of Pu-239 in Background Soil.



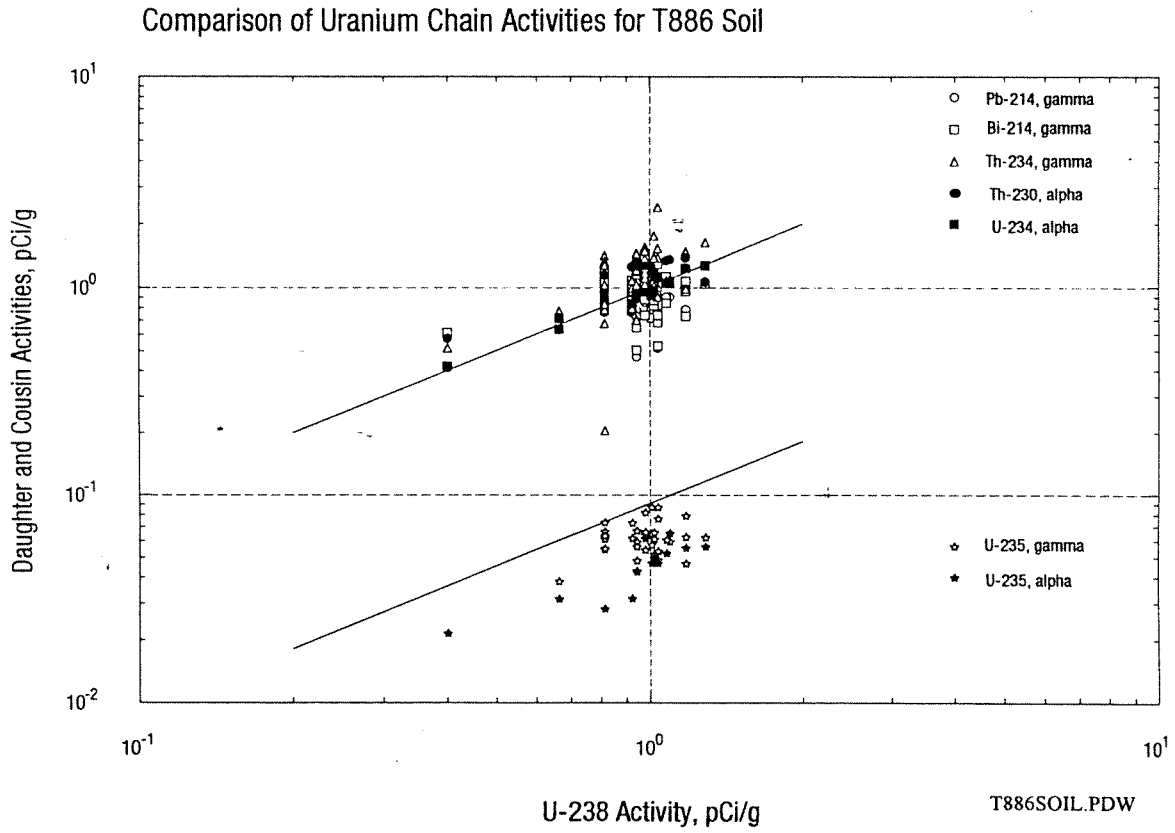


Figure 5. Decay chain daughter activities for soil from the Former Sodium Disposal Facility

Table 1A. Results of gamma spectrometry analyses of soil and rock samples.

Sample Location	K40		CS137		PB212		PB214		BI214		AC228		TH234		U235	
SOIL	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
10130331SRN0	19.66	0.58	0.009		1.377	0.035	0.769	0.047	0.885	0.149	1.524	0.107	0.963	0.319	0.005	
10246220SRN0	21.43	0.61	0.021	0.016	1.450	0.037	0.878	0.045	1.017	0.211	1.416	0.103	0.966	0.320	0.062	0.010
10346220SRN0	21.37	0.62	0.052	0.014	1.381	0.038	0.763	0.052	0.778	0.241	1.383	0.111	0.800	0.325	0.007	
10430331SRN0	19.49	0.55	0.010		1.504	0.036	0.968	0.048	0.891	0.160	1.591	0.105	0.995	0.317	0.062	0.008
10530331SRN0	21.53	0.58	0.010		1.648	0.037	1.069	0.048	1.083	0.209	1.662	0.099	1.082	0.291	0.073	0.009
10530331SRN2	22.41	0.61	0.010		1.439	0.036	0.890	0.046	0.951	0.152	1.420	0.098	0.997	0.313	0.006	
20130331SRN0	17.85	0.52	0.009		1.166	0.032	0.793	0.043	0.939	0.167	1.429	0.091	1.416	0.361	0.005	
20246220SRN0	21.33	0.62	0.047	0.028	1.241	0.036	0.860	0.049	1.009	0.220	1.480	0.113	1.022	0.319	0.007	
20346310SRN0	23.59	0.58	0.078	0.020	1.365	0.034	0.890	0.047	0.851	0.152	1.427	0.098	0.804	0.326	0.062	0.009
20446370SRN0	21.40	0.54	0.073	0.018	1.203	0.031	0.765	0.040	0.889	0.172	1.113	0.097	0.788	0.303	0.005	
20646220SRN0	23.64	0.66	0.034	0.015	1.564	0.040	1.027	0.056	1.027	0.207	1.609	0.108	1.291	0.415	0.073	0.022
20730331SRN0	19.27	0.49	0.008		1.381	0.031	0.845	0.039	0.778	0.147	1.429	0.093	0.678	0.247	0.005	
20946220SRN0	22.37	0.58	0.044	0.014	1.428	0.035	1.128	0.056	1.017	0.181	1.362	0.095	1.035	0.369	0.061	0.009
21030331SRN0	20.50	0.52	0.009		1.532	0.034	0.901	0.045	0.925	0.166	1.530	0.095	0.869	0.289	0.054	0.017
21120331SRN0	22.11	0.60	0.012		1.277	0.035	0.790	0.047	0.718	0.183	1.316	0.104	1.052	0.284	0.057	0.009
21230331SRN0	21.54	0.70	0.014		1.581	0.044	0.977	0.062	1.215	0.216	1.616	0.137	1.168	0.402	0.066	0.021
21346220SRN0	22.59	0.61	0.062	0.018	1.467	0.037	1.026	0.050	0.992	0.167	1.553	0.116	1.037	0.316	0.006	
21346220SRN2	23.04	0.64	0.077	0.018	1.507	0.038	1.058	0.056	0.956	0.210	1.623	0.116	1.234	0.428	0.006	
21646220SRN0	22.83	0.59	0.055	0.016	1.439	0.035	1.004	0.050	1.053	0.212	1.547	0.104	0.838	0.306	0.063	0.009
21736220SRN0	24.80	0.71	0.014		1.462	0.042	0.874	0.059	1.052	0.249	1.467	0.124	1.314	0.388	0.065	0.011
21946220SRN0	22.07	0.66	0.096	0.023	1.541	0.042	1.029	0.053	1.067	0.232	1.613	0.114	1.316	0.394	0.064	0.010
22046220SRN0	21.65	0.55	0.108	0.021	1.314	0.032	0.922	0.047	0.883	0.213	1.405	0.088	1.110	0.323	0.066	0.009
22146220SRN0	23.38	0.62	0.010		1.380	0.036	0.984	0.051	0.820	0.212	1.486	0.101	0.205		0.055	0.009
22236220SRN0	26.17	0.72	0.026	0.023	1.578	0.043	1.116	0.056	1.060	0.219	1.572	0.124	1.321	0.346	0.087	0.014
30113170SRN0	20.58	0.65	0.014		1.614	0.043	1.039	0.055	1.226	0.212	1.641	0.125	1.549	0.397	0.008	
30113170SRN2	21.42	0.68	0.015		1.648	0.044	1.064	0.061	0.988	0.206	1.631	0.119	1.364	0.375	0.008	
30123080SRN0	23.56	0.59	0.229	0.024	1.582	0.036	1.043	0.050	1.154	0.185	1.558	0.108	1.189	0.344	0.067	0.009
30123380SRN0	21.79	0.54	0.055	0.014	1.347	0.033	0.867	0.046	0.738	0.157	1.305	0.085	1.195	0.348	0.054	0.008
30139040SRN0	21.50	0.64	0.037	0.018	1.645	0.041	1.086	0.056	1.204	0.183	1.671	0.110	1.492	0.392	0.006	
30219160SRN0	21.68	0.63	0.011		1.705	0.042	1.208	0.057	1.418	0.199	1.636	0.118	1.173	0.354	0.082	0.010
30309040SRN0	20.90	0.54	0.567	0.025	1.314	0.032	0.905	0.047	1.071	0.176	1.342	0.086	1.088	0.284	0.059	0.008
30315160SRN0	22.33	0.57	0.047	0.018	1.469	0.035	1.010	0.047	1.041	0.210	1.504	0.107	1.371	0.336	0.006	
30345110SRN0	21.34	0.58	0.063	0.016	1.377	0.037	0.855	0.050	0.880	0.163	1.257	0.095	1.250	0.403	0.007	
30413170SRN0	19.59	0.55	0.050	0.022	1.615	0.037	1.022	0.054	0.918	0.152	1.718	0.104	1.330	0.402	0.006	
30427300SRN0	20.67	0.58	0.013		1.352	0.037	0.922	0.053	0.789	0.163	1.360	0.092	1.284	0.416	0.007	
40102080SRN0	22.58	0.59	0.012		1.089	0.034	0.753	0.050	0.681	0.206	1.184	0.094	1.388	0.359	0.007	
40208080SRN0	24.18	0.55	0.009		1.201	0.032	0.818	0.044	0.806	0.164	1.151	0.077	0.962	0.316	0.053	0.009
40310080SRN0	22.80	0.59	0.010		0.827	0.030	0.515	0.039	0.528	0.157	0.877	0.080	0.906	0.299	0.006	
40414080SRN0	20.85	0.58	0.036	0.016	1.067	0.033	0.753	0.047	0.823	0.186	1.179	0.101	1.009	0.296	0.007	
40518080SRN0	24.71	0.59	0.072	0.015	1.537	0.037	1.296	0.054	1.297	0.195	1.475	0.092	1.536	0.334	0.077	0.008
40620580SRN0	21.63	0.54	0.041	0.013	1.403	0.033	1.022	0.049	1.036	0.167	1.398	0.094	2.413	0.365	0.087	0.009
40728080SRN0	24.25	0.53	0.020	0.013	0.826	0.025	0.631	0.036	0.715	0.185	0.841	0.073	0.773	0.262	0.038	0.016
40832080SRN0	21.05	0.49	0.022	0.012	0.993	0.026	0.803	0.037	0.737	0.133	1.050	0.072	0.904	0.246	0.049	0.006
40933580SRN0	20.63	0.60	0.062	0.019	1.643	0.040	1.042	0.053	1.073	0.191	1.636	0.113	1.480	0.343	0.079	0.009
41038580SRN0	22.58	0.55	0.108	0.015	1.460	0.035	1.010	0.045	0.957	0.151	1.391	0.091	1.237	0.345	0.062	0.009
41047580SRN0	23.86	0.56	0.038	0.012	1.069	0.030	0.786	0.038	0.733	0.153	1.035	0.090	0.986	0.295	0.046	0.008
41049080SRN0	20.22	0.60	0.205	0.024	1.518	0.040	1.052	0.059	1.043	0.177	1.518	0.103	1.638	0.339	0.062	0.010
41102090SRN0	22.97	0.53	0.009		1.579	0.036	1.095	0.044	1.128	0.211	1.495	0.095	1.051	0.313	0.006	
41206390SRN0	20.43	0.52	0.008		1.279	0.031	0.903	0.043	0.842	0.184	1.443	0.097	1.074	0.275	0.060	0.008
41310090SRN0	18.86	0.59	0.209	0.019	1.274	0.036	0.892	0.055	0.987	0.220	1.381	0.112	1.203	0.366	0.066	0.009
41414090SRN0	20.13	0.51	0.118	0.023	1.301	0.032	0.925	0.047	0.894	0.161	1.301	0.088	1.123	0.336	0.052	0.008
41430090SRN0	19.89	0.51	0.216	0.021	1.249	0.030	0.934	0.040	0.819	0.158	1.316	0.083	1.384	0.295	0.061	0.008
41518090SRN0	20.80	0.54	0.297	0.020	1.253	0.032	0.902	0.045	0.870	0.195	1.270	0.089	1.117	0.317	0.005	
41622090SRN0	19.07	0.50	0.167	0.017	1.150	0.030	0.884	0.044	0.938	0.201	1.232	0.086	1.082	0.268	0.005	
41726090SRN0	20.36	0.53	0.297	0.022	1.199	0.030	0.880	0.046	1.020	0.167	1.138	0.097	1.020	0.248	0.005	
41934090SRN0	22.49	0.57	0.117	0.019	1.435	0.035	1.029	0.050	1.177	0.189	1.370	0.095	1.763	0.427	0.006	
42038090SRN0	21.65	0.54	0.008		1.497	0.036	1.059	0.051	0.993	0.190	1.368	0.090	1.451	0.346	0.059	0.010
42142090SRN0	21.39	0.59	0.042	0.015	1.199	0.034	0.785	0.050	0.899	0.231	1.242	0.093	0.903	0.326	0.056	0.009
42246090SRN0	20.21	0.58	0.012		1.393	0.036	0.882	0.051	0.908	0.208	1.335	0.097	1.035	0.319	0.007	
42351990SRN0	20.74	0.54	0.097	0.019	1.426	0.033	0.926	0.044	0.906	0.192	1.453	0.093	1.215	0.353	0.005	
42455090SRN2	22.52	0.54	0.017	0.012	0.907	0.029	0.413	0.038	0.612	0.158	0.898	0.077	0.514	0.252	0.005	
42455090SRN0	22.18	0.55	0.023	0.014	0.945	0.030	0.468	0.039	0.503	0.158	0.915	0.081	0.704	0.281	0.005	
42559090SRN0	21.53	0.52	0.072	0.016	1.078	0.028	0.732	0.039	0.645	0.155	1.142	0.082	0.701	0.231	0.048	0.006
SOIL	K40		CS137		PB212		PB214		BI214		AC228		TH234		U235	
	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
number	63		63		63		63		63		63		63		63	
maximum	26.17		0.567		1.705		1.296		1.418		1.718		2.413		0.087	
mean	21.68	3.14	0.069	0.189	1.360	0.420	0.913	0.321	0.934	0.353	1.385	0.418	1.129	0.642	0.037	0.059
minimum	17.85		0.008		0.826		0.413		0.503		0.841		0.205		0.005	

Sample Location	K40		CS137		PB212		PB214		BI214		AC228		TH234		U235	
BEDROCK	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
30511230BRN0	22.39	0.55	0.009		1.374	0.033	0.895	0.048	0.920	0.157	1.392	0.089	1.159	0.343	0.005	
30515270BRN0	20.50	0.58	0.013		1.800	0.042	1.296	0.057	1.225	0.220	1.649	0.112	1.845	0.456	0.008	0.000
30530340BRN0	22.44	0.56	0.008		1.219	0.033	0.937	0.050	0.872	0.196	1.168	0.087	0.672	0.285	0.005	
30540490BRN0	21.20	0.60	0.013		1.822	0.043	1.259	0.055	1.196	0.184	1.663	0.107	1.626	0.432	0.069	0.011
30547080BRN0	21.63	0.54	0.009		1.680	0.037	1.032	0.050	1.054	0.175	1.701	0.105	1.009	0.335	0.005	
30604500BRN0	22.61	0.57	0.009		1.510	0.035	1.081	0.048	1.036	0.158	1.405	0.102	1.247	0.337	0.006	
30630280BRN0	20.04	0.59	0.013		1.725	0.040	1.204	0.057	1.283	0.211	1.668	0.105	1.151	0.315	0.007	
30648280BRN0	22.18	0.53	0.008		1.413	0.034	0.715	0.043	0.833	0.145	1.416	0.099	0.937	0.265	0.005	
30648390BRN0	23.91	0.55	0.008		1.453	0.035	1.207	0.049	1.124	0.155	1.369	0.093	1.157	0.314	0.006	
30724500BRN0	23.12	0.55	0.008		1.204	0.031	0.577	0.039	0.558	0.168	1.109	0.091	0.681	0.326	0.005	
30940300BRN0	22.30	0.54	0.009		1.401	0.033	1.086	0.045	1.078	0.169	1.387	0.087	1.068	0.349	0.056	0.009
30950430BRN0	22.00	0.53	0.009		1.810	0.038	1.364	0.049	1.249	0.162	1.634	0.101	1.341	0.362	0.074	0.009
31027430BRN0	22.55	0.56	0.010		2.361	0.044	1.781	0.059	1.768	0.189	2.184	0.111	1.621	0.413	0.092	0.011
31044050BRN0	23.31	0.54	0.008		1.488	0.035	1.087	0.046	1.044	0.176	1.477	0.104	1.124	0.311	0.005	
31111220BRN0	21.10	0.60	0.013		2.068	0.044	1.493	0.058	1.532	0.227	2.082	0.116	1.387	0.343	0.009	
BEDROCK	K40		CS137		PB212		PB214		BI214		AC228		TH234		U235	
	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
number	15		15		15		15		15		15		15		15	
maximum	23.91		0.013		2.361		1.781		1.768		2.184		1.845		0.092	
mean	22.09	2.09	0.010	0.004	1.622	0.636	1.134	0.598	1.118	0.578	1.554	0.590	1.202	0.658	0.024	0.063
minimum	20.04		0.008		1.204		0.577		0.558		1.109		0.672		0.005	

Table 1B. Results of radiochemistry analyses of soil and rock samples.

Sample Location	SR90		TH228		TH230		TH232		U234		U235		U238		PU238		PU239	
SOIL	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
10130331SRN0	0.402	0.189	1.506	0.186	1.257	0.163	1.420	0.178	0.841	0.098	0.032	0.021	0.923	0.103	0.013	0.033	-0.01	0.027
10246220SRN0	0.402	0.189	1.506	0.186	1.257	0.163	1.420	0.178	0.841	0.098	0.032	0.021	0.923	0.103	0.013	0.033	-0.01	0.027
10346220SRN0	0.402	0.189	1.506	0.186	1.257	0.163	1.420	0.178	0.841	0.098	0.032	0.021	0.923	0.103	0.013	0.033	-0.01	0.027
10430331SRN0	0.402	0.189	1.506	0.186	1.257	0.163	1.420	0.178	0.841	0.098	0.032	0.021	0.923	0.103	0.013	0.033	-0.01	0.027
10530331SRN0	0.402	0.189	1.506	0.186	1.257	0.163	1.420	0.178	0.841	0.098	0.032	0.021	0.923	0.103	0.013	0.033	-0.01	0.027
10530331SRN2	0.402	0.189	1.506	0.186	1.257	0.163	1.420	0.178	0.841	0.098	0.032	0.021	0.923	0.103	0.013	0.033	-0.01	0.027
20130331SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
20246220SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
20346310SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
20446370SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
20646220SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
20730331SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
20946220SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
21030331SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
21120331SRN0	-0.05	0.124	1.549	0.191	1.262	0.164	1.391	0.174	0.915	0.104	0.047	0.023	1.008	0.110	0.022	0.024	-0.01	0.015
21230331SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
21346220SRN0	-0.02	0.130	1.572	0.193	1.272	0.163	1.511	0.186	0.953	0.104	0.061	0.024	0.978	0.106	0.065	0.070	0.054	0.059
21346220SRN2	-0.02	0.130	1.572	0.193	1.272	0.163	1.511	0.186	0.953	0.104	0.061	0.024	0.978	0.106	0.065	0.070	0.054	0.059
21646220SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
21736220SRN0	-0.05	0.124	1.549	0.191	1.262	0.164	1.391	0.174	0.915	0.104	0.047	0.023	1.008	0.110	0.022	0.024	-0.01	0.015
21946220SRN0	-0.02	0.130	1.572	0.193	1.272	0.163	1.511	0.186	0.953	0.104	0.061	0.024	0.978	0.106	0.065	0.070	0.054	0.059
22046220SRN0	-0.02	0.130	1.572	0.193	1.272	0.163	1.511	0.186	0.953	0.104	0.061	0.024	0.978	0.106	0.065	0.070	0.054	0.059
22146220SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
22236220SRN0	-0.05	0.124	1.549	0.191	1.262	0.164	1.391	0.174	0.915	0.104	0.047	0.023	1.008	0.110	0.022	0.024	-0.01	0.015
30113170SRN0	-0.02	0.130	1.572	0.193	1.272	0.163	1.511	0.186	0.953	0.104	0.061	0.024	0.978	0.106	0.065	0.070	0.054	0.059
30113170SRN2	-0.02	0.130	1.572	0.193	1.272	0.163	1.511	0.186	0.953	0.104	0.061	0.024	0.978	0.106	0.065	0.070	0.054	0.059
30123080SRN0	0.493	0.192	1.473	0.153	1.263	0.135	1.391	0.146	0.893	0.088	0.043	0.017	0.942	0.091	0.013	0.010	0.00	0.008
30123380SRN0	-0.02	0.130	1.572	0.193	1.272	0.163	1.511	0.186	0.953	0.104	0.061	0.024	0.978	0.106	0.065	0.070	0.054	0.059
30139040SRN0	-0.02	0.130	1.572	0.193	1.272	0.163	1.511	0.186	0.953	0.104	0.061	0.024	0.978	0.106	0.065	0.070	0.054	0.059
30219160SRN0	-0.02	0.130	1.572	0.193	1.272	0.163	1.511	0.186	0.953	0.104	0.061	0.024	0.978	0.106	0.065	0.070	0.054	0.059
30309040SRN0	0.569	0.188	1.512	0.155	1.364	0.142	1.422	0.147	1.059	0.100	0.065	0.021	1.095	0.102	0.000	0.005	0.002	0.004
30315160SRN0	-0.02	0.130	1.572	0.193	1.272	0.163	1.511	0.186	0.953	0.104	0.061	0.024	0.978	0.106	0.065	0.070	0.054	0.059
30345110SRN0	-0.02	0.130	1.572	0.193	1.272	0.163	1.511	0.186	0.953	0.104	0.061	0.024	0.978	0.106	0.065	0.070	0.054	0.059
30413170SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
30427300SRN0	0.051	0.140	1.380	0.184	1.149	0.162	1.222	0.166	0.903	0.100	0.028	0.022	0.815	0.093	0.031	0.029	0.005	0.023
40102080SRN0	0.188	0.156	1.279	0.141	1.106	0.125	1.230	0.136	1.128	0.100	0.047	0.016	1.037	0.093	0.010	0.010	0.00	0.008
40208080SRN0	0.188	0.156	1.279	0.141	1.106	0.125	1.230	0.136	1.128	0.100	0.047	0.016	1.037	0.093	0.010	0.010	0.00	0.008
40310080SRN0	0.188	0.156	1.279	0.141	1.106	0.125	1.230	0.136	1.128	0.100	0.047	0.016	1.037	0.093	0.010	0.010	0.00	0.008
40414080SRN0	0.188	0.156	1.279	0.141	1.106	0.125	1.230	0.136	1.128	0.100	0.047	0.016	1.037	0.093	0.010	0.010	0.00	0.008
40518080SRN0	0.188	0.156	1.279	0.141	1.106	0.125	1.230	0.136	1.128	0.100	0.047	0.016	1.037	0.093	0.010	0.010	0.00	0.008
40620580SRN0	0.188	0.156	1.279	0.141	1.106	0.125	1.230	0.136	1.128	0.100	0.047	0.016	1.037	0.093	0.010	0.010	0.00	0.008
40728080SRN0	0.096	0.168	0.782	0.108	0.718	0.102	0.672	0.097	0.634	0.084	0.031	0.024	0.664	0.084	0.057	0.031	0.003	0.016
40832080SRN0	0.188	0.156	1.279	0.141	1.106	0.125	1.230	0.136	1.128	0.100	0.047	0.016	1.037	0.093	0.010	0.010	0.00	0.008
40933580SRN0	0.086	0.150	1.782	0.213	1.387	0.172	1.667	0.201	1.238	0.106	0.055	0.018	1.174	0.102	0.002	0.011	0.002	0.007
41038580SRN0	0.086	0.150	1.782	0.213	1.387	0.172	1.667	0.201	1.238	0.106	0.055	0.018	1.174	0.102	0.002	0.011	0.002	0.007
41047580SRN0	0.086	0.150	1.782	0.213	1.387	0.172	1.667	0.201	1.238	0.106	0.055	0.018	1.174	0.102	0.002	0.011	0.002	0.007
41049080SRN0	0.258	0.164	1.347	0.141	1.066	0.117	1.201	0.128	1.269	0.112	0.056	0.019	1.284	0.113	0.000	0.007	0.000	0.005
41102090SRN0	0.004	0.135	1.614	0.634	1.343	0.546	1.356	0.538	1.054	0.098	0.052	0.018	1.079	0.100	0.028	0.017	0.003	0.007
41206390SRN0	0.004	0.135	1.614	0.634	1.343	0.546	1.356	0.538	1.054	0.098	0.052	0.018	1.079	0.100	0.028	0.017	0.003	0.007
41310090SRN0	0.161	0.145	1.414	0.142	1.184	0.123	1.377	0.139	0.967	0.087	0.049	0.017	1.019	0.091	0.017	0.011	0.008	0.010
41414090SRN0	0.161	0.145	1.414	0.142	1.184	0.123	1.377	0.139	0.967	0.087	0.049	0.017	1.019	0.091	0.017	0.011	0.008	0.010
41430090SRN0	0.161	0.145	1.414	0.142	1.184	0.123	1.377	0.139	0.967	0.087	0.049	0.017	1.019	0.091	0.017	0.011	0.008	0.010
41518090SRN0	0.161	0.145	1.414	0.142	1.184	0.123	1.377	0.139	0.967	0.087	0.049	0.017	1.019	0.091	0.017	0.011	0.008	0.010
41622090SRN0	0.161	0.145	1.414	0.142	1.184	0.123	1.377	0.139	0.967	0.087	0.049	0.017	1.019	0.091	0.017	0.011	0.008	0.010
41726090SRN0	0.161	0.145	1.414	0.142	1.184	0.123	1.377	0.139	0.967	0.087	0.049	0.017	1.019	0.091	0.017	0.011	0.008	0.010
41934090SRN0	0.161	0.145	1.414	0.142	1.184	0.123	1.377	0.139	0.967	0.087	0.049	0.017	1.019	0.091	0.017	0.011	0.008	0.010
42038090SRN0	0.207	0.156	1.307	0.189	1.330	0.191	1.312	0.188	0.942	0.110	0.043	0.022	0.942	0.109	0.019	0.020	-0.01	0.024
42142090SRN0	0.207	0.156	1.307	0.189	1.330	0.191	1.312	0.188	0.942	0.110	0.043	0.022	0.942	0.109	0.019	0.020	-0.01	0.024
42246090SRN0	0.207	0.156	1.307	0.189	1.330	0.191	1.312	0.188	0.942	0.110	0.043	0.022	0.942	0.109	0.019	0.020	-0.01	0.024
42351990SRN0	0.207	0.156	1.307	0.189	1.330	0.191	1.312	0.188	0.942	0.110	0.043	0.022	0.942	0.109	0.019	0.020	-0.01	0.024
42455090SRN2	0.166	0.176	0.752	0.106	0.574	0.090	0.682	0.099	0.421	0.065	0.021	0.019	0.401	0.062	0.014	0.017	0.003	0.006
42455090SRN0	0.207	0.156	1.307	0.189	1.330	0.191	1.312	0.188	0.942	0.110	0.043	0.022	0.942	0.109	0.019	0.020	-0.01	0.024
42559090SRN0	0.207	0.156	1.307	0.189	1.330	0.191	1.312	0.188	0.942	0.110	0.043	0.022	0.942	0.109	0.019	0.020	-0.01	0.024

SOIL	SR90		TH228		TH230		TH232		U234		U235		U238		PU238		PU239	
	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
number	63		63		62		63		63		62		63		63		63	
maximum	0.569		1.782		1.387		1.667		1.269		0.065		1.284		0.065		0.054	
mean	0.131	0.146	1.429	0.176	1.206	0.134	1.340	0.174	0.959	0.133	0.044	0.013	0.953	0.130	0.027	0.020	0.008	0.022
minimum	-0.05		0.752		0.574		0.672		0.421		0.021		0.401		0.000		-0.01	

Sample Location	SR90		TH228		TH230		TH232		U234		U235		U238		PU238		PU239	
BEDROCK	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
30511230BRN0	0.211	0.166	1.452	0.155	1.205	0.135	1.361	0.147	0.981	0.110	0.048	0.022	0.885	0.102	0.000	0.000	0.000	0.000
30515270BRN0	0.211	0.166	1.452	0.155	1.205	0.135	1.361	0.147	0.981	0.110	0.048	0.022	0.885	0.102	0.000	0.000	0.000	0.000
30530340BRN0	0.211	0.166	1.452	0.155	1.205	0.135	1.361	0.147	0.981	0.110	0.048	0.022	0.885	0.102	0.000	0.000	0.000	0.000
30540490BRN0	0.211	0.166	1.452	0.155	1.205	0.135	1.361	0.147	0.981	0.110	0.048	0.022	0.885	0.102	0.000	0.000	0.000	0.000
30547080BRN0	0.206	0.159	1.728	0.229	1.236	0.178	1.255	0.178	0.596	0.081	0.036	0.022	0.680	0.088	0.004	0.014	0.00	0.008
30604500BRN0	0.280	0.168	1.555	0.204	1.172	0.165	1.385	0.186	0.681	0.090	0.036	0.019	0.711	0.091	0.008	0.015	0.004	0.013
30630280BRN0	0.280	0.168	1.555	0.204	1.172	0.165	1.385	0.186	0.681	0.090	0.036	0.019	0.711	0.091	0.008	0.015	0.004	0.013
30648280BRN0	0.280	0.168	1.555	0.204	1.172	0.165	1.385	0.186	0.681	0.090	0.036	0.019	0.711	0.091	0.008	0.015	0.004	0.013
30648390BRN0	0.280	0.168	1.555	0.204	1.172	0.165	1.385	0.186	0.681	0.090	0.036	0.019	0.711	0.091	0.008	0.015	0.004	0.013
30724500BRN0	0.227	0.167	1.254	0.139	0.679	0.087	1.246	0.138	0.567	0.063	0.018	0.011	0.638	0.068	0.004	0.006	0.000	0.000
30940300BRN0	0.206	0.159	1.728	0.229	1.236	0.178	1.255	0.178	0.596	0.081	0.036	0.022	0.680	0.088	0.004	0.014	0.00	0.008
30950430BRN0	0.206	0.159	1.728	0.229	1.236	0.178	1.255	0.178	0.596	0.081	0.036	0.022	0.680	0.088	0.004	0.014	0.00	0.008
31027430BRN0	0.280	0.168	1.555	0.204	1.172	0.165	1.385	0.186	0.681	0.090	0.036	0.019	0.711	0.091	0.008	0.015	0.004	0.013
31044050BRN0	0.206	0.159	1.728	0.229	1.236	0.178	1.255	0.178	0.596	0.081	0.036	0.022	0.680	0.088	0.004	0.014	0.00	0.008
31111220BRN0	0.280	0.168	1.555	0.204	1.172	0.165	1.385	0.186	0.681	0.090	0.036	0.019	0.711	0.091	0.008	0.015	0.004	0.013
BEDROCK	SR90		TH228		TH230		TH232		U234		U235		U238		PU238		PU239	
	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
number	15		15		15		15		15		15		15		15		15	
maximum	0.280		1.728		1.236		1.385		0.981		0.048		0.885		0.008		0.004	
mean	0.238	0.071	1.554	0.269	1.165	0.274	1.334	0.121	0.731	0.323	0.038	0.016	0.745	0.180	0.004	0.006	0.000	0.006
minimum	0.206		1.254		0.679		1.246		0.567		0.018		0.638		0.000		0.00	

Table 1C. Minimum Detectable Activity

Sample Location	CO60	ZN65	SR90	SB125	CS134	CS137	CE144	EU152	EU154	TH228	TH230	TH232	U234	U235	U238	PU238	PU239
SOIL	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
10130331SRN0	0.034	0.062	0.256	0.057	0.018	0.023	0.110	0.058	0.100	0.022	0.010	0.004	0.016	0.010	0.003	0.014	0.021
10246220SRN0	0.024	0.044	0.256	0.040	0.014	0.018	0.083	0.041	0.072	0.022	0.010	0.004	0.016	0.010	0.003	0.014	0.021
10346220SRN0	0.034	0.060	0.256	0.050	0.018	0.020	0.100	0.052	0.099	0.022	0.010	0.004	0.016	0.010	0.003	0.014	0.021
10430331SRN0	0.034	0.062	0.256	0.057	0.019		0.112	0.058	0.105	0.022	0.010	0.004	0.016	0.010	0.003	0.014	0.021
10530331SRN0	0.025	0.044	0.256	0.046	0.015		0.097	0.047	0.081	0.022	0.010	0.004	0.016	0.010	0.003	0.014	0.021
10530331SRN2	0.024	0.046	0.256	0.044	0.015		0.091	0.043	0.082	0.022	0.010	0.004	0.016	0.010	0.003	0.014	0.021
20130331SRN0	0.020	0.037	0.256	0.035	0.012		0.074	0.035	0.063	0.022	0.010	0.004	0.016	0.010	0.003	0.014	0.021
20246220SRN0	0.037	0.067	0.256	0.063	0.021		0.126	0.066	0.115	0.022	0.020	0.014	0.015	0.012	0.010	0.022	0.015
20346310SRN0	0.025	0.045	0.256	0.042	0.014		0.090	0.044	0.074	0.022	0.020	0.014	0.015	0.012	0.010	0.022	0.015
20446370SRN0	0.024	0.043	0.256	0.041	0.014		0.087	0.041	0.071	0.022	0.020	0.014	0.015	0.012	0.010	0.022	0.015
20646220SRN0	0.024	0.044	0.241	0.042	0.014	0.018	0.093	0.045	0.076	0.226	0.239	0.111	0.016	0.010	0.008	0.019	0.013
20730331SRN0	0.022	0.042	0.241	0.041	0.014	0.017	0.084	0.041	0.077	0.226	0.239	0.111	0.016	0.010	0.008	0.019	0.013
20946220SRN0	0.034	0.064	0.238	0.060	0.020		0.118	0.059	0.109	0.009	0.016	0.003	0.008	0.012	0.008	0.010	0.015
21030331SRN0	0.024	0.044	0.238	0.043	0.013		0.087	0.042	0.079	0.009	0.016	0.003	0.008	0.012	0.008	0.010	0.015
21120331SRN0	0.022	0.042	0.238	0.040	0.013		0.082	0.040	0.070	0.009	0.016	0.003	0.008	0.012	0.008	0.010	0.015
21230331SRN0	0.025	0.045	0.238	0.043	0.014		0.087	0.043	0.078	0.009	0.016	0.003	0.008	0.012	0.008	0.010	0.015
21346220SRN0	0.022	0.043	0.238	0.040	0.013		0.081	0.040	0.075	0.009	0.016	0.003	0.008	0.012	0.008	0.010	0.015
21346220SRN2	0.023	0.040	0.238	0.040	0.014		0.081	0.041	0.073	0.009	0.016	0.003	0.008	0.012	0.008	0.010	0.015
21646220SRN0	0.026	0.047	0.238	0.044	0.014		0.098	0.046	0.086	0.009	0.016	0.003	0.008	0.012	0.008	0.010	0.015
21736220SRN0	0.023	0.038	0.252	0.042	0.014	0.017	0.085	0.044	0.079	0.046	0.049	0.030	0.037	0.019	0.019	0.013	0.058
21946220SRN0	0.033	0.064	0.252	0.057	0.019		0.116	0.055	0.104	0.046	0.049	0.030	0.037	0.019	0.019	0.013	0.058
22046220SRN0	0.032	0.061	0.252	0.058	0.021	0.025	0.117	0.058	0.112	0.046	0.049	0.030	0.037	0.019	0.019	0.013	0.058
22146220SRN0	0.026	0.045	0.252	0.045	0.015		0.090	0.042	0.083	0.046	0.049	0.030	0.037	0.019	0.019	0.013	0.058
22236220SRN0	0.030	0.058	0.252	0.050	0.016		0.100	0.050	0.090	0.046	0.049	0.030	0.037	0.019	0.019	0.013	0.058
30113170SRN0	0.023	0.041	0.252	0.037	0.013		0.075	0.037	0.068	0.046	0.049	0.030	0.037	0.019	0.019	0.013	0.058
30113170SRN2	0.024	0.043	0.243	0.042	0.014	0.018	0.088	0.041	0.076	0.045	0.065	0.025	0.037	0.030	0.029	0.031	0.048
30123080SRN0	0.035	0.066	0.243	0.059	0.021		0.121	0.059	0.120	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
30123380SRN0	0.025	0.048	0.243	0.045	0.015		0.094	0.046	0.081	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
30139040SRN0	0.025	0.045	0.243	0.041	0.014		0.085	0.042	0.075	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
30219160SRN0	0.031	0.052	0.243	0.052	0.018		0.104	0.055	0.096	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
30309040SRN0	0.022	0.041	0.243	0.037	0.013	0.016	0.083	0.039	0.073	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
30315160SRN0	0.028	0.048	0.243	0.045	0.015		0.098	0.047	0.088	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
30345110SRN0	0.023	0.043	0.243	0.040	0.015	0.018	0.087	0.042	0.078	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
30413170SRN0	0.041	0.074	0.243	0.071	0.024	0.029	0.133	0.073	0.136	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
30427300SRN0	0.027	0.047	0.243	0.045	0.015		0.090	0.047	0.086	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
40102080SRN0	0.027	0.050	0.243	0.046	0.016	0.021	0.094	0.047	0.082	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
40208080SRN0	0.025	0.045	0.243	0.046	0.016		0.100	0.046	0.082	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
40310080SRN0	0.033	0.061	0.243	0.060	0.020	0.026	0.121	0.061	0.115	0.045	0.065	0.025	0.037	0.030	0.029	0.038	0.048
40414080SRN0	0.034	0.065	0.228	0.055	0.019	0.024	0.114	0.058	0.113	0.044	0.057	0.027	0.028	0.022	0.020	0.033	0.048
40518080SRN0	0.041	0.075	0.228	0.066	0.024	0.028	0.131	0.070	0.134	0.044	0.057	0.027	0.028	0.022	0.020	0.033	0.048
40620580SRN0	0.040	0.081	0.228	0.073	0.023		0.137	0.068	0.138	0.044	0.057	0.027	0.028	0.022	0.020	0.033	0.048
40728080SRN0	0.027	0.049	0.234	0.045	0.016		0.091	0.046	0.089	0.036	0.031	0.007	0.017	0.006	0.020	0.100	0.080
40832080SRN0	0.027	0.051	0.234	0.049	0.016		0.101	0.049	0.093	0.036	0.031	0.007	0.017	0.006	0.020	0.100	0.080
40933580SRN0	0.039	0.075	0.234	0.067	0.024		0.133	0.069	0.131	0.036	0.031	0.007	0.017	0.006	0.020	0.100	0.080
41038580SRN0	0.026	0.048	0.234	0.044	0.014		0.089	0.044	0.077	0.036	0.031	0.007	0.017	0.006	0.020	0.100	0.080
41047580SRN0	0.038	0.071	0.234	0.067	0.023	0.028	0.129	0.069	0.129	0.036	0.031	0.007	0.017	0.006	0.020	0.100	0.080
41049080SRN0	0.038	0.073	0.234	0.070	0.024	0.030	0.137	0.069	0.141	0.036	0.031	0.007	0.017	0.006	0.020	0.100	0.080
41102090SRN0	0.024	0.042	0.234	0.043	0.014		0.086	0.043	0.077	0.036	0.031	0.007	0.017	0.006	0.020	0.100	0.080
41206390SRN0	0.031	0.049	0.234	0.053	0.017		0.104	0.053	0.100	0.036	0.031	0.007	0.017	0.006	0.020	0.100	0.080
41310090SRN0	0.029	0.054	0.234	0.052	0.018	0.022	0.103	0.052	0.097	0.036	0.031	0.007	0.017	0.006	0.020	0.100	0.080
41414090SRN0	0.027	0.048	0.234	0.047	0.015		0.098	0.048	0.082	0.036	0.031	0.007	0.017	0.006	0.020	0.100	0.080
41430090SRN0	0.033	0.061	0.234	0.058	0.019		0.117	0.060	0.103	0.036	0.031	0.007	0.017	0.006	0.020	0.100	0.080
41518090SRN0	0.024	0.042	0.289	0.044	0.015	0.019	0.089	0.044	0.086	0.019	0.033	0.019	0.040	0.027	0.030	0.062	0.072
41622090SRN0	0.028	0.048	0.289	0.048	0.016		0.093	0.048	0.091	0.019	0.033	0.019	0.040	0.027	0.030	0.062	0.072
41726090SRN0	0.036	0.066	0.289	0.062	0.021		0.121	0.063	0.113	0.019	0.033	0.019	0.040	0.027	0.030	0.062	0.072
41934090SRN0	0.024	0.046	0.289	0.044	0.016	0.019	0.094	0.046	0.085	0.019	0.033	0.019	0.040	0.027	0.030	0.062	0.072
42038090SRN0	0.026	0.047	0.289	0.049	0.016	0.020	0.095	0.047	0.088	0.019	0.033	0.019	0.040	0.027	0.030	0.062	0.072
42142090SRN0	0.026	0.049	0.289	0.047	0.016	0.020	0.092	0.046	0.087	0.019	0.033	0.019	0.040	0.027	0.030	0.062	0.072
42246090SRN0	0.026	0.047	0.285	0.047	0.016		0.094	0.048	0.089	0.012	0.020	0.012	0.024	0.015	0.012	0.005	0.018
42351990SRN0	0.022	0.044	0.269	0.044	0.014		0.087	0.043	0.075	0.019	0.020	0.009	0.023	0.013	0.015	0.013	0.005
42455090SRN2	0.035	0.067	0.260	0.063	0.022		0.127	0.064	0.119	0.010	0.017	0.004	0.022	0.015	0.012	0.017	0.014
42455090SRN0	0.030	0.055	0.293	0.045	0.016		0.098	0.047	0.092	0.025	0.036	0.030	0.029	0.026	0.018	0.026	0.008
42559090SRN0	0.023	0.042	0.288	0.036	0.012		0.080	0.037	0.068	0.021	0.021	0.017	0.050	0.034	0.038	0.032	0.032
SOIL	CO60	ZN65	SR90	SB125	CS134	CS137	CE144	EU152	EU154	TH228	TH230	TH232	U234	U235	U238	PU238	PU239
	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
number	63	63	63	63	63	22	63	63	63	63	63	63	63	63	63	63	63
maximum	0.041	0.081	0.293	0.073	0.024	0.030	0.137	0.073	0.141	0.226	0.239	0.111	0.050	0.034	0.038	0.100	0.080
mean	0.028	0.052	0.250	0.049	0.017	0.021	0.100	0.050	0.092	0.037	0.043	0.018	0.026	0.018	0.019	0.040	0.045
minimum	0.020	0.037	0.228	0.035	0.012	0.016	0.074	0.035	0.063	0.009	0.010	0.003	0.008	0.006	0.003	0.005	0.005

Sample Location	CO60	ZN65	SR90	SB125	CS134	CS137	CE144	EU152	EU154	TH228	TH230	TH232	U234	U235	U238	PU238	PU239
BEDROCK	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
30511230BRN0	0.024	0.048	0.266	0.042	0.014	0.017	0.092	0.042	0.075	0.020	0.030	0.025	0.029	0.007	0.018	0.037	0.047
30515270BRN0	0.033	0.063	0.266	0.062	0.022	0.025	0.132	0.065	0.120	0.020	0.030	0.025	0.029	0.007	0.018	0.037	0.047
30530340BRN0	0.026	0.045	0.266	0.043	0.015	0.017	0.092	0.043	0.077	0.020	0.030	0.025	0.029	0.007	0.018	0.037	0.047
30540490BRN0	0.035	0.065	0.266	0.063	0.021	0.025	0.133	0.067	0.122	0.020	0.030	0.025	0.029	0.007	0.018	0.037	0.047
30547080BRN0	0.025	0.045	0.257	0.045	0.016	0.019	0.098	0.045	0.080	0.046	0.063	0.040	0.015	0.024	0.006	0.029	0.029
30604500BRN0	0.027	0.048	0.266	0.044	0.015	0.018	0.098	0.047	0.084	0.041	0.044	0.035	0.033	0.007	0.006	0.028	0.028
30630280BRN0	0.033	0.066	0.266	0.064	0.021	0.025	0.133	0.064	0.120	0.041	0.044	0.035	0.033	0.007	0.006	0.028	0.028
30648280BRN0	0.023	0.041	0.266	0.041	0.013	0.016	0.086	0.042	0.071	0.041	0.044	0.035	0.033	0.007	0.006	0.028	0.028
30648390BRN0	0.023	0.042	0.266	0.044	0.014	0.016	0.093	0.046	0.078	0.041	0.044	0.035	0.033	0.007	0.006	0.028	0.028
30724500BRN0	0.024	0.045	0.269	0.041	0.014	0.016	0.088	0.040	0.074	1.254	0.679	0.011	0.019	0.018	0.638	0.010	0.013
30940300BRN0	0.025	0.046	0.257	0.045	0.014	0.017	0.095	0.044	0.077	0.046	0.063	0.040	0.015	0.024	0.006	0.029	0.029
30950430BRN0	0.022	0.046	0.206	0.047	0.014	0.018	0.098	0.049	0.081	0.046	0.063	0.040	0.015	0.024	0.006	0.029	0.029
31027430BRN0	0.025	0.049	0.266	0.051	0.016	0.019	0.113	0.054	0.091	0.041	0.044	0.035	0.033	0.007	0.006	0.028	0.028
31044050BRN0	0.024	0.044	0.257	0.043	0.014	0.017	0.090	0.045	0.074	0.046	0.063	0.040	0.015	0.024	0.006	0.029	0.029
31111220BRN0	0.035	0.067	0.266	0.069	0.024	0.026	0.139	0.070	0.128	0.041	0.044	0.035	0.033	0.007	0.006	0.028	0.028
BEDROCK	CO60	ZN65	SR90	SB125	CS134	CS137	CE144	EU152	EU154	TH228	TH230	TH232	U234	U235	U238	PU238	PU239
	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g	pCi/g
number	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15	15
maximum	0.035	0.067	0.269	0.069	0.024	0.026	0.139	0.070	0.128	1.254	0.679	0.040	0.033	0.024	0.638	0.037	0.047
mean	0.027	0.051	0.260	0.050	0.016	0.019	0.105	0.051	0.090	0.118	0.088	0.032	0.026	0.012	0.051	0.029	0.032
minimum	0.022	0.041	0.206	0.041	0.013	0.016	0.086	0.040	0.071	0.020	0.030	0.011	0.015	0.007	0.006	0.010	0.013

Table 2. Grouping of samples for composite analyses.

COMPOSITE NUMBER	LAB COMPOSITE ID	LAB ID	Sample Location
1	22494	22322	40310080SRN0
1		22324	40208080SRN0
1		22325	40102080SRN0
1		22359	40728080SRN0
1		22360	40414080SRN0
1		22361	40620580SRN0
1		22362	40518080SRN0
1		22363	40832080SRN0
2	22495	22347	41047580SRN0
2		22350	41038580SRN0
2		22351	40933580SRN0
3	22496	22331	41206390SRN0
3		22348	41102090SRN0
4	22497	22342	41518090SRN0
4		22345	41622090SRN0
4		22349	41934090SRN0
4		22353	41414090SRN0
4		22354	41430090SRN0
4		22355	41310090SRN0
4		22357	41726090SRN0
5	22498	22339	42038090SRN0
5		22340	42559090SRN0
5		22341	42455090SRN0
5		22346	42246090SRN0
5		22352	42142090SRN0
5		22356	42351990SRN0
6	22499	22277	21646220SRN0
6		22278	22146220SRN0
6		22282	21030331SRN0
6		22284	21230331SRN0
6		22285	20646220SRN0
6		22307	20946220SRN0
6		22308	20730331SRN0
6		22323	20346310SRN0
6		22327	20130331SRN0
6		22329	30427300SRN0
6		22332	20246220SRN0
6		22333	30413170SRN0
6		22344	20446370SRN0
7	22500	22276	21120331SRN0
7		22279	31027430BRN0
7		22280	30604500BRN0
8	22501	22287	30113170SRN2
8		22290	30113170SRN0
8		22291	21946220SRN0
8		22292	21346220SRN2
8		22293	21346220SRN0
8		22288	30139040SRN0
8		22289	30219160SRN0
8		22330	22046220SRN0
8		22334	30123380SRN0
8		22335	30345110SRN0
8		22336	30315160SRN0
9	22502	22271	10130331SRN0
9		22272	10246220SRN0
9		22273	10346220SRN0
9		22274	10530331SRN2
9		22275	10430331SRN0
9		22281	10530331SRN0
10	22503	22295	30530340BRN0
10		22303	30540490BRN0
10		22304	30511230BRN0
10		22306	30510270BRN0
11	22504	22297	31027430BRN0
11		22298	30604500BRN0
11		22299	30648280BRN0
11		22300	30630280BRN0
11		22302	30648390BRN0
11		22309	31111220BRN0
12	22505	22294	30940300BRN0
12		22296	31044050BRN0
12		22305	30950430BRN0
12		22310	30547080BRN0
13	22506	22283	10546220WRN1
13		22326	21431330WRN1
13		22337	40414080WRN1
13		22338	30543090WRN1
14	22286	22286	30123080SRN0
15	22301	22301	30724500BRN0
16	22328	22328	30309040SRN0
17	22358	22358	41049080SRN0
18	22343	22343	42455090SRN2
19	22359	22359	40728080SRN0

end

Table 3A. Comparison of Field Duplicate Samples for Radionuclides, Gamma Spectrometry

Sample Location	K40		CS137		PB212		PB214		BI214		AC228		TH234		U235	
SOIL	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
10530331SRN0	21.53	0.58	0.010	0.010	1.648	0.037	1.069	0.048	1.083	0.209	1.662	0.099	1.082	0.291	0.073	0.009
10530331SRN2	22.41	0.61	0.010	0.010	1.439	0.036	0.890	0.046	0.951	0.152	1.420	0.098	0.997	0.313	0.006	0.006
30113170SRN0	20.58	0.65	0.014	0.014	1.614	0.043	1.039	0.055	1.226	0.212	1.641	0.125	1.549	0.397	0.008	0.008
30113170SRN2	21.42	0.68	0.015	0.015	1.648	0.044	1.064	0.061	0.988	0.206	1.631	0.119	1.364	0.375	0.008	0.008
42455090SRN0	22.18	0.55	0.023	0.014	0.945	0.030	0.468	0.039	0.503	0.158	0.915	0.081	0.704	0.281	0.005	0.005
42455090SRN2	22.52	0.54	0.017	0.012	0.907	0.029	0.413	0.038	0.612	0.158	0.898	0.077	0.514	0.252	0.005	0.005
Comparison, relative difference second/first																
10530331SRN	0.040	0.038	0.000	1.414	-0.14	0.034	-0.18	0.067	-0.13	0.254	-0.16	0.090	-0.08	0.411	-1.71	0.276
30113170SRN	0.040	0.045	0.062	1.415	0.021	0.038	0.024	0.078	-0.22	0.267	-0.01	0.106	-0.13	0.375	0.034	1.414
42455090SRN	0.015	0.035	-0.29	0.910	-0.04	0.045	-0.12	0.125	0.196	0.400	-0.02	0.123	-0.31	0.619	0.017	1.414

SOIL	K40		CS137		PB212		PB214		BI214		AC228		TH234		U235	
	diff	unc	diff	unc	diff	unc	diff	unc	diff	unc	diff	unc	diff	unc	diff	unc
number	3		3		3		3		3		3		3		3	
maximum	0.040	0.045	0.062	0.910	0.021	0.038	0.024	0.078	0.196	0.400	-0.01	0.106	-0.08	0.411	0.034	0.411
mean	0.032	0.029	-0.08	0.910	-0.05	0.157	-0.09	0.213	-0.05	0.434	-0.06	0.168	-0.17	0.243	-0.55	2.006
minimum	0.015	0.035	-0.29	0.910	-0.14	0.034	-0.18	0.067	-0.22	0.267	-0.16	0.106	-0.31	0.619	-1.71	0.619

Table 3B. Comparison of Field Duplicate Samples for Radionuclides, Radiochemistry

Sample Location	SR90		TH228		TH230		TH232		U234		U235		U238		PU238		PU239	
SOIL	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
42455090SRN0	0.207	0.156	1.307	0.189	1.330	0.191	1.312	0.188	0.942	0.110	0.043	0.022	0.942	0.109	0.019	0.020	-0.01	0.024
42455090SRN2	0.166	0.176	0.752	0.106	0.574	0.090	0.682	0.099	0.421	0.065	0.021	0.019	0.401	0.062	0.014	0.017	0.003	0.006
10530331SRN0					1.257	0.163												
10530331SRN5					1.665	0.246												
42455090SRN0					1.330	0.191												
42455090SRN5					0.665	0.182												
Comparison, relative difference second/first																		
42455090SRN0	-0.22	1.261	-0.54	0.210	-0.79	0.222	-0.63	0.213	-0.76	0.188	-0.66	0.898	-0.81	0.187	-0.32	1.549	-3.62	7.087
10530331SRN0					0.746	0.202												
42455090SRN0					0.279	0.264												

Table 4A. Comparison of Laboratory Duplicate Analyses for Radionuclides, Gamma Spectrometry

Sample Location	K40		CS137		PB212		PB214		BI214		AC228		TH234		U235	
	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
10346220SRN0	21.37	0.62	0.052	0.014	1.381	0.038	0.763	0.052	0.778	0.241	1.383	0.111	0.800	0.325	0.007	0.007
10346220SRN0	21.63	0.56	0.046	0.015	1.400	0.034	1.043	0.047	1.089	0.188	1.373	0.100	0.748	0.271	0.005	0.005
21946220SRN0	22.07	0.66	0.096	0.023	1.541	0.042	1.029	0.053	1.067	0.232	1.613	0.114	1.316	0.394	0.064	0.010
21946220SRN0	21.69	0.61	0.124	0.022	1.509	0.038	1.274	0.055	1.180	0.202	1.514	0.097	1.255	0.342	0.068	0.009
22146220SRN0	23.38	0.62	0.010	0.010	1.380	0.036	0.984	0.051	0.820	0.212	1.486	0.101	0.850	0.330	0.055	0.009
22146220SRN0	23.73	0.68	0.015	0.015	1.481	0.041	1.178	0.063	1.106	0.214	1.466	0.120	0.205	0.205	0.010	0.010
30309040SRN0	20.90	0.54	0.567	0.025	1.314	0.032	0.905	0.047	1.071	0.176	1.342	0.086	1.088	0.284	0.059	0.008
30309040SRN0	21.62	0.56	0.561	0.028	1.460	0.035	1.098	0.049	1.167	0.187	1.369	0.099	1.275	0.276	0.005	0.005
30315160SRN0	22.33	0.57	0.047	0.018	1.469	0.035	1.010	0.047	1.041	0.210	1.504	0.107	1.371	0.336	0.006	0.006
30315160SRN0	22.76	0.58	0.048	0.017	1.488	0.036	1.165	0.051	1.153	0.190	1.446	0.107	1.426	0.380	0.005	0.005
30540490BRN0	21.20	0.60	0.013	0.013	1.822	0.043	1.259	0.055	1.196	0.184	1.663	0.107	1.626	0.432	0.069	0.011
30540490BRN0	22.34	0.57	0.010	0.010	1.865	0.039	1.373	0.051	1.500	0.216	1.818	0.110	1.576	0.366	0.070	0.009
30547080BRN0	21.63	0.54	0.009	0.009	1.680	0.037	1.032	0.050	1.054	0.175	1.701	0.105	1.009	0.335	0.005	0.005
30547080BRN0	21.18	0.53	0.010	0.010	1.797	0.038	1.104	0.051	1.067	0.201	1.671	0.104	1.023	0.317	0.005	0.005
30648280BRN0	22.18	0.53	0.008	0.008	1.413	0.034	0.715	0.043	0.833	0.145	1.416	0.099	0.937	0.265	0.005	0.005
30648280BRN0	20.87	0.57	0.010	0.010	1.381	0.037	0.676	0.045	0.680	0.182	1.249	0.098	0.984	0.342	0.005	0.005
42246090SRN0	20.21	0.58	0.012	0.012	1.393	0.036	0.882	0.051	0.908	0.208	1.335	0.097	1.035	0.319	0.007	0.007
42246090SRN0	19.99	0.56	0.015	0.015	1.362	0.036	0.990	0.050	1.006	0.203	1.399	0.101	1.553	0.394	0.060	0.010
42351990SRN0	20.74	0.54	0.097	0.019	1.426	0.033	0.926	0.044	0.906	0.192	1.453	0.093	1.215	0.353	0.005	0.005
42351990SRN0	21.29	0.54	0.083	0.018	1.436	0.033	0.947	0.044	0.985	0.153	1.484	0.096	1.003	0.321	0.005	0.005

Comparison, relative difference second/first

10346220SRN0	0.012	0.039	-0.11	0.416	0.014	0.037	0.311	0.077	0.333	0.328	-0.01	0.109	-0.07	0.547	-0.36	1.436
21946220SRN0	-0.02	0.041	0.257	0.289	-0.02	0.037	0.213	0.066	0.101	0.274	-0.06	0.096	-0.05	0.406	0.065	0.210
22146220SRN0	0.015	0.039	0.373	1.439	0.071	0.038	0.179	0.075	0.297	0.313	-0.01	0.106	-1.22	0.736	-1.38	0.408
30309040SRN0	0.034	0.037	-0.01	0.066	0.105	0.034	0.193	0.068	0.086	0.229	0.020	0.096	0.158	0.335	-1.69	0.303
30315160SRN0	0.019	0.036	0.019	0.514	0.013	0.034	0.143	0.064	0.102	0.258	-0.04	0.103	0.039	0.363	-0.14	1.418
30540490BRN0	0.052	0.038	-0.24	1.424	0.023	0.032	0.087	0.057	0.226	0.211	0.089	0.088	-0.03	0.353	0.013	0.205
30547080BRN0	-0.02	0.035	0.061	1.415	0.067	0.030	0.067	0.066	0.012	0.252	-0.02	0.087	0.014	0.454	0.000	1.414
30648280BRN0	-0.06	0.036	0.239	1.424	-0.02	0.036	-0.06	0.089	-0.20	0.308	-0.13	0.105	0.049	0.451	0.000	1.414
42246090SRN0	-0.01	0.040	0.196	1.421	-0.02	0.037	0.116	0.077	0.102	0.304	0.047	0.102	0.400	0.392	1.573	0.366
42351990SRN0	0.026	0.037	-0.16	0.284	0.007	0.033	0.023	0.066	0.083	0.259	0.021	0.091	-0.19	0.430	0.000	1.414

	K40		CS137		PB212		PB214		BI214		AC228		TH234		U235	
	diff	unc	diff	unc	diff	unc	diff	unc	diff	unc	diff	unc	diff	unc	diff	unc
number	10		10		10		10		10		10		10		10	
maximum	0.052	0.038	0.373	0.289	0.105	0.034	0.311	0.077	0.333	0.328	0.089	0.088	0.400	0.392	1.573	0.210
mean	0.005	0.065	0.064	0.398	0.023	0.088	0.127	0.209	0.114	0.303	-0.01	0.119	-0.09	0.856	-0.19	1.767
minimum	-0.06	0.036	-0.24	0.284	-0.02	0.036	-0.06	0.089	-0.20	0.308	-0.13	0.105	-1.22	0.430	-1.69	0.205

Table 4B. Comparison of Laboratory Duplicate Analyses for Radionuclides, Radiochemistry

Sample Location	SR90		TH228		TH230		TH232		U234		U235		U238		PU238		PU239	
	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
IPL-506-2-3	6.248	0.389	7.716	0.801	1.696	0.258	7.519	0.782	3.594	0.359	0.241	0.085	3.839	0.375	0.122	0.087	2.903	0.524
IPL-506-2-3D	6.743	0.408	9.266	1.054	1.741	0.299	9.116	1.037	7.082	0.629	0.311	0.107	7.103	0.627	0.018	0.051	2.698	0.446

Comparison, relative difference second/first

IPL-506-2-3	0.076	0.087	0.183	0.156	0.026	0.230	0.192	0.156	0.653	0.136	0.254	0.495	0.597	0.134	-1.49	1.441	-0.07	0.246

Table 5A. Comparison of Laboratory Matrix Spike Analyses for Radionuclides, Gamma Spectrometry

Sample Location		CS137	
		pCi/g	unc
10530331SRN2	Added	2.000	0.090
	Measured	2.240	0.130
	Recovery	1.120	0.082
20446370SRN0	Added	2.000	0.080
	Measured	2.040	0.120
	Recovery	1.020	0.073
21030331SRN0	Added	1.990	0.090
	Measured	1.990	0.120
	Recovery	1.000	0.075
30113170SRN0	Added	1.970	0.090
	Measured	2.020	0.150
	Recovery	1.025	0.089
30309040SRN0	Added	2.010	0.080
	Measured	2.020	0.110
	Recovery	1.005	0.068
30345110SRN0	Added	2.010	0.080
	Measured	2.010	0.130
	Recovery	1.000	0.076
30511230BRN0	Added	2.010	0.080
	Measured	2.160	0.110
	Recovery	1.075	0.069
30540490BRN0	Added	2.000	0.080
	Measured	1.900	0.130
	Recovery	0.950	0.075
41726090SRN0	Added	2.000	0.080
	Measured	1.970	0.110
	Recovery	0.985	0.068
IPL-506-2-1	Added	5.260	0.050
10530331SRN5	Measured	5.420	0.170
	Recovery	1.030	0.034
IPL-506-2-2	Added	4.560	0.050
42455090SRN5	Measured	4.880	0.140
	Recovery	1.070	0.033
IPL-506-2-3	Added	5.460	0.050
20646220SRN5	Measured	5.560	0.150
	Recovery	1.018	0.029
AVERAGE	Recovery	1.025	0.064

Table 5B. Comparison of Laboratory Matrix Spike Analyses for Radionuclides, Radiochemistry

Sample Location		SR90		TH228		TH230		TH232		U234		U235		U238		PU238		PU239	
		pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc	pCi/g	unc
IPL-506-2-1	Added	2.450	0.054	8.040	0.289	none added		8.040	0.289	7.171	0.258	0.326	0.012	6.990	0.252	0.012	0.000	3.123	0.066
10530331SRN5	Measured	2.526	0.280	8.872	0.865	1.665	0.246	8.002	0.791	6.205	0.577	0.271	0.092	6.388	0.589	0.072	0.076	4.033	0.717
	Recovery	1.031	0.117	1.103	0.115	no measure		0.995	0.105	0.865	0.086	0.831	0.284	0.914	0.090	5.882	6.210	1.292	0.231
IPL-506-2-2	Added	2.240	0.049	6.970	0.251	none added		6.970	0.251	6.248	0.225	0.284	0.010	6.090	0.219	0.010	0.000	2.434	0.051
42455090SRN5	Measured	2.193	0.267	4.028	0.568	0.665	0.182	3.348	0.491	2.914	0.348	0.189	0.083	2.706	0.330	0.076	0.095	1.172	0.279
	Recovery	0.979	0.121	0.578	0.084	no measure		0.480	0.073	0.466	0.058	0.666	0.293	0.444	0.056	7.967	9.960	0.482	0.115
IPL-506-2-3	Added	2.830	0.062	9.090	0.327	none added		9.090	0.327	5.376	0.194	0.244	0.009	5.240	0.189	0.012	0.000	3.037	0.064
20646220SRN5	Measured	6.248	0.389	7.716	0.801	1.696	0.258	7.519	0.782	3.594	0.359	0.241	0.085	3.839	0.375	0.122	0.087	2.903	0.524
	Recovery	2.208	0.146	0.849	0.093	no measure		0.827	0.091	0.669	0.071	0.986	0.350	0.733	0.076	10.25	7.312	0.956	0.174
IPL-506-2-3D	Added	2.830	0.062	9.090	0.327	none added		9.090	0.327	5.376	0.194	0.244	0.009	5.240	0.189	0.012	0.000	3.037	0.064
20646220SRN5	Measured	6.743	0.408	9.266	1.054	1.741	0.299	9.116	1.037	7.082	0.629	0.311	0.107	7.103	0.627	0.018	0.051	2.698	0.446
	Recovery	2.383	0.153	1.019	0.122	no measure		1.003	0.120	1.317	0.126	1.273	0.440	1.356	0.129	1.512	4.285	0.889	0.148
AVERAGE	Recovery	1.650	0.134	0.887	0.103	no measure		0.826	0.097	0.829	0.085	0.939	0.342	0.862	0.088	6.403	6.942	0.904	0.167

10. Appendix A

The Certificates of Calibration for the blind spike samples prepared by Isotope Product Laboratories are presented here. The activity values, uncertainties, and isotopic fractions stated on these sheets have been used in the intercomparisons discussed in this report.

CERTIFICATE OF CALIBRATION
MULTINUCLIDE STANDARD SOURCE

Customer: ROCKWELL INTL/ ROCKETDYNE
Catalog No.: EG-0075
Source No.: 506-2-1

P.O.No.: R54PJO-95162004
Reference Date: September 1 1995 12:00 PST.
Total Radioactivity: 28.9 nCi.
Total Radioactivity: 1,068 Bq.

Description of Source

a. Capsule type: Customer supplied bottle
b. Nature of active deposit: SrCl2, CsCl, Th(NO3)4, UO2(NO3)2, and Pu(NO3)3 dispersed in a sand matrix
c. Active diameter/volume: Approximately 1.0 L (Mass of sand = 1,125.60 g)
d. Backing: Glass
e. Cover: Glass

Nuclide	Half-life	Activity. (nCi)	Concentration (pCi/g)	Systematic Uncert.	Random Uncert.	Total Uncert.
Sr-90	28.5 ± 0.2 years	2.76	2.45	2.0%	0.9%	2.2%
Cs-137	30.17 ± 0.16 years	5.92	5.26	1.0%	0.7%	1.2%
Th-232	(1.405 ± 0.006) x 10^10 years	9.05	8.04	3.0%	2.0%	3.6%
U-238	(4.468 ± 0.005) x 10^9 years	7.87	6.99	3.0%	2.0%	3.6%
Pu-239	24,110 ± 30 years	3.26	2.90	2.1%	0.3%	2.1%

Method of Calibration

This source was prepared from weighed aliquots of solutions whose concentrations, in nCi/g, were determined as follows: 1) for Sr-90 and Pu-239 by a liquid scintillation counter. 2) for Cs-137 by a well type ionization chamber, and 3) for Th-232 and U-238 by specific activity and mass calculations. Sr-90 has a daughter(Y-90) in equilibrium. U-238 and Pu-239 have attached technical data sheets for impurities and daughters.

Daughter decay scheme for Th-232

Ra-228 -> Ac-228 -> Th-228 -> Ra-224 -> Rn-220 -> Po-216 -> Pb-212 -> Bi-212 -> Po-212 -> Tl-208 -> Pb-208

NIST Traceability

This calibration is implicitly traceable to the National Institute of Standards and Technology.

Leak Test(s)

See reverse side for Leak Test(s) applied to this source.

Notes

1. IPL participates in an NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (As in NRC Regulatory Guide 4.15).
2. Overall uncertainty is calculated at the 95.5% confidence level.

Ann U. Um
QUALITY CONTROL

14 Sep 1995
Date Signed

ISOTOPE PRODUCTS LABORATORIES
3017 N. SAN FERNANDO BLVD.
BURBANK, CALIFORNIA 91504
818•843•7000 FAX 818•843•6168

IPL Ref No. 506-2-1

CERTIFICATE OF CALIBRATION
MULTINUCLIDE STANDARD SOURCE

Customer: ROCKWELL INTL/ ROCKETDYNE
Catalog No.: EG-0075
Source No.: 506-2-2

P.O.No.: RS4PJO-95162004
Reference Date: September 1 1995 12:00 PST.
Total Radioactivity: 28.3 nCi.
Total Radioactivity: 1,048 Bq.

Description of Source

a. Capsule type: Customer supplied bottle
b. Nature of active deposit: SrCl2, CsCl, Th(NO3)4, UO2(NO3)2, and Pu(NO3)3 dispersed in a sand matrix
c. Active diameter/volume: Approximately 1.0 L (Mass of sand = 1,283.96 g)
d. Backing: Glass
e. Cover: Glass

Nuclide	Half-life	Activity, (nCi)	Concentration (pCi/g)	Systematic Uncert.	Random Uncert.	Total Uncert.
Sr-90	28.5 ± 0.2 years	2.88	2.24	2.0%	0.9%	2.2%
Cs-137	30.17 ± 0.16 years	5.86	4.56	1.0%	0.7%	1.2%
Th-232	(1.405 ± 0.006) x 10^10 years	8.95	6.97	3.0%	2.0%	3.6%
U-238	(4.468 ± 0.005) x 10^9 years	7.81	6.09	3.0%	2.0%	3.6%
Pu-239	24,110 ± 30 years	2.83	2.26	2.1%	0.3%	2.1%

Method of Calibration

This source was prepared from weighed aliquots of solutions whose concentrations, in nCi/g, were determined as follows: 1) for Sr-90 and Pu-239 by a liquid scintillation counter. 2) for Cs-137 by a well type ionization chamber, and 3) for Th-232 and U-238 by specific activity and mass calculations. Sr-90 has a daughter(Y-90) in equilibrium. U-238 and Pu-239 have attached technical data sheets for impurities and daughters.

Daughter decay scheme for Th-232

Ra-228 -> Ac-228 -> Th-228 -> Ra-224 -> Rn-220 -> Po-216 -> Pb-212 -> Bi-212 -> Po-212 -> Tl-208 -> Pb-208

NIST Traceability

This calibration is implicitly traceable to the National Institute of Standards and Technology.

Leak Test(s)

See reverse side for Leak Test(s) applied to this source.

Notes

1. IPL participates in an NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (As in NRC Regulatory Guide 4.15).
2. Overall uncertainty is calculated at the 95.5% confidence level.

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IPL Ref No. 506-2-2

CERTIFICATE OF CALIBRATION
MULTINUCLIDE STANDARD SOURCE

Customer: ROCKWELL INTL/ ROCKETDYNE **P.O.No.:** RS4PJO-95162004
Catalog No.: EG-0075 **Reference Date:** September 1 1995 12:00 PST
Source No.: 506-2-3 **Total Radioactivity:** 25.3 nCi.
Total Radioactivity: 938 Bq.

Description of Source

a. Capsule type: Customer supplied bottle
b. Nature of active deposit: SrCl2, CsCl, Th(NO3)4, UO2(NO3)2, and Pu(NO3)3 dispersed in a sand matrix
c. Active diameter/volume: Approximately 1.0 L (Mass of sand = 995.76g)
d. Backing: Glass
e. Cover: Glass

Nuclide	Half-life	Activity, (nCi)	Concentration (pCi/g)	Systematic Uncert.	Random Uncert.	Total Uncert.
Sr-90	28.5 ± 0.2 years	2.82	2.83	2.0%	0.9%	2.2%
Cs-137	30.17 ± 0.16 years	5.44	5.46	1.0%	0.7%	1.2%
Th-232	(1.405 ± 0.006) x 10^10 years	9.05	9.09	3.0%	2.0%	3.6%
U-238	(4.468 ± 0.005) x 10^9 years	5.22	5.24	3.0%	2.0%	3.6%
Pu-239	24,110 ± 30 years	2.81	2.82	2.1%	0.3%	2.1%

Method of Calibration

This source was prepared from weighed aliquots of solutions whose concentrations, in nCi/g, were determined as follows: 1) for Sr-90 and Pu-239 by a liquid scintillation counter. 2) for Cs-137 by a well type ionization chamber, and 3) for Th-232 and U-238 by specific activity and mass calculations. Sr-90 has a daughter(Y-90) in equilibrium. U-238 and Pu-239 have attached technical data sheets for impurities and daughters.

Daughter decay scheme for Th-232

Ra-228 -> Ac-228 -> Th-228 -> Ra-224 -> Rn-220 -> Po-216 -> Pb-212 -> Bi-212 -> Po-212 -> Tl-208 -> Pb-208

NIST Traceability

This calibration is implicitly traceable to the National Institute of Standards and Technology.

Leak Test(s)

See reverse side for Leak Test(s) applied to this source.

Notes

1. IPL participates in an NIST measurement assurance program to establish and maintain implicit traceability for a number of nuclides, based on the blind assay (and later NIST certification) of Standard Reference Materials (As in NRC Regulatory Guide 4.15).
2. Overall uncertainty is calculated at the 95.5% confidence level.

Ann U. Kim
QUALITY CONTROL

14 Sep 1995
Date Signed

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IPL Ref No. 506-2-3

U-238 TECHNICAL DATA

The U-238 used to prepare your order was taken from Isotope Products Laboratories Lot #6794 and had the following composition as of June 1, 1994.

Corporate Offices
3017 N. San Fernando Blvd.
Burbank, California
91504

Main Laboratory
1800 N. Keystone Street
Burbank, California
91504

818·843·7000
Fax 818·843·6168

NUCLIDE	ATOM%	ACTIVITY%
U-232	N/D	------
U-233	N/D	------
U-234	0.005	49.501
U-235	0.720	2.250
U-236	N/D	------
U-238	99.274	48.249

Isotopic composition provided by Oak Ridge National Laboratory.

If you have any questions, please contact Technical Service.

(818)843-7000

ISOTOPE PRODUCTS LABORATORIES

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Pu-239 TECHNICAL DATA

The Pu-239 used to prepare your order was taken from Isotope Products Laboratories Lot #6617-1 and had the following composition as of October 1, 1994.

NUCLIDE	ATOM%	ACTIVITY%	TOTAL α ACTIVITY %
Pu-238	0.002	0.337	0.388
Pu-239	97.933	79.717	91.887
Pu-240	2.056	6.124	7.058
Pu-241	0.010	13.241	N/A
Pu-242	0.001	0.000	0.000
Am-241	-----	0.582	0.671

Note: Pu-241 is beta active.

Isotopic composition provided by New Brunswick Laboratory.

If you have any questions, please contact Technical Service.

11. Appendix B - Interpretation of Results

All soil sample analytical results are well below the approved limits for release of land areas for use without radiological restrictions (see "Proposed Sitewide Release Criteria for Remediation of Facilities at the SSFL", B. M. Oliver and R. J. Tuttle, Rocketdyne Document N001SRR140127, 8/22/96). That document provided single-isotope limits for all radionuclides that are possible contaminants at SSFL, and those limits were approved by the Department of Energy, Oakland Operations Offiice, and by the State of California Department of Health Services, Radiologic Health Branch. Potential doses to future users of the site, for residential, industrial, and wilderness use situations were considered, and concentrations were calculated that provided a Total Effective Dose Equivalent (TEDE) equal to the limit of 15 mrem/year recommended by the EPA. For the two radionuclides detected in the soil sampling survey, Sr-90 and Cs-137, the limits are 36.0 and 9.2 pCi/g, respectively. All analytical results were well below these limits. The maximum value for Sr-90 was 0.569 pCi/g, or 1.58% of the single-isotope limit. The maximum value for Cs-137 was 0.567 pCi/g, or 6.16% of the single-isotope limit. Combining these two percentages to test for the combined sum of fractions rule, results in a percentage of 7.74%, far below the allowable 100%.

To demonstrate the satisfactory condition of the radiologically remediated Former Sodium Disposal Facility, a pathways analysis was performed to estimate potential dose to a hypothetical resident of the area. This analysis used the pathways code, RESRAD (version 5.61), with the same parameters that were used in establishing the generic limits on radioactivity in soil at SSFL. The Former Sodium Disposal Facility was represented as a slightly smaller area, 8,200 m^2, than the generic reference case, 10,000 m^2.

The residual contamination of the site was assumed to be equal to the average of the measured values, for Sr-90 and Cs-137, the only contaminants detected in the radiometric analyses. These values were, respectively, 0.131 pCi/g for Sr-90 and 0.069 pCi/g for Cs-137. Residual contamination was assumed to be uniformly distributed through the upper 1 meter of the soil. (This is a conservative assumption, since much of the area was excavated down to bedrock and only a very thin residual layer of soil remains. For this calculation the top 1 meter of the site is considered to be soil. Studies of the depth distribution of the original contamination showed that the radioactivity, which had initially been deposited on the surface of the soil, had not penetrated beyond about 18 inches.)

RESRAD calculates the dose from a variety of exposure pathways. The only significant pathways were direct radiation from the ground for the Cs-137, and plant uptake (in vegetables) for the Sr-90. If the Former Sodium Disposal Facility had been occupied in a residential manner immediately after completion of the soil sampling, that is, in August 1995, the first-year dose is calculated to be 0.166 mrem. This is small compared to the recommended limit of 15 mrem per year, established by the EPA, and trivial compared to the natural dose from "clean" soil approximately 80 mrem/year. The estimated dose declines with time into the future. This is

shown in Figure A.1, where the dose becomes essentially zero after 100 years.

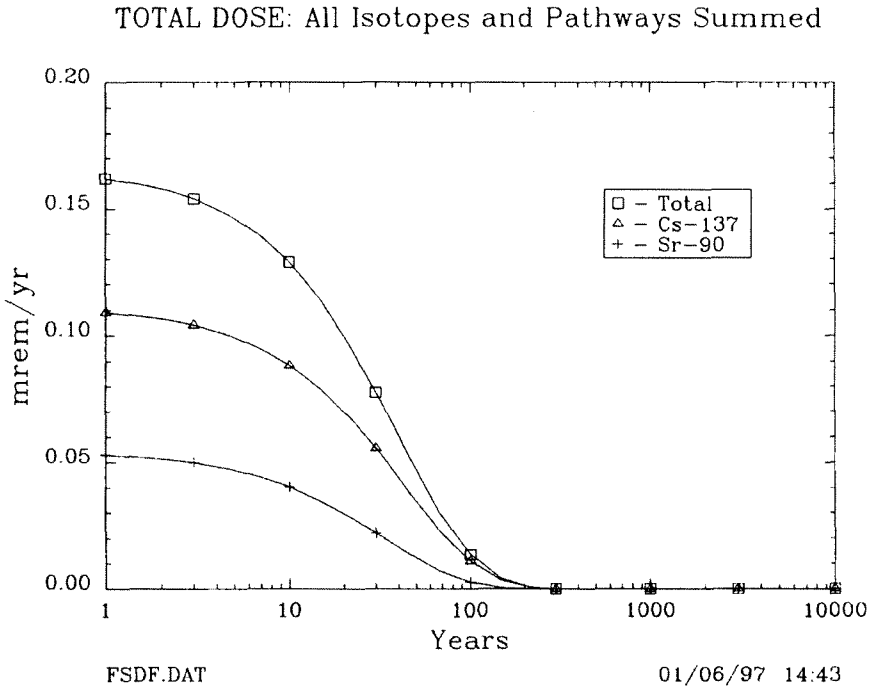

Figure A-1. Calculated potential dose to resident of remediated Former Sodium Disposal Facility.

The average values assumed for contamination are comparable to the fallout background found in surface soil in this region. Subtraction of background activities is not suitable in this case, however, because many of the samples are from deep below the original surface of the soil where the background activity of these radionuclides is essentially zero. Therefore, a comparison calculation was performed, representing an undisturbed plot of land with the same characteristics and usage as proposed for the Former Sodium Disposal Facility, except that the residual contamination was replaced by the values of activity found for the surrounding, unaffected, terrain. These background values were derived from the Area IV Characterization Survey results, by excluding all samples that were suggestive of possible contamination, and the deliberately selected offsite (background) soil sample results. (See "Area IV Radiological Characterization Survey - Final Report", ETEC Document A4CM-ZR-0011, Revision A, Volumes I-IV, August 15, 1996.) For unaffected soil, contaminated only by fallout activity, the activity was assumed to be limited to the upper 10 cm of the soil (4 inches). This calculation shows that the dose on unaffected, and unremediated, land would be 0.171 mrem in the first year, slightly more than for the remediated Former Sodium Disposal Facility. When naturally occurring concentrations of potassium-40, uranium (plus daughters) and thorium (plus daughters) are included in the "clean" soil, a similar RESRAD calculation yields 81.74 mrem/year, as an additional, natural dose from the natural radioactivity alone.

As a further demonstration of the conservatism in the cleanup conducted here, a RESRAD calculation was also done with the assumption that the entire site was contaminated at the level found in the single most contaminated sample, that is, the sample taken at location 3030904, in the former Lower Pond. (All soil had been removed from the Lower Pond, so that only bedrock remains.) This calculation showed that these greater amounts of Sr-90 (0.569 pCi/g) and Cs-137

(0.567 pCi/g) would produce only 1.157 mrem/year in the first year, still far below the limit of 15 mrem/year and the natural dose of 81.74 mrem/year.

This study shows that the Former Sodium Disposal Facility is in compliance with the recommended acceptance limit of 15 mrem per year for radiological exposure, and is essentially no different, radiologically, from any similar unaffected plot of land.