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NMED / LANL 1996 Soil Results: Data Evaluation and Statistical Comparison

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ABSTRACT

In 1996, the DOE Oversight Bureau of the New Mexico Environment Department collected duplicate soil samples with Los Alamos National Laboratory at 16 locations. A commercial laboratory analyzed the samples for beryllium, lead, isotopic plutonium, and isotopic uranium. Comparisons of plutonium-238, plutonium -239,240, and beryllium data showed no significant differences between the Department's data and the Laboratory's. The comparison of lead data showed that our measurements were slightly higher than the Laboratory's. Isotopic uranium data, expressed as total uranium, were slightly lower than the Laboratory's non-isotopic, total uranium data. However, differences between individual data pairs were small and within acceptance tolerances. A summary comparison of all data showed no significant differences. Based on this evaluation of sample collection and analytical methods and the data comparisons, the Laboratory's measurements for plutonium -238, plutonium-239,240, total uranium, lead, and beryllium in soils were shown to be valid.

INTRODUCTION

Soils are sampled by the Los Alamos National Laboratory (LANL or the Laboratory) Ecology Group (ESH-20), to monitor the concentration, inventory, and distribution of contaminants on and around the Laboratory. In 1996, LANL's environmental monitoring program for soils included 28 standard sampling locations, called "stations". These stations are located on Laboratory property, around the perimeter and at off-site, regional locations.

To determine whether LANL's environmental programs are protective of human health and the environment, the New Mexico Environment Department (NMED or the Department) should have confidence in the accuracy of the Laboratory's environmental data. To obtain this confidence, NMED's Department of Energy Oversight Bureau duplicated part of LANL's surveillance program. NMED collected soil samples from 16 LANL stations during 1996 and had them analyzed for five contaminants. NMED and LANL data sets were then compared. If the data sets proved to be statistically equivalent at a 95% confidence level, the results would support the validity of LANL's environmental data. If NMED and LANL data were not found to be statistically equivalent, either LANL or NMED's collection or analytical methods would be questionable.

Except for uranium, NMED duplicated LANL's sampling and analytical procedures. LANL submitted its samples to LANL Analytical Services Group (CST-9) and analyzed them for radionuclides, radioactivity, metals, and in some cases, organic suites. NMED submitted its samples to a commercial laboratory, Paragon Analytics, Inc., and analyzed them for isotopic plutonium, isotopic uranium, lead, and beryllium.

LANL's Surveillance Program

ESH-20, LANL's Ecology Group, annually collects soil samples at 28 regional, perimeter, and on-site sampling stations. The sites are selected to represent the soil conditions of those local

environments. Most sites are positioned on mesa tops in level, open, and undisturbed areas.

The annual surveillance stations are categorized according to proximity to the Laboratory. Regional stations are established at distances beyond the known influence of the Laboratory (at least 15 km), perimeter stations are established within 4 km of the Laboratory boundaries, and on-site stations are located within the Laboratory boundaries. Data from perimeter stations provide information regarding migration of contaminants from Laboratory property. Data collected on-site are used to assess impacts within Laboratory boundaries. Data from regional stations are used to determine background levels of man-made and naturally occurring analytes. Regional stations are shown on Figure 1. Since there are no regulatory standards for contaminants in soils (ESP 1997), the existence and degree of contamination in soil samples are based on comparisons to Regional Statistical Reference Levels (RSRLs), which function as statistical upper limits for background. They are the average concentrations of historical regional measurements plus a measure of variation in the data (mean plus two standard deviations). Results of radionuclide analyses of soils from regional stations collected annually from 1974 through 1995 were used to establish RSRLs (Fresquez and others, 1996).

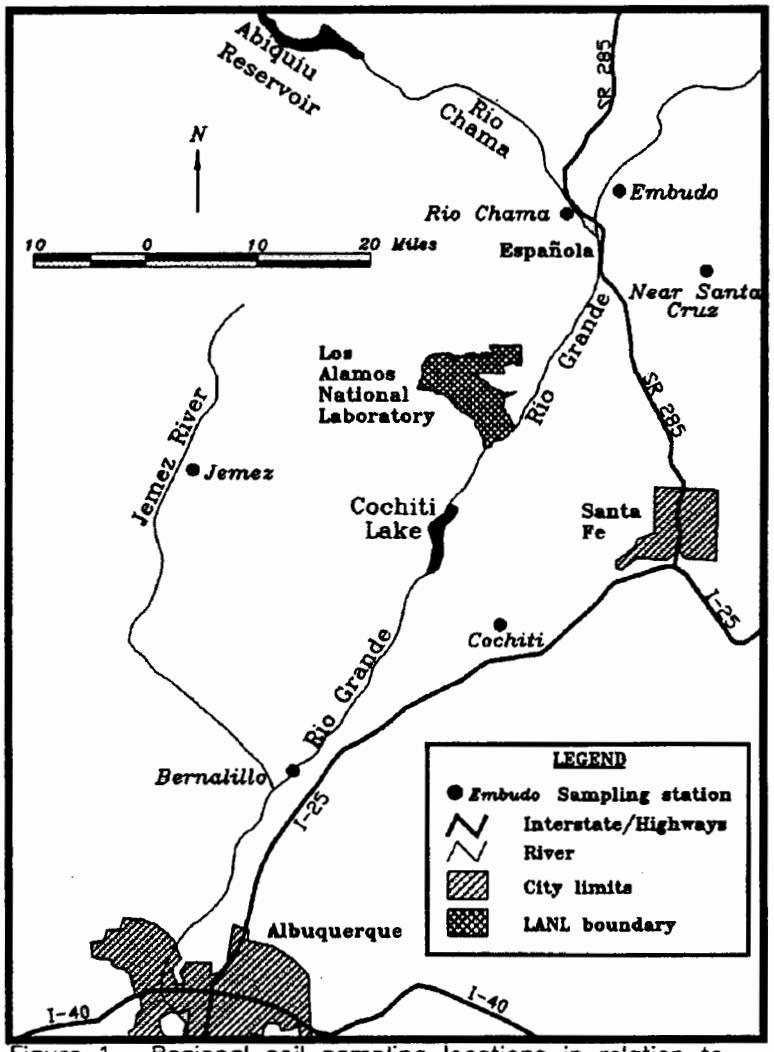

Figure 1. Regional soil sampling locations in relation to Los Alamos National Laboratory.

Station data for soils are interpreted in the context of LANL activities and climate attributes, such as wind and precipitation. Stack emissions, explosive testing at firing sites, resuspension of soil materials from waste handling operations, demolition and disposal activities, and inactive solid waste management units are potential sources from which winds redistribute Laboratory contaminants. Sampling stations are positioned downwind of major facilities and operations to monitor fugitive materials transported by wind from LANL activities.

Other stations are located in inhabited areas, such as Los Alamos Townsite, White Rock, San Ildefonso Pueblo, and Bandelier National Monument. Most perimeter and on-site locations are positioned on mesa tops. Most regional stations are located on terrace deposits of the main northern New Mexico drainages, the Chama and Jemez Rivers and the Rio Grande.

Analyte Selection Rationale

To select analytical parameters for this study, we evaluated concentrations of contaminants on or near the Laboratory reported in LANL's 1995 Environmental Surveillance Report (ESR). Radiological constituents measured by LANL include tritium, strontium-90, total uranium, cesium-137, plutonium-238, plutonium-239,240 (unresolved isotopes), americium-241, and gross alpha, beta, and gamma radioactivity. For the perimeter stations, the means for gross gamma, plutonium-238, and total uranium were reported above their respective background means; only plutonium-238 exceeded its RSRL. For the on-site stations, the means for plutonium-239,240 and total uranium exceeded their respective background averages but were not above RSRLs. Although the means for all but the perimeter plutonium-238 measurements were below their RSRL, measurements of a number of individual on-site and perimeter sites were above RSRLs for one or more contaminants

Trace and heavy metals monitored by the Laboratory include silver, arsenic, barium, beryllium, cadmium, chromium, mercury, nickel, lead, antimony, selenium, and thallium. In 1995, the ESR reported the average concentrations of beryllium and lead at perimeter and on-site stations to be above background averages. The perimeter mean for lead also exceeded its RSRL. Measurements of beryllium, lead, and mercury from a number of individual sites were above tolerance levels established for background.

None of the measurements exceeded screening action levels (SALs), which are threshold limits based on Environmental Protection Agency guidance for human health risk for metals or DOE 10-mrem/yr dose limits for radionuclides (EPA, 1988 and 1993).

According to this evaluation, the radionuclides most commonly measured above background were the plutonium isotopes and total uranium. The metals most commonly measured above background were lead and beryllium. Also, the beryllium background levels appeared to approach the SAL. Therefore, we focused our statistical comparisons on plutonium-238, combined plutonium-239 and -240, total uranium, lead, and beryllium.

Site Selection Rationale

At least eight samples with measurable levels of constituents selected for this study were required to make an acceptable statistical comparison. Therefore, eight of the 16 stations in this study were selected because of elevated levels of plutonium or uranium noted in the 1995 ESR. These include four perimeter sites (Near TA-8 GT-Site, Near TA-49, White Rock East, and Tsankawi) and four on-site locations (TA-21, West of TA-53, R Site Road East, and Potrillo Drive). Lead or beryllium was measured above RSRLs at seven locations (North Mesa, Near TA-8 GT Site, Near TA-49, Tsankawi, TA-21 DP-Site, Two Mile Mesa, and Potrillo Drive). Three regional sites and two on-site locations that had not demonstrated Laboratory impacts were also selected. Regional sites at Cochiti, Bernalillo, and Jemez, as well as on-site locations at TA-49 near test

well DT-9 and S-Site (TA-16) were selected to test for the absence of elevated measurements of the analytes selected for this study. An additional location east of TA-53 not measured by LANL in 1995 was also selected. All perimeter and on-site locations where NMED collected duplicate samples are shown on Figure 2.

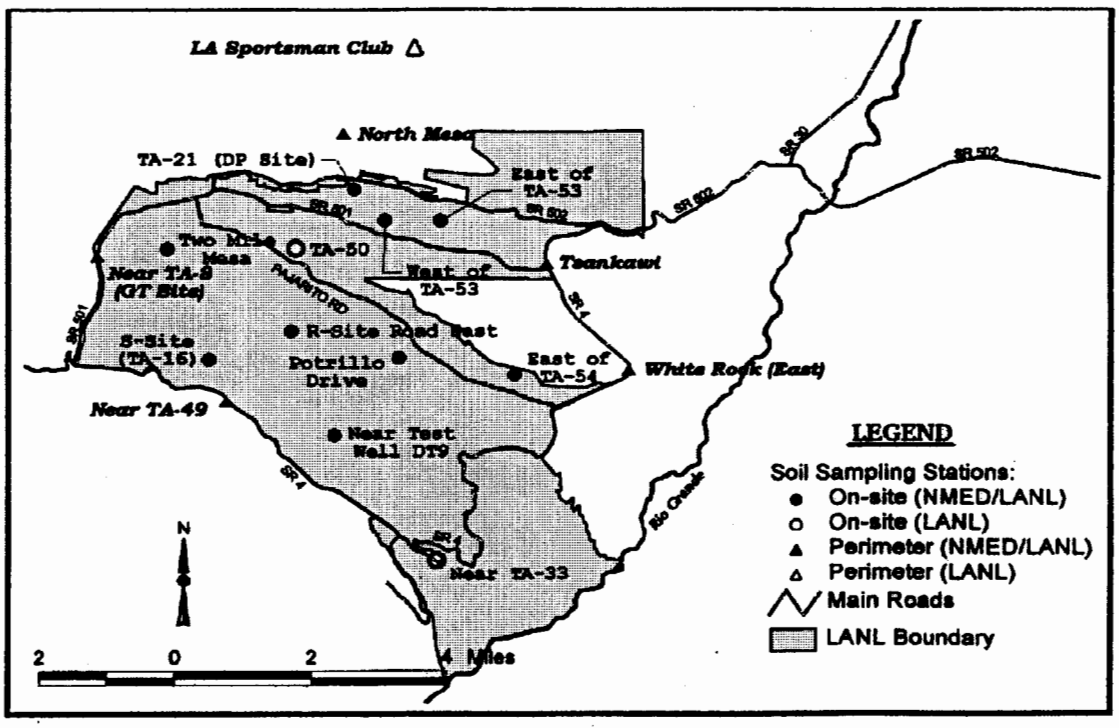

Figure 2. Perimeter and on-site soil stations sampled for 1996 (see legend for specific NMED and LANL samples.)

METHODS

We collected 16 duplicate soil samples. The collection method was identical in that a sufficient amount of soil for two samples was collected at each site, thoroughly mixed and then equally divided between LANL and our group. LANL submitted their samples to its on-site analytical laboratory, CST-9. A commercial analytical laboratory analyzed our samples. We screened our results for basic quality parameters, evaluated them for elevated measurements, and then compared it to LANL's.

NMED reviewed literature regarding field methods and participated in sample collection to evaluate whether the sampling methods were appropriate. Discussions with personnel from both analytical laboratories and a literature review helped assess the appropriateness of the analytical methods. After receiving its analytical results, NMED evaluated standard quality control requirements to establish the reliability and accuracy of our data. NMED's results were then compared to LANL 1996 background means, RSRLs, and SALs for identification of potentially contaminated locations. We then made statistical comparisons on LANL/NMED data to evaluate whether there were any significant differences.

Collection Methods

Soil sample collection methods follow guidelines recommended by the American Society for Testing and Materials (ASTM 1990 as cited in ESP 1997) and are in accordance with the "Standard Operating Procedures for the New Mexico DOE Oversight Bureau Sampling Activities" (Englert, 1996). Enough sample material (approximately 4 kg) was collected to divide into two samples. At each site, the total sample was collected by either NMED or LANL, before being divided.

Surficial soils were collected at predetermined sites from level, open, and undisturbed areas. A 10-cm diameter by 5-cm long stainless-steel ring was driven into the ground surface after organic debris (grass and twigs for example) and pebbles were removed. The plug of soil retained in the ring was collected into a 3-gallon zip-top bag and thoroughly mixed. This was repeated four more times until samples were taken at the center and corners of an approximately 100-m^2 area. The samples were then divided by alternately pouring soil into LANL and NMED containers. NMED collected at least 250-g soil into a 500-mL polypropylene bottle.

After each sample was collected, the equipment was scrubbed and rinsed with deionized water and dried with paper towels. The sample bottles were marked with site identification, date, time, and the name of the person collecting the sample. The sample bottles were double bagged and placed into coolers at 4° C for submittal to Paragon Analytics, Inc. No chemical preservation was required and the samples were submitted within the six-month holding time.

Analytical Methods

Analytical procedures were in keeping with the EPA's accepted methods (EPA, 1997) or other generally recognized and accepted methods. With the exception of uranium, NMED's analytical laboratory used the same methods as LANL's on-site laboratory.

In the case of uranium, NMED's laboratory measured individual isotopes using alpha spectroscopy. The sample was totally dissolved using hydrofluoric acid. The uranium in solution was chemically separated and then micro-precipitated with lanthanum fluoride, and counted for alpha activity. LANL's laboratory reported total uranium using Kinetic Phosphorescence Analysis (KPA). This method requires similar dissolution of the sample, but the analysis (measurement of photon emissions) is done on an aliquot of the hydrofluoric-acid dissolved solution.

Isotopic plutonium was evaluated using alpha spectroscopy. For both groups, the extraction for isotopic plutonium analysis employed a total dissolution using hydrofluoric acid and chemical separation by anion exchange. LANL electroplated the solution onto a planchette. NMED's laboratory micro-precipitated the solution by adding lanthanum fluoride and then filtering. The precipitate on the planchette or filter was then counted for alpha activity.

Both analytical laboratories analyzed beryllium and lead using EPA SW-846 method 6010. This Inductively Coupled Plasma-Atomic Emission Spectrometry method measures the intensity of the lead and beryllium spectra. CST-9 extracted metals from soils using EPA SW-846 method 3051, a total recoverable dissolution microwave digestion, while Paragon used EPA SW-846 method 3050B, an equivalent steam bath digestion.

Before the digestion and analysis, the soil samples were dried by the analytical laboratories at a minimum of 75° C for 24 hours, (or until the sample ceased to lose weight) then ground and sieved. The values were then reported as dry weight of analyte per gram of dry soil.

Comparison Methods

After receipt of the analytical results, the data were reviewed to assure data quality objectives and quality control (QC) criteria were met. The data were then evaluated for elevated measurements by comparisons to means of regional measurements, upper limits for background (RSRLs), and LANL SALs. Finally, NMED's data were compared to LANL's to determine whether there was a statistical difference.

Descriptive statistics were calculated and histograms were prepared for each data set. The mean, median, standard deviation, kurtosis, skewness, and range were calculated for each LANL and NMED data set. Each data set was also screened for normality using the Shapiro Wilks test. These statistics and histograms were inspected to qualitatively evaluate the central tendencies, dispersions, and associations of the NMED/LANL data

In this report, a data pair consists of an NMED and a LANL measurement at one station (a split sample) for an individual constituent. Comparative statistical analyses were run on paired data using three statistical tests: (1) the paired t-test, (2) the Wilcoxon matched pairs signed rank test, and (3) the Pearson correlation. The distribution of the differences between the paired data sets was represented by the x-y distribution histogram.

Conventional laboratory QC comparisons (Duplicate Error Ratios (DER) and Relative Percent Differences (RPD)) were calculated to evaluate differences between NMED/LANL data pairs. If the DER was less than or equal to 1.42, then a sample pair was considered equal within a 95% confidence level. If the RPD was less than 25%, the difference between the matched samples was considered acceptable. DERs were calculated for radionuclide measurements. RPDs were calculated for the metal measurements. An example of DER and RPD calculations is presented in the Appendix.

Parametric tests based on the normal distribution can be used to evaluate normally distributed data sets, while non-parametric tests can be used to evaluate data sets without making assumptions about the distribution. The paired t-test is a parametric method for evaluating difference in means between two groups where one member of a group can be "paired" with a single member of the second group. Although this parametric test assumes each group of data is normally distributed, it is often reliable even when the data are not normally distributed.

The Wilcoxon matched pairs signed rank test is a non-parametric alternative to the parametric paired t-test. This evaluation computes the number of times measurements from one data set are larger than paired data from the other data set and ranks the magnitude of the differences. For two sets of paired data that differ only randomly, corresponding data from the first set will be larger than the second approximately 50% of the time. If one set of data is systematically different from the other, that is, if there is a bias, then data from the first set will be either larger or smaller than their pairs more than 50% of the time. The Wilcoxon test is also sensitive to the ranking of the magnitude of the differences between each data comparison, which makes this test

only slightly less powerful than the paired t-test. For both the paired t-test and the Wilcoxon test, differences were considered significant at the 95% confidence level.

The Pearson correlation test is used to describe the relationship between two data sets. This test measures how closely two sets of data track, that is, whether both paired measurements are similarly high or low in respect to other data pairs. If either or both the paired t-test and the Wilcoxon test show that the paired data are significantly different, and the Pearson test finds that the data sets correlate, a bias may be indicated. If the data sets are found to be significantly different and the Pearson test finds that the data sets do not correlate, the measurements cannot be verified.

A summary comparison of all data for 1996 was also done (Figure A-7). All five parameters from the 16 locations were grouped and compared to the corresponding data from LANL; increasing the number of data comparisons from approximately 15 to 65 matched pairs. The descriptive and comparative statistics described above were then used to evaluate whether a significant difference existed between the data.

In addition to the statistical methods used to compare the data, each of our measurements was compared to three screening levels used to determine the existence or degree of contaminants in the environment. These levels were: 1) the background mean, 2) the RSRL, and 3) the SAL.

Before the data statistics were calculated, we reviewed the quality control measurements for all NMED results. Conventional quality control parameters include additional laboratory samples. These samples include method blanks, matrix spikes, blank spikes, and an assortment of duplicate samples. The results are compared to predetermined acceptance criteria. Method blank results indicated whether cross contamination problems exist. Matrix spike analysis indicated whether acceptable chemical recoveries and instrument efficiencies were obtained. Blank spikes provided samples with known 'true values' and accuracy was established. An assortment of duplicate measurements; such as matrix spike, and sample and spiked sample duplicates, indicated whether acceptable precision levels were met.

RESULTS

NMED sample data are presented in Table 1. LANL's soil data from the 1996 ESR and our results are presented together in the following sections as tables. Inspection of the data tables and subsequent graphs provides a qualitative comparison of the data. Descriptive and comparative statistics are discussed in the section text for each constituent. The Appendix contains NMED and LANL data, statistical analysis, and graphs for each parameter.

Analytical laboratory QC results indicate that the data were all within control limits. However, all plutonium-238 and approximately half of the plutonium-239,240 measurements are less than the estimated Total Propagated Uncertainties (TPUs) expressed as 2 times sigma, and therefore effectively below the detection limits. TPU values are sample specific measurements of variability that reflect the uncertainty of a radiochemical analytical result. Measurement variability includes such things as counting uncertainties, weighing, volume measurement, and chemical recoveries.

Table 1. NMED radiochemical and trace metal analysis of soils from the LANL area during 1996[a,b]

LOCATION	Date Collected	Beryllium (mg/kg)	Lead (mg/kg)	Pu-238 (pCi/g)	counting uncertainties[c] 2 σ	Pu-239/240 (pCi/g)	counting uncertainties 2 σ	U 234 (pCi/g)	counting uncertainties 2 σ	U-235 (pCi/g)	counting uncertainties 2 σ	U-238 (pCi/g)	counting uncertainties 2 σ	Total U[r] mg/kg	counting uncertainties 2 σ
REGIONAL															
Near Cochiti	03/25/96	0.5	9.0	0.00	0.01	0.01	0.01	0.44	0.08	0.03	0.02	0.44	0.08	1.32	0.25
Bernalillo	03/25/96	NA[e]	NA	0.00	0.01	0.01	0.01	0.56	0.09	0.03	0.02	0.67	0.10	2.01	0.31
Jemez	03/25/96	0.6	7.5	0.00	0.01	0.01	0.01	NA		NA		NA		NA	
Mean (+/- 2 SD)[f]		0.55[k] (0.07)	8.25 (1.06)	0.00 (0.00)		0.01(0.00)								1.67 (0.98)	
RSRL[g]		0.74	14.4	0.008		0.028								4.05	
SAL[h]		0.9	500	27		24								29	
PERIMETER															
North Mesa	03/20/96	0.7	13	NA		NA		0.95	0.14	0.03	0.02	1.04	0.15	3.11	0.46
Near TA-8 (GT Site)	03/21/96	<0.5[n]	10	0.00	0.01	0.01	0.01	NA		NA		NA		NA	
Near TA-49	03/21/96	0.7	14	0.00	0.01	0.02	0.01	NA		NA		NA		NA	
White Rock (East)	03/20/96	NA	18[m]	NA		NA		0.87	0.13	0.05	0.02	0.82	0.12	2.46	0.37
Tsankawi	03/20/96	0.9[m]	17[m]	NA		NA		1.37	0.19	0.06	0.03	1.49	0.20	4.46[m]	0.61
Mean (+/- 2 SD)		0.638[k] (0.275)	14.4[k] (1.4)	0.00 (0.00)		0.015[k] (0.007)								3.43 [k](2.04)	
ON-SITE															
TA-21 (DP Site)	03/20/96	0.7	25[m]	0.00	0.02	0.01	0.01	NA		NA		NA		NA	
East of TA-53	03/20/96	0.5	11	0.00	0.02	0.02	0.01	0.68	0.11	0.03	0.02	0.80	0.12	2.39	0.37
West of TA-53	03/20/96	0.7	12	0.00	0.02	0.02	0.01	NA		NA		NA		NA	
Two Mile Mesa	03/21/96	0.6	14	0.00	0.05	0.01	0.01	0.91	0.14	0.04	0.02	0.95	0.14	2.85	0.43
R Site Rd. (East)	03/21/96	0.9[m]	17[m]	0.01[m]	0.01	0.02	0.01	1.39	0.19	0.07	0.03	1.50	0.21	4.50[m]	0.64
Potrillo Drive	3/96[p]	<0.5	11	0.01[m]	0.01	0.02	0.01	0.68	0.11	0.03	0.02	0.65	0.10	1.95	0.31
S-Site (TA-16)	03/21/96	0.8	10	0.01[m]	0.01	0.02	0.01	1.40	0.20	0.07	0.03	1.45	0.20	4.35[m]	0.61
Near Test Well DT-9	03/21/96	0.8	9.6	0.00	0.02	0.03[m]	0.01	NA		NA		NA		NA	
Mean (+/- 2 SD)		0.656[k] (0.206)	13.7[k] (5.2)	0.004[k] (0.005)		0.02[k] (0.01)								3.21[k] (2.32)	

[a]Radiochemical and Trace Metal Analysis reported on a dry weight basis (i.e. pCi/g dry or mg/kg dry)
[b]Metals were digested following SW-846 Method 3050A and analyzed following Method 6010A. Radioisotopes digested with hydrofloric acid and analyzed by alpha spectroscopy
[c]Total Propagated Uncertainty, reported by Paragon Analytics, Inc. as 2 x sigma
[e]NA indicates analysis not requested (not analyzed)
[f]NMED means +/- 2 standard deviations (SD) are calculated from data presented in this table
[g]Regional Statistical Reference Levels; upper limit background concentration, from Fresquez et. al. (1996a).
[h]SALs; (Los Alamos National Laboratory Screening Action Level) from Fresquez et. al. (1996a).
[k]Means that exceed background averages presented in 1996 ESR as Regional Means +/- 2 SD
[m]Any level, mean or individual measurement, that exceed its RSRL
[n]< indicates not detected at or above the reporting limit. To calculate means, 1/2 reporting limit value used.
[p]Collection date not recorded in field records
[r]NMED Total Uranium data calcuated from Uranium isotopic measurements

Plutonium-238

NMED and LANL plutonium-238 data are presented in Table 2 and plotted in Figure A-1 of the Appendix. Notably, NMED's average counting uncertainty (2σ) is 0.02 pCi/g while LANL's average counting uncertainty (2σ) is 0.002 pCi/g. All NMED plutonium-238 measurements are reported less than or equal to the TPU derived by Paragon. LANL plutonium-238 measurements for the same station samples are also reported less than or equal to the estimated uncertainty for each sample. This indicates that plutonium-238 in NMED and LANL samples are less than levels that the laboratories were able to confidently measure.

Table 2. NMED/LANL Plutonium 238 soil data from 1996 activities

LOCATION	NMED Pu-238 (pCi/g)		LANL Pu-238 (pCi/g)	
	reported value	TPU (2σ)	reported value	uncertainty (2σ)
Near Cochiti	0.00	0.01	0.001	0.002
Bernalillo	0.00	0.01	0.004	0.004
Jemez	0.00	0.01	0.002	0.002
Near TA-8 (GT Site)	0.00	0.01	0.002	0.002
Near TA-49	0.00	0.01	0.000	0.002
TA-21 (DP Site)	0.00	0.02	0.004	0.004
East of TA-53	0.00	0.02	0.002	0.002
West of TA-53	0.00	0.02	0.001	0.002
Two Mile Mesa	0.00	0.05	0.001	0.002
R Site Rd. (East)	0.01	0.01	0.000	0.002
Potrillo Drive	0.01	0.01	0.001	0.002
S-Site (TA-16)	0.01	0.01	0.001	0.002
Near Test Well DT-9	0.00	0.02	0.002	0.002

Total Propagated Uncertainties as reported by Paragon Analytics, Inc.
Uncertainties as reported by LANL's analytical laboratory (CST-9)

Three NMED measurements are greater than the 1996 regional mean (0.002 pCi/g) and the RSRL (0.008 pCi/g), although equal to the uncertainty associated with the measurement. On-site station measurements at R Site Rd. (East), Potrillo Drive, and S-Site (TA-16), are 0.01 pCi/g. LANL measurements of 0.004 pCi/g at Bernalillio and TA-21 (DP Site) are greater than the regional mean but less than the RSRL, and equal to the uncertainty associated with the measurement. Plutonium-238 measurements in this group did not approach the 27 pCi/g SAL.

Descriptive statistics, histograms, and comparative statistical tests for plutonium 238 are presented in Figure A-1 of the Appendix. The histograms show a group of NMED and LANL data around the regional mean and a group of our data that exceeds the RSRL. The bimodal distribution of our data suggests some differences may exist at the sites sampled. NMED data indicate on-site locations R-Site Rd East, Potrillo Drive, and S-Site (TA-16) may have been impacted by Laboratory emissions. These measurements are not greater than their uncertainties nor are they substantiated by LANL measurements. The histograms demonstrate the greater sensitivities achieved by LANL and the relationship of data to the regional mean and RSRL.

Differences in the analytical sensitivities for plutonium-238 measurements may have resulted from varying the alpha spectrometry count duration and/or sample mass. LANL CST-9 counted 10-gram samples for 80,000 seconds while Paragon count time was 60,000 seconds for 2-gram

samples. Increasing the count time and sample mass appears to have increased LANL measuring sensitivity for low-level plutonium-238 measurements by a factor of 10.

Neither the Wilcoxon test nor the paired t-test shows any significant difference between NMED and LANL data. However, the Pearson test indicates that the data sets track poorly, this is likely due to the inability of the analytical methods to distinguish the low concentrations from zero. The average duplicate error ratio (DER) is 0.16. A DER less than 1.42 demonstrates a 95% confidence level the data are approximately equal. The similarity of NMED and LANL plutonium-238 data, the descriptive statistics, and the comparative statistical tests suggest that the measurements taken by LANL are accurate. LANL measurements also show a greater sensitivity to low environmental levels than those achieved by NMED.

In summary, the statistical comparisons of plutonium-238 data show these things:

1. The Wilcoxon test ($p = 0.6712$) and the paired t-test ($p = 0.6159$) indicate the data are not different at the 95% confidence level.
2. The Pearson correlation indicates the data sets track poorly ($r = 0.4290$).

Plutonium-239,240

NMED and LANL plutonium-239,240 data are presented in Table 3 and plotted in Figure A-2 of the Appendix. Notably, NMED's average counting uncertainty (2σ) is 0.01 pCi/g while LANL's average counting uncertainty (2σ) is 0.005 pCi/g. Only half of NMED plutonium -239,240 measurements (7 of 13) are reported greater than their counting uncertainties. All LANL plutonium-239,240 measurements are greater than the estimated uncertainty for each sample.

Seven NMED measurements are greater than the 1996 regional mean (0.010 pCi/g) and one measurement is above the 0.028 pCi/g RSRL. An on-site station, Near Test Well DT-9, is 0.03 pCi/g. Although most of LANL measurements are greater than the regional mean, none of the measurements in this group exceeded the RSRL. Plutonium -239, -240 measurements in this group did not approach the 24 pCi/g SAL.

The descriptive and comparative statistics, and histograms for plutonium-239,240 are presented in Figure A-2 of the Appendix. The histograms show most of the NMED and LANL data distributions around the regional mean, some potential elevated levels below the RSRL, and one measurement above the upper tolerance level for background. The NMED measurement above the RSRL is not substantiated by LANL. The histograms demonstrate the greater sensitivities achieved by LANL and the relationship of data to the regional mean and the RSRL.

Neither the Wilcoxon test nor the paired t-test shows any significant difference between NMED and LANL data. However, the Pearson test indicates that the data sets track poorly, possibly due to the greater analytical sensitivity achieved by LANL laboratories. The average DER is 0.30, demonstrating the data are approximately equal. The similarity of NMED and LANL plutonium-239,240 data, the descriptive statistics and the comparative statistical tests suggest that the measurements taken by LANL are accurate. LANL measurements also show a greater sensitivity to low environmental levels than those achieved by NMED.

Table 3. NMED/LANL plutonium-239,240 soil data from 1996 activities

LOCATION	NMED Pu-239/240 (pCi/g)		LANL Pu-239/240 (pCi/g)	
	reported value	TPU (2σ)	reported value	uncertainty (2σ)
Near Cochiti	0.01	0.01	0.006	0.004
Bernalillo	0.01	0.01	0.005	0.004
Jemez	0.01	0.01	0.012	0.006
Near TA-8 (GT Site)	0.01	0.01	0.025	0.004
Near TA-49	0.02	0.01	0.022	0.004
TA-21 (DP Site)	0.01	0.01	0.015	0.006
East of TA-53	0.02	0.01	0.025	0.006
West of TA-53	0.02	0.01	0.026	0.008
Two Mile Mesa	0.01	0.01	0.017	0.004
R Site Rd. (East)	0.02	0.01	0.012	0.004
Potrillo Drive	0.02	0.01	0.015	0.004
S-Site (TA-16)	0.02	0.01	0.025	0.004
Near Test Well DT-9	0.03	0.01	0.013	0.004

Total Propagated Uncertainties as reported by Paragon Analytics, Inc.
Uncertainties as reported by LANL's analytical laboratory (CST-9)

Differences in the analytical sensitivities for plutonium-239,240 measurements may have resulted from varying the alpha spectrometry count duration and/or sample mass. LANL CST-9 counted 10-gram samples for 80,000 seconds while Paragon count time was 60,000 seconds for 2-gram samples. Increasing the count time and sample mass appears to have increased LANL measuring sensitivity for low-level plutonium-239,240 measurements by a factor of 2.

In summary, the statistical comparisons for plutonium-239,240 show these things:

1. The Wilcoxon test ($p = 0.6848$) and the paired t-test ($p = 0.7821$) indicate that the data are not from different populations at a 95% confidence level.
2. The Pearson correlation ($r = 0.2964$) indicates that the data sets track poorly.

Isotopic Uranium and Total Uranium

NMED and LANL total uranium data are presented in Table 4 and plotted in Figure A-3 of the Appendix. Isotopic uranium measurements and conversions to total uranium are presented in Figure A-4 of the Appendix. In this case, NMED analytical sensitivities are approximately 1.6 times greater than LANL's. All measurements for NMED and LANL are greater than analytical uncertainties (2σ) described by the laboratories.

NMED converted its measurements for species-specific isotopic uranium to those of total uranium for the purposes of comparing the data with LANL. The isotopic measurements,

conversions of each uranium isotope (234, 235, and 238) to a mass figure, and isotopic mass ratios are presented in Figure A-4 of the Appendix.

Almost all perimeter and on-site measurements are above the regional mean (2.32 pCi/g). NMED and LANL measurements at Tsankawi (4.46, 4.36 pCi/g), R-Site Road (4.50, 4.42 pCi/g), and S-Site (4.35, 5.13 pCi/g) are above the 4.05 pCi/g RSRL. All uranium measurements in this group are much smaller than the 29 pCi/g SAL.

The statistics and associated histograms for total uranium are presented in Figure A-3 of the Appendix. The histograms show distributions of NMED and LANL data around two levels: the regional mean and a level that exceeds the RSRL.

The Wilcoxon and paired t-test indicate there is a 95% confidence the data are from different populations. The Pearson test indicates the data track well. The data shows a bias between LANL and NMED data; that is, LANL measurements are consistently higher than NMED's. The mean for LANL data is 3.36 mg/kg while NMED's is 2.94 mg/kg. This bias is further depicted in Figure A-3, by the distribution of differences between NMED and LANL data. The average DER is 0.31, demonstrating the data are approximately equal. Analysis of the data indicates that although there is a bias between the data sets, the magnitude of the differences is very small.

Table 4. NMED/LANL uranium soil data from 1996 activities

LOCATIONS	NMED Total U by calculation mg/kg		LANL Total U by KPA measurement mg/kg	
	calculated value	TPU (2σ)	reported value	uncertainty (2σ)
Near Cochiti	1.32	0.25	1.88	0.38
Bernalillo	2.01	0.31	2.35	0.48
North Mesa	3.11	0.46	3.91	0.78
White Rock (East)	2.46	0.37	2.77	0.56
Tsankawi	4.46	0.61	4.36	0.88
East of TA-53	2.39	0.37	2.49	0.50
Two Mile Mesa	2.85	0.43	3.71	0.74
R Site Rd. (East)	4.50	0.64	4.42	0.88
Potrillo Drive	1.95	0.31	2.62	0.52
S-Site (TA-16)	4.35	2.38	5.13	1.02

Total Propagated Uncertainties as reported by Paragon Analytics, Inc.
Uncertainties as reported by LANL's analytical laboratory (CST-9)
Uranium activity converted to mass measurement

In summary, the statistical comparisons for total uranium show these things:

1. The Wilcoxon test ($p = 0.0136$) and the paired t-test ($p = 0.0128$) indicate the data are from different populations at a 95% confidence level.
2. The Pearson correlation ($r = 0.9476$) indicates the data sets track well.

Lead

NMED and LANL lead data are presented in Table 5 and plotted in Figure A-5 of the Appendix. All but two NMED measurements and three LANL measurements are above the lead 1996 regional mean (9.44 mg/kg). Four NMED measurements are above the 14.40 mg/kg RSRL; two perimeter stations; White Rock (East) and Tsankawi - and two on-site stations; TA-21 (DP Site) and R Site Rd (East) have respective measurements of 18, 17, 25, and 17 mg/kg. Three of those stations have similarly high LANL measurements; White Rock (East), Tsankawi, and TA-21 (DP Site) have respective measurements of 16.05, 15.50, and 38.90 mg/kg. All measurements of lead in this group are much less than the 500 mg/kg SAL.

Table 5. NMED/LANL lead soil data from 1996 activities

LOCATION	NMED Lead (mg/kg)	LANL Lead (mg/kg)
	reported value	reported value
Near Cochiti	9.0	8.32
Jemez	7.5	6.96
North Mesa	13	11.70
Near TA-8 (GT Site)	10	11.50
Near TA-49	14	11.90
White Rock (East)	18	16.05
Tsankawi	17	15.50
TA-21 (DP Site)	25	38.90
East of TA-53	11	10.00
West of TA-53	12	11.10
Two Mile Mesa	14	8.95
R Site Rd. (East)	17	12.00
Potrillo Drive	11	9.32
S-Site (TA-16)	10	9.31
Near Test Well DT-9	9.6	10.10

The descriptive statistics, histograms and the comparative statistical tests for lead are presented in Figure A-5 of the Appendix. The histograms indicate distributions of NMED and LANL data are similar. The range, minimum, maximum, and means of the data sets are also similar. The bimodal nature of the distributions demonstrates that the samples were taken from two distinct sample populations: relatively clean locations with lead measurements around 10 mg/kg and at TA-21 (DP Site), a potentially impacted on-site location.

The paired t-test indicates no difference and the Pearson test shows that the data track well. The Wilcoxon ranked-sum test indicates a difference. The difference appears to be a bias between NMED and LANL data - NMED data is consistently reported higher. The average RPD between LANL and NMED measurements is 16%. A percent difference of less than 25% is acceptable. Although a positive bias exists between NMED and LANL data, the magnitude of difference is small.

In summary, the comparative statistics for lead show these things;

1. The Wilcoxon test ($p = 0.0480$) indicates the data are from different populations.
2. The paired t-test ($p = 0.6939$) indicates the data are not from different populations and the Pearson correlation ($r = 0.8688$) indicates the data sets track well.

Beryllium

NMED and LANL beryllium data are presented in Table 6 and plotted in Figure A-6 of the Appendix. All NMED data are potentially greater than the 1996 regional mean. Two of the 14 NMED measurements are less than the Paragon 0.5 mg/kg detection limit for beryllium. The detection limit is greater than the 0.49 mg/kg regional mean. Ten LANL measurements are greater than the regional mean. NMED results at Tsankawi (0.9 mg/kg) and R Site Rd. (East) (0.9 mg/kg) are greater than the RSRL (0.74 mg/kg) and equal to the SAL (0.9 mg/kg). Additional NMED measurements at S - Site (TA-16) and Near Test Well DT-9 are above the RSRL. Five LANL results are above the RSRL and one of those is above the SAL. The LANL measurement at Tsankawi is 0.906 mg/kg. TA-21 (DP Site), R Site Rd. (East), S-Site (TA-16), and Near Test Well DT-9 measurements are greater than the RSRL at 0.827, 0.869, 0.825, and 0.873 mg/kg respectively.

Table 6. NMED/LANL beryllium soil data from 1996 activities

LOCATION	NMED Beryllium (mg/kg)	LANL Beryllium (mg/kg)
	reported value	reported value
Near Cochiti	0.5	0.43
Jemez	0.6	0.46
North Mesa	0.7	0.65
Near TA-8 (GT Site)	<0.5	0.511
Near TA-49	0.7	0.695
Tsankawi	0.9	0.906
TA-21 (DP Site)	0.7	0.827
East of TA-53	0.5	0.452
West of TA-53	0.7	0.651
Two Mile Mesa	0.6	0.499
R Site Rd. (East)	0.9	0.869
Potrillo Drive	<0.5	0.463
S-Site (TA-16)	0.8	0.825
Near Test Well DT-9	0.8	0.873

Descriptive statistics, histograms, and the comparative statistical tests for beryllium are presented in Figure A-6 of the Appendix. The histograms indicate that the distributions of NMED and LANL data are similar. The range, minimum, maximum, and means of the data sets are also similar. A bimodal distribution is difficult to determine and a distinction between non-impacted and impacted areas is not conclusive.

All comparative statistics tests: the Wilcoxon ranked-sum test, the paired t-test, and the Pearson test, indicate there are no differences between the data sets and that the data track well. The average RPD is 18%, which is within the 25 % acceptance criteria. This parameter implies that the data are readily reproducible between the analytical laboratories.

In summary, the comparative statistics for beryllium show these things;

1. Both the Wilcoxon test ($p = 0.4130$) and the paired t-test ($p = 0.7547$) indicate the data are not from different populations.
2. The Pearson correlation indicates the data sets track well ($r = 0.9204$).

Summary Comparison

A summary test of all data for 1996 is tabulated and the data differences are graphed in Figure A-7. Table 7 includes all NMED and LANL data, presented side by side for comparison. A more robust statistical test can be achieved by increasing sample size (number of comparisons). In this case, the sample size is increased to a total of 65 samples overall. The Wilcoxon, t-test, and Pearson tests were run on the two data sets. For the t-test, the data for each analyte were normalized (mean = 0, standard deviation = 1). For the Wilcoxon and Pearson tests, the raw (not normalized) data were used. The tests indicate the data are not different and track well.

The statistical tests for the summary data show these things:

1. Both the Wilcoxon test ($p = 0.4579$) and the paired t-test ($p = 0.4461$) indicate the data are not from different populations at a 95% confidence level.

2. The Pearson correlation indicates that the data sets track well ($r = 0.9455$).

CONCLUSIONS

To evaluate the validity of LANL's soil sampling results for 1996, we reviewed the Laboratory's sample collection protocols and chemical analytical methods. We then independently analyzed duplicate samples from 16 locations for selected parameters, evaluated the data quality, and statistically compared the analytical results to LANL's. The reviews, analytical results, and statistical comparisons support the following conclusions:

1. The LANL plutonium-238 data are consistent with NMED data and are accurate. Their measurements have a greater sensitivity to the low levels of plutonium-238 found in environmental media.

2. The LANL data for plutonium-239,240 are consistent with NMED data and are accurate. CST-9 analytical sensitivity to low levels of plutonium-239,240 found in the environment is greater than that achieved by the analytical laboratory used by NMED.

3. Total uranium measurements by LANL and NMED are inconsistent. The data comparison indicates that LANL uranium measurements are accurate although they are slightly higher than NMED's. Our uranium measurements demonstrated a greater analytical sensitivity.

4. Lead measurements by LANL and NMED are inconsistent. The data comparison indicates that LANL lead measurements are accurate although slightly lower than NMED's. This difference is within analytical acceptance criteria.

5. The LANL beryllium data are consistent with NMED data and are accurate. NMED beryllium results at Tsankawi (0.9 mg/kg) and R Site Rd. (East) (0.9 mg/kg) are equal to the health risk SAL (0.9 mg/kg). The LANL measurement at Tsankawi is 0.906 mg/kg. These measurements probably reflect naturally occurring levels of beryllium.

6. With the exception of beryllium, all sample measurements reported in this study are 10 to 1000 times less than their respective SALs.

ACKNOWLEDGMENTS

Figures 1 and 2, Regional locations and Sample locations were digitized by Alice Meyer from U.S.G.S. 7.5' quadrangles and sample location coordinates were from the 1995 ESR. Thanks to Tim Michael for his editing efforts and to William Stone, David Beach, and David Bagget for their review and comments. LANL ESH-20 personnel, particularly Philip Fresquez and Louie Naranjo, made this report possible by their coordination efforts and technical help during the 1996 sampling season.

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APPENDIX
STATISTICAL AND ANALYTICAL DATA

Figure A-1. Statistical Comparisons of NMED/LANL Plutonium-238 in Soils

Figure A-2. Statistical Comparisons of NMED/LANL Plutonium-239,240 in Soils

Figure A-3. Statistical Comparisons of NMED/LANL Uranium in Soils

Figure A-4. Isotopic Uranium Conversions to Total Mass

Figure A-5. Statistical Comparisons of NMED/LANL Lead in Soils

Figure A-6. Statistical Comparisons of NMED/LANL Beryllium in Soils

Figure A-7. Statistical Comparisons of NMED/LANL Summary data

Figure A-8. Duplicate Error Ratio, Relative Percent Difference, and Uranium Activity to Mass Calculation Examples

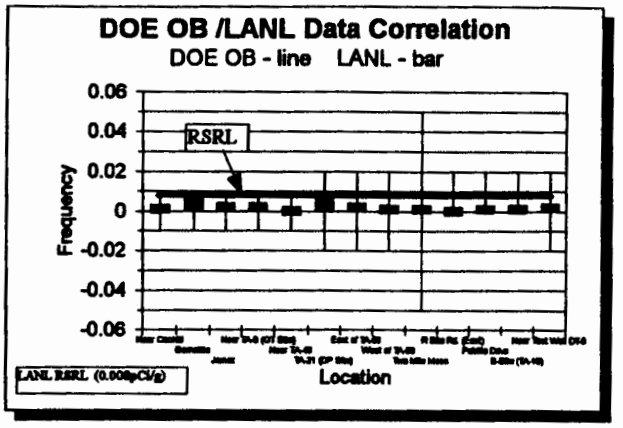
Figure A-9. NMED/LANL radiochemical and trace metal analysis of soils from the LANL area during 1996

LOCATION	DOE OB Pu-238 (pCi/g)		LANL Pu-238 (pCi/g)		DER[3]
	reported value	uncertainty[1] 2σ	reported value	uncertainty[2] 2σ	
Near Cochiti	0.00	0.01	0.001	0.002	0.05
Bernalillo	0.00	0.01	0.004	0.004	0.19
Jemez	0.00	0.01	0.002	0.002	0.10
Near TA-8 (GT Site)	0.00	0.01	0.002	0.002	0.10
Near TA-49	0.00	0.01	0.000	0.002	0.00
TA-21 (DP Site)	0.00	0.02	0.004	0.004	0.10
East of TA-53	0.00	0.02	0.002	0.002	0.05
West of TA-53	0.00	0.02	0.001	0.002	0.02
Two Mile Mesa	0.00	0.05	0.001	0.002	0.01
R Site Rd. (East)	0.01	0.01	0.000	0.002	0.49
Potrillo Drive	0.01	0.01	0.001	0.002	0.44
S-Site (TA-16)	0.01	0.01	0.001	0.002	0.44
Near Test Well DT-8	0.00	0.02	0.002	0.002	0.05

[1]Uncertainties as reported by Paragon Analytical Laboratory

[2] Uncertainties as reported by LANL's analytical laboratory (CST-9)

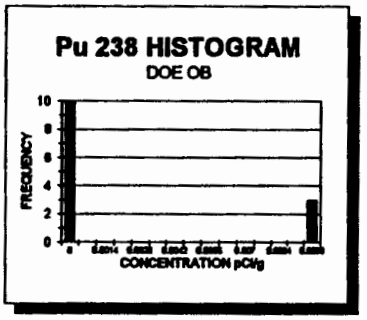
[3]DER = Duplicate Error Ratio, value less than 1.42 indicates duplicate values approximately equal at 95% confidence level



DESCRIPTIVE STATISTICS

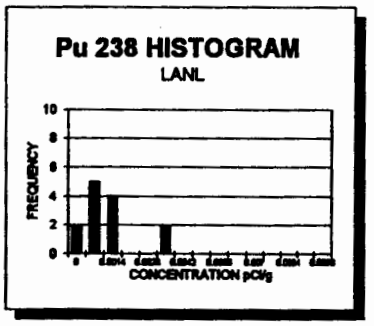
DOE OB

Mean	0.00
Median	0.00
Standard Deviation	0.00
Variance	0.00
Kurtosis	0.09
Skewness	1.45
Range	0.01
Minimum	0.00
Maximum	0.01



LANL

Mean	0.002
Median	0.001
Standard Deviation	0.001
Variance	0.000
Kurtosis	0.388
Skewness	0.672
Range	0.004
Minimum	0.000
Maximum	0.004



Statistical Comparison of Data Sets

Results:

Wilcoxon:	n=12	P=0.6712	(32.88% confident that data sets are from different populations)
t-Test:	n=13	P=0.6159	(38.41% confident that data sets are from different populations)
Pearson:	n=13	r=-0.4290	(data sets do not track)

X	Y	X-Y	|X-Y|	Rank	*Bin*	*Frequency*
0.00	0.001	-0.001	0.001	2	-0.010	0
0.00	0.004	-0.004	0.004	8.5	-0.008	0
0.00	0.002	-0.002	0.002	5.5	-0.006	0
0.00	0.002	-0.002	0.002	5.5	-0.005	2
0.00	0.004	-0.004	0.004	8.5	-0.003	7
0.00	0.002	-0.002	0.002	5.5	-0.001	0
0.00	0.001	-0.001	0.001	2	0.001	0
0.00	0.001	-0.001	0.001	2	0.003	0
0.01	0.000	0.01	0.01	12	0.005	0
0.01	0.001	0.009	0.009	10.5	0.006	0
0.01	0.001	0.009	0.009	10.5	0.008	3
0.00	0.002	-0.002	0.002	5.5		

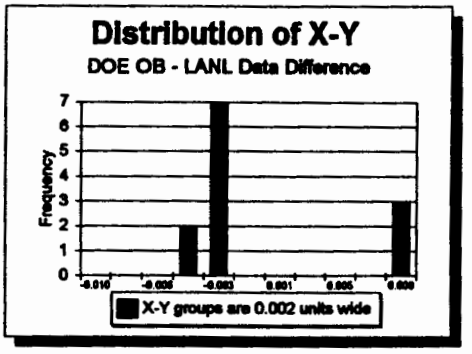


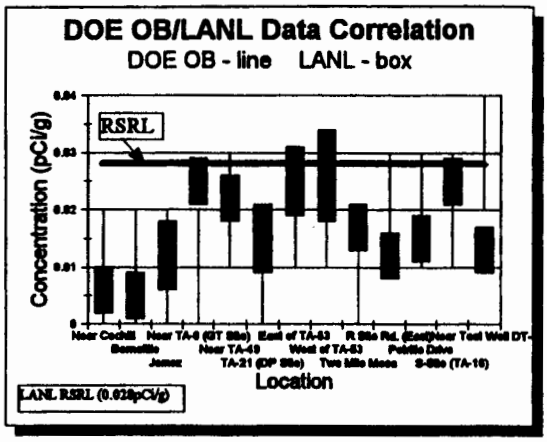
Figure A-1. Statistical comparisons of NMED/LANL 1996 plutonium-238 data for soils

LOCATION	DOE OB Pu-239/240 (pCi/g)		LANL Pu-239/240 (pCi/g)		DER[3]
	reported value	uncertainty[1] 2σ	reported value	uncertainty[2] 2σ	
Near Cochiti	0.01	0.01	0.006	0.004	0.19
Bernalillo	0.01	0.01	0.005	0.004	0.23
Jemez	0.01	0.01	0.012	0.006	0.09
Near TA-8 (GT Site)	0.01	0.01	0.025	0.004	0.70
Near TA-49	0.02	0.01	0.022	0.004	0.09
TA-21 (DP Site)	0.01	0.01	0.015	0.006	0.21
East of TA-53	0.02	0.01	0.025	0.006	0.21
West of TA-53	0.02	0.01	0.026	0.006	0.23
Two Mile Mesa	0.01	0.01	0.017	0.004	0.32
R Site Rd. (East)	0.02	0.01	0.012	0.004	0.37
Potrillo Drive	0.02	0.01	0.015	0.004	0.23
S-Site (TA-16)	0.02	0.01	0.025	0.004	0.23
Near Test Well DT-9	0.03	0.01	0.013	0.004	0.79

[1]Uncertainties as reported by Paragon Analytical Laboratory

[2] Uncertainties as reported by LANL's analytical laboratory (CST-9)

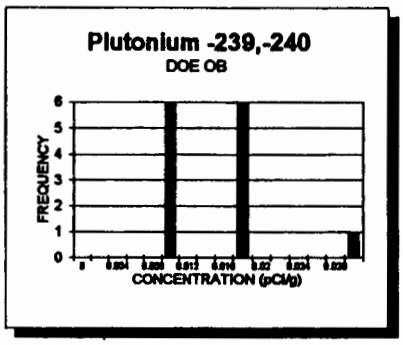
[3]DER = Duplicate Error Ratio, value less than 1.42 indicates duplicate values approximately equal at 95% confidence level



Descriptive Statistics

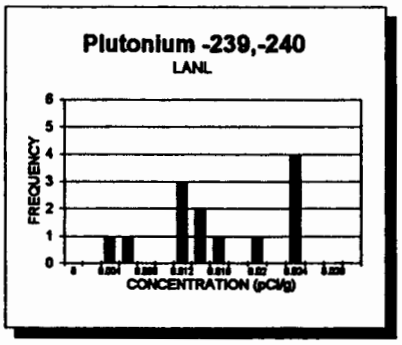
DOE OB

Mean	0.02
Median	0.02
Standard Deviation	0.01
Variance	0.00
Kurtosis	-0.33
Skewness	0.57
Range	0.02
Minimum	0.01
Maximum	0.03



LANL

Mean	0.019
Median	0.016
Standard Deviation	0.006
Variance	0.000
Kurtosis	-2.059
Skewness	0.418
Range	0.014
Minimum	0.012
Maximum	0.026



Statistical Comparison of Data Sets

Results:

Wilcoxon:	n=13	P=0.6848	(31.52% confident that data sets are from different populations)
t-Test:	n=13	P=0.7821	(21.79% confident that data sets are from different populations)
Pearson:	n=13	r=0.2964	(data sets do not track)

X	Y	X-Y	|X-Y|	Rank	*Bin*	*Frequency*
0.01	0.006	0.004	0.004	3	-0.017	1
0.01	0.005	0.005	0.005	5	-0.014	0
0.01	0.012	-0.002	0.002	2	-0.011	0
0.01	0.025	-0.015	0.015	12	-0.008	0
0.02	0.022	-0.002	0.002	1	-0.005	0
0.01	0.015	-0.005	0.005	4	-0.002	9
0.02	0.025	-0.005	0.005	7	0.002	0
0.02	0.026	-0.006	0.006	9	0.005	0
0.01	0.017	-0.007	0.007	10	0.008	0
0.02	0.012	0.008	0.008	11	0.011	0
0.02	0.015	0.005	0.005	7	0.014	0
0.02	0.025	-0.005	0.005	7		
0.03	0.013	0.017	0.017	13	-0.017	

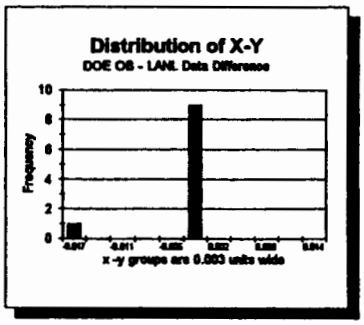


Figure A-2. Statistical comparisons of NMED/LANL 1996 plutonium-239, -240 data for soils

LOCATIONS	DOE OB Total U by calculation[1] mg/kg		LANL Total U by KPA measurement mg/kg		DER[4]
	calculated value	uncertainty[2] 2σ	reported value	uncertainty[3] 2σ	
Near Cochiti	1.32	0.25	1.88	0.38	0.61
Bernalillo	2.01	0.31	2.35	0.48	0.30
North Mesa	3.11	0.46	3.91	0.78	0.44
White Rock (East)	2.46	0.37	2.77	0.56	0.23
Tsankawi	4.46	0.61	4.36	0.88	0.05
East of TA-53	2.39	0.37	2.49	0.50	0.08
Two Mile Mesa	2.85	0.43	3.71	0.74	0.50
R Site Rd. (East)	4.50	0.64	4.42	0.88	0.04
Potrillo Drive	1.95	0.31	2.62	0.52	0.55
S-Site (TA-16)	4.35	0.61	5.13	1.02	0.33

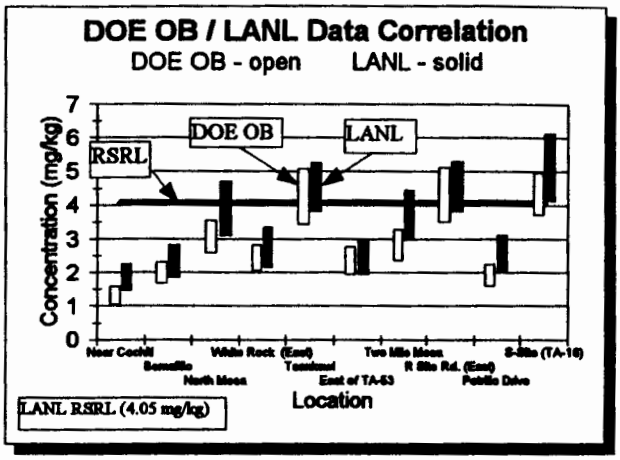
[1] Total Uranium concentration derived from Paragon Analytics, Inc. reported values of specific activities and, activity to mass calculations

[2] Uncertainties as reported by Paragon analytical laboratory and converted to mass

[3] Uncertainties as reported by LANL's analytical laboratory (CST-8)

[4] DER = Duplicate Error Ratio, value less than 1.42 indicates duplicate values approximately equal at 95% confidence level

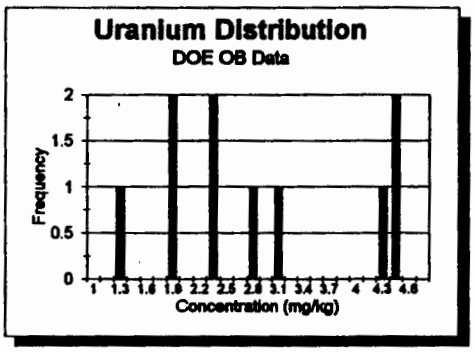
[5] RPD = Relative Percent Difference, used when reported value exceeds 10 x uncertainty, value less than 25 within acceptance criteria



Descriptive Statistics

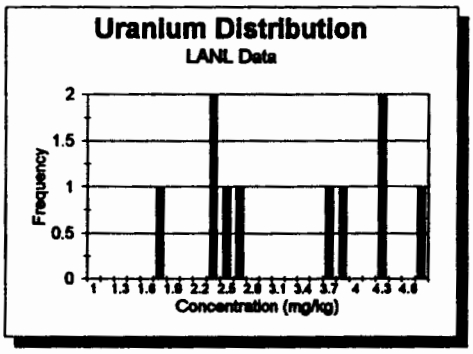
DOE OB

Mean	2.94
Median	2.85
Standard Deviation	1.14
Variance	1.31
Kurtosis	-1.28
Skewness	0.36
Range	3.17
Minimum	1.32
Maximum	4.50



LANL

Mean	3.36
Median	3.24
Standard Deviation	1.08
Variance	1.17
Kurtosis	-1.32
Skewness	0.25
Range	3.25
Minimum	1.88
Maximum	5.13



Statistical Comparison of Data Sets

Results:

Wilcoxon:	n=10	P=0.0136	(98.64% confident that data sets are from different populations)
t-Test:	n=10	P=0.0128	(98.72% confident that data sets are from different populations)
Pearson:	n=10	r=0.9476	(data sets do track)

X	Y	X -Y	|X -Y|	Rank	*Bin*	*Frequency*
1.32	1.88	-0.557	0.557	6	-0.86	3
2.01	2.35	-0.342	0.342	5	-0.71	2
3.11	3.91	-0.801	0.801	9	-0.55	0
2.46	2.77	-0.306	0.306	4	-0.39	2
4.46	4.36	0.103	0.103	3	-0.24	1
2.39	2.49	-0.095	0.095	2	-0.08	1
2.85	3.71	-0.864	0.864	10	0.08	1
4.50	4.42	0.077	0.077	1	0.24	0
1.95	2.62	-0.671	0.671	7	0.39	0
4.35	5.13	-0.782	0.782	8	0.55	0
					0.71	0

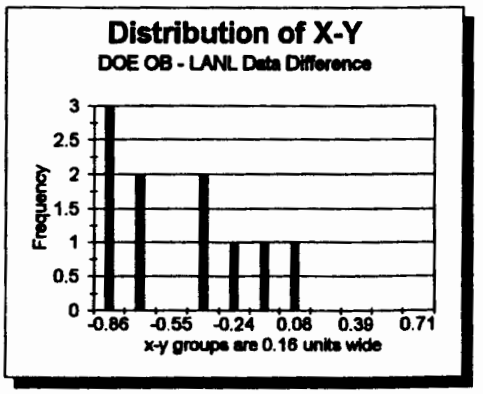


Figure A-3. Statistical comparisons of NMED/LANL 1996 total uranium data for soils

Isotopic Analysis

LOCATION	U 234 (pCi/g)	U-235 (pCi/g)	U-238 (pCi/g)
Near Cochiti	0.44 +/- 0.08	0.03 +/- 0.02	0.44 +/- 0.08
Bernalillo	0.56 +/- 0.09	0.03 +/- 0.02	0.67 +/- 0.10
North Mesa	0.95 +/- 0.14	0.03 +/- 0.02	1.04 +/- 0.15
White Rock (East)	0.87 +/- 0.13	0.05 +/- 0.02	0.82 +/- 0.12
Tsankawi	1.37 +/- 0.19	0.06 +/- 0.03	1.49 +/- 0.20
East of TA-53	0.68 +/- 0.11	0.03 +/- 0.02	0.80 +/- 0.12
Two Mile Mesa	0.91 +/- 0.14	0.04 +/- 0.02	0.95 +/- 0.14
R Site Rd. (East)	1.39 +/- 0.19	0.07 +/- 0.03	1.50 +/- 0.21
Potrillo Drive	0.68 +/- 0.11	0.03 +/- 0.02	0.65 +/- 0.10
S-Site (TA-16)	1.40 +/- 0.20	0.07 +/- 0.03	1.45 +/- 0.20

From "The Health Physics and Radiological Health Handbook," by B. Shleien

	Half Life (yr)	Specific Activity (Ci/g)
U-234	244,500	6.25E-03
U-235	7.04E+08	2.16E-06
U-238	4.47E+09	3.36E-07

	ABUNDANCE (%)		
	U-234	U-235	U-238
U Natural	0.005	0.72	99.276
U Enriched	0.957	93.29	5.61
U Depleted	0.0005	0.25	99.75

Uranium Activity Converted to Mass Calculations

LOCATION	U-234 (mg/kg)	U-235 (mg/kg)	U-238 (mg/kg)	Total U (mg/kg)
Near Cochiti	7.04E-05	1.39E-02	1.31E+00	1.32 +/- 0.25
Bernalillo	8.96E-05	1.39E-02	1.99E+00	2.01 +/- 0.31
North Mesa	1.52E-04	1.39E-02	3.10E+00	3.11 +/- 0.46
White Rock (East)	1.39E-04	2.31E-02	2.44E+00	2.46 +/- 0.37
Tsankawi	2.19E-04	2.78E-02	4.43E+00	4.46 +/- 0.61
East of TA-53	1.09E-04	1.39E-02	2.38E+00	2.39 +/- 0.37
Two Mile Mesa	1.46E-04	1.85E-02	2.83E+00	2.85 +/- 0.43
R Site Rd. (East)	2.22E-04	3.24E-02	4.46E+00	4.50 +/- 0.64
Potrillo Drive	1.09E-04	1.39E-02	1.93E+00	1.95 +/- 0.31
S-Site (TA-16)	2.24E-04	3.24E-02	4.32E+00	4.35 +/- 0.61

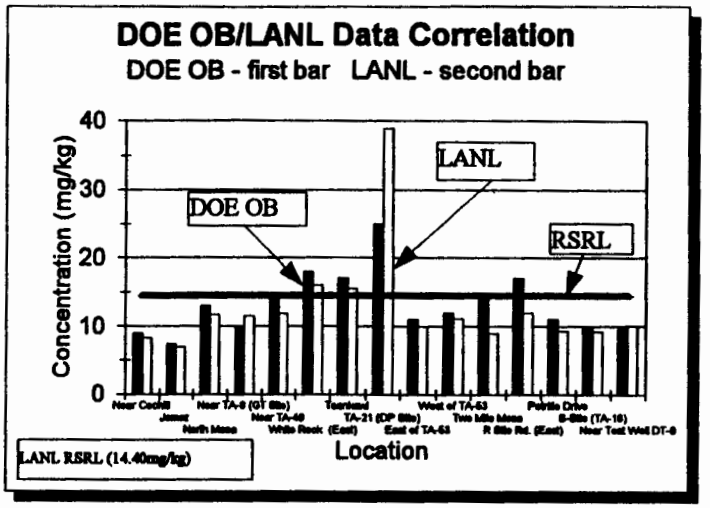
Percentages of Isotopic Mass

	% U-234 mass	% U-235 mass	% U-238 mass
	0.005	0.45	99.548
	0.005	0.62	99.373
	0.006	0.94	99.055
	0.006	0.77	99.222
	0.004	0.69	99.304
	0.005	1.05	98.945
	0.005	0.72	99.274
	0.005	0.75	99.250
	0.005	0.65	99.344
	0.006	0.71	99.282
mean	0.005	0.74	99.260
U Natural	0.005	0.72	99.276
U Enriched	0.957	93.29	5.61
U Depleted	0.0005	0.25	99.75

Figure A-4. Isotopic uranium conversions to total mass and uranium signature

LOCATION	DOE OB Lead (mg/kg) reported value	LANL Lead (mg/kg) reported value	RPD[1]
Near Cochiti	9.0	8.32	8
Jemez	7.5	6.96	7
North Mesa	13	11.70	11
Near TA-8 (GT Site)	10	11.50	14
Near TA-49	14	11.90	16
White Rock (East)	18	16.05	11
Tsankawi	17	15.50	9
TA-21 (DP Site)	25	38.90	44
East of TA-53	11	10.00	10
West of TA-53	12	11.10	8
Two Mile Mesa	14	8.95	44
R Site Rd. (East)	17	12.00	34
Potrillo Drive	11	9.32	17
S-Site (TA-16)	10	9.31	7
Near Test Well DT-9	9.6	10.10	5

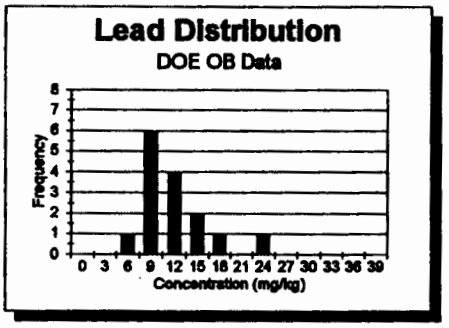
[1] RPD = Relative Percent Difference, value less than 25% indicates duplicate values within acceptance criteria



Descriptive Statistics

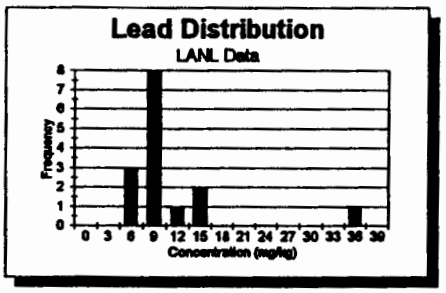
DOE OB

Mean	13
Median	12
Standard Deviation	5
Variance	21
Kurtosis	2
Skewness	1
Range	18
Minimum	8
Maximum	25



LANL

Mean	12.77
Median	11.10
Standard Deviation	7.63
Variance	58.19
Kurtosis	11.42
Skewness	3.23
Range	31.94
Minimum	6.96
Maximum	38.90



Statistical Comparison of Data Sets

Results:

Wilcoxon:	n=15	P=0.0480	(95.20% confident that data sets are from different populations)
t-Test:	n=15	P=0.6939	(30.61% confident that data sets are from different populations)
Pearson:	n=15	r=0.8688	(data sets do track)

X	Y	X -Y	[X -Y]	Rank	*Bin*	*Frequency*
9.0	8.32	0.68	0.68	3	-14	1
7.5	6.96	0.54	0.54	2	-11	0
13	11.70	1.3	1.3	7	-9	0
10	11.50	-1.5	1.5	8.5	-6	0
14	11.90	2.1	2.1	12	-4	1
18	16.05	1.95	1.95	11	-1	6
17	15.50	1.5	1.5	8.5	1	5
25	38.90	-13.9	13.9	15	4	2
11	10.00	1	1	6	6	0
12	11.10	0.9	0.9	5	9	0
14	8.95	5.05	5.05	14	11	0
17	12.00	5	5	13		
11	9.32	1.68	1.68	10		
10	9.31	0.69	0.69	4		
9.6	10.10	-0.5	0.5	1		

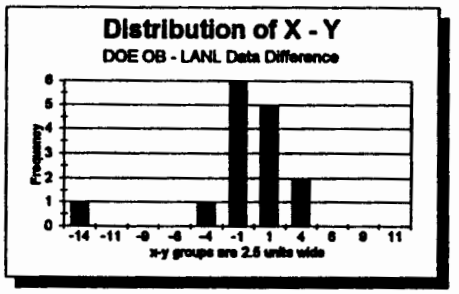
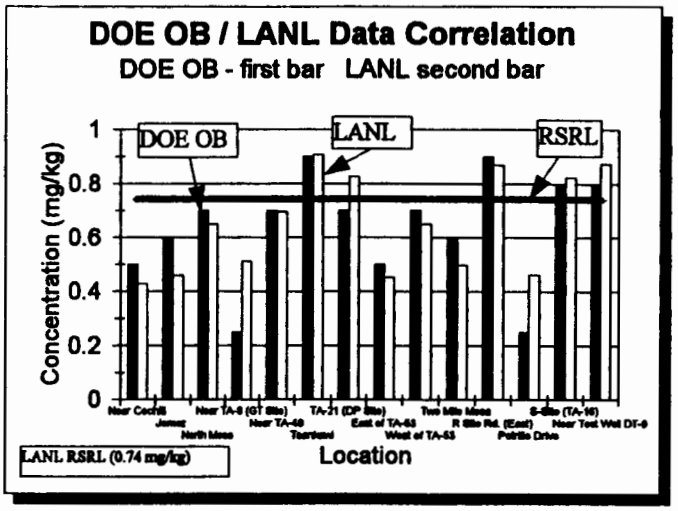


Figure A- 5. Statistical comparisons of NMED/LANL 1996 lead data for soils

LOCATION	DOE OB Beryllium (mg/kg) reported value	LANL Beryllium (mg/kg) reported value	RPD[1]
Near Cochiti	0.5	0.43	15
Jemez	0.6	0.46	26
North Mesa	0.7	0.65	7
Near TA-8 (GT Site)	0.25	0.511	69
Near TA-49	0.7	0.695	1
Tsankawi	0.9	0.906	1
TA-21 (DP Site)	0.7	0.827	17
East of TA-53	0.5	0.452	10
West of TA-53	0.7	0.651	7
Two Mile Mesa	0.6	0.499	18
R Site Rd. (East)	0.9	0.869	4
Potrillo Drive	0.25	0.463	60
S-Site (TA-16)	0.8	0.825	3
Near Test Well DT-9	0.8	0.873	9

[1] RPD = Relative Percent Difference, value less than 25% indicates duplicate values within acceptance criteria

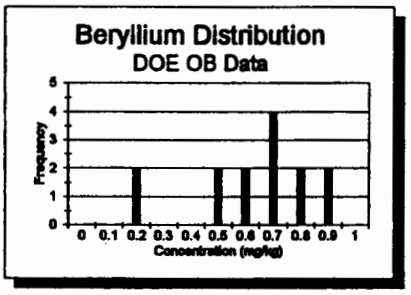
[2] 1/2 detection values used in graphs



Discriptive Statistics

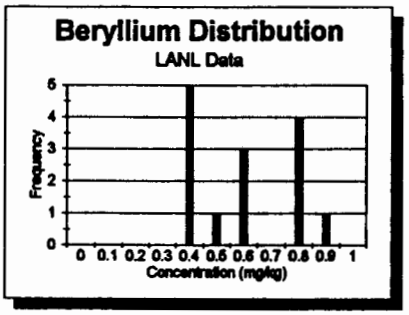
DOE OB

Mean	0.64
Median	0.70
Standard Deviation	0.21
Variance	0.04
Kurtosis	0.04
Skewness	-0.76
Range	0.65
Minimum	0.25
Maximum	0.90



LANL

Mean	0.65
Median	0.65
Standard Deviation	0.18
Variance	0.03
Kurtosis	-1.78
Skewness	0.16
Range	0.48
Minimum	0.43
Maximum	0.91



Statistical Comparison of Data Sets

Results:

Wilcoxon:	n=11	P=0.4130	(58.70% confident that data sets are from different populations)
t-Test:	n=14	P=0.7547	(24.53% confident that data sets are from different populations)
Pearson:	n=14	r=0.9204	(data sets do track)

X	Y	X -Y	|X -Y|	Rank	*Bin*	*Frequency*
0.6	0.46	0.14	0.14	11	-0.14	1
0.7	0.65	0.05	0.05	7	-0.11	0
0.7	0.695	0.005	0.005	1	-0.09	1
0.9	0.906	-0.006	0.006	2	-0.06	0
0.7	0.827	-0.127	0.127	10	-0.04	1
0.5	0.452	0.048	0.048	5	-0.01	2
0.7	0.651	0.049	0.049	6	0.01	1
0.6	0.499	0.101	0.101	9	0.04	3
0.9	0.869	0.031	0.031	4	0.06	0
0.8	0.825	-0.025	0.025	3	0.09	1
0.8	0.873	-0.073	0.073	8	0.11	1

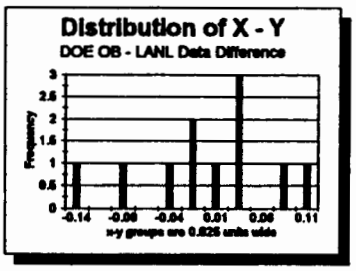


Figure A-6. Statistical comparison of DOE OB/LANL 1996 berylium data for soils

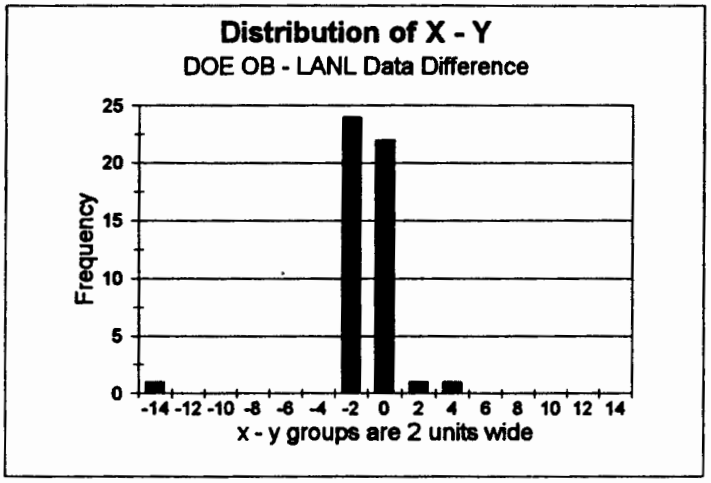
		NMED	Normalized	LANL	Normalized
1	Beryllium	0.5	-0.66	0.43	-1.221
2		0.6	-0.18	0.46	-1.055
3		0.7	0.31	0.65	-0.006
4		0.25	-1.88	0.511	-0.773
5		0.7	0.31	0.695	0.243
6		0.9	1.29	0.906	1.409
7		0.7	0.31	0.827	0.972
8		0.5	-0.66	0.452	-1.099
9		0.7	0.31	0.651	0.000
10		0.6	-0.18	0.499	-0.840
11		0.9	1.29	0.869	1.204
12		0.25	-1.88	0.463	-1.039
13		0.8	0.80	0.825	0.961
14		0.8	0.80	0.873	1.227
15	Lead	9.0	-0.93	8.32	-0.584
16		7.5	-1.26	6.96	-0.762
17		13	-0.05	11.70	-0.141
18		10	-0.71	11.50	-0.167
19		14	0.18	11.90	-0.115
20		18	1.06	16.05	0.429
21		17	0.84	15.50	0.357
22		25	2.60	38.90	3.425
23		11	-0.49	10.00	-0.364
24		12	-0.27	11.10	-0.219
25		14	0.18	8.95	-0.501
26		17	0.84	12.00	-0.101
27		11	-0.49	9.32	-0.453
28		10	-0.71	9.31	-0.454
29		9.6	-0.80	10.10	-0.351
30	Pu-238	0.00	-0.50	0.001	-1.000
31		0.00	-0.50	0.004	2.000
32		0.00	-0.50	0.002	0.000
33		0.00	-0.50	0.002	0.000
34		0.00	-0.50	0.000	-2.000
35		0.00	-0.50	0.004	2.000
36		0.00	-0.50	0.002	0.000
37		0.00	-0.50	0.001	-1.000
38		0.00	-0.50	0.001	-1.000
39		0.01	2.00	0.000	-2.000
40		0.01	2.00	0.001	-1.000
41		0.01	2.00	0.001	-1.000
42		0.00	-0.50	0.002	0.000
43	Pu-239/240	0.01	-0.86	0.006	-1.571
44		0.01	-0.86	0.005	-1.714
45		0.01	-0.86	0.012	-0.714
46		0.01	-0.86	0.025	1.143
47		0.02	0.57	0.022	0.714
48		0.01	-0.86	0.015	-0.286
49		0.02	0.57	0.025	1.143
50		0.02	0.57	0.026	1.286
51		0.01	-0.86	0.017	0.000
52		0.02	0.57	0.012	-0.714
53		0.02	0.57	0.015	-0.286
54		0.02	0.57	0.025	1.143
55		0.03	2.00	0.013	-0.571
56	Total U	1.32	-1.41	1.88	-1.372
57		2.01	-0.82	2.35	-0.937
58		3.11	0.15	3.91	0.505
59		2.46	-0.42	2.77	-0.549
60		4.46	1.33	4.36	0.921
61		2.39	-0.48	2.49	-0.808
62		2.85	-0.08	3.71	0.320
63		4.50	1.36	4.42	0.976
64		1.95	-0.87	2.62	-0.688
65		4.35	1.23	5.13	1.632
	Mean	3.64		3.61	
	Median	0.70		0.70	
	Standard Deviation	5.79		6.31	
	Minimum	0.00		0.00	
	Maximum	25.00		38.90	

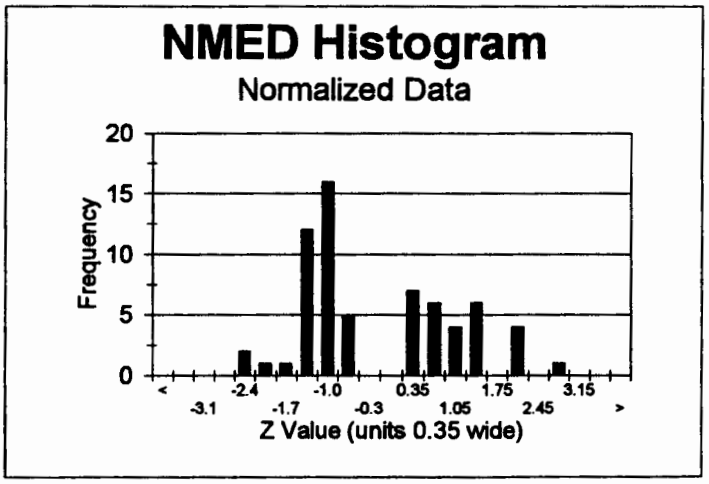
Table A-7. Statistical evaluation of summary data

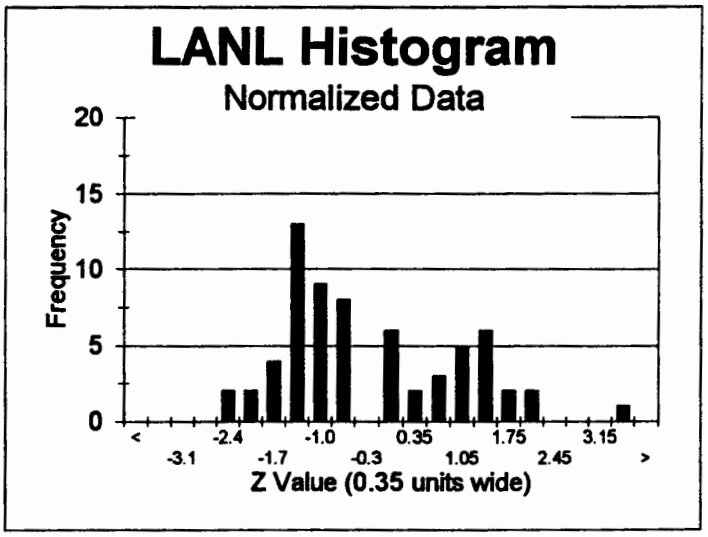
Normalized data calculation = (reported value - mean) / standard deviation

Results:

Wilcoxon:	n=65	P=0.4579	(54.21% confident that data sets are from different populations)
t-Test: (normalized)	n=65	P=0.4461	(55.39% confident that data sets are from different populations)
Pearson:	n=65	r=0.9455	(data sets do track)







Quality control equations used to calculate differences between Los Alamos National Laboratory and NMED soil sample measurements

$$\text{Duplicate Error Ratio} = \frac{|\text{Sample result} - \text{Duplicate result}|}{2 * \sqrt{\text{sample uncertainty}^2 + \text{duplicate uncertainty}^2}}$$

Duplicate error ratio (DER) calculations are used when the reported sample values are less than 10 times one σ uncertainty. DER values less than or equal to 1.42 demonstrate the differences are within an acceptable level.

$$\text{Relative Percent Difference} = \frac{|\text{Sample result} - \text{Duplicate result}|}{\frac{\text{Sample Result} + \text{Duplicate result}}{2}} * 100$$

Relative Percent Difference (RPD) calculations are used when the reported sample values are greater than 10 times one σ uncertainty. RPD values less than 25% demonstrate the differences are within an acceptable level.

LOCATIONS	Total U by calculation		Total U by KPA measurement		DER	RPD
	mg/kg calculated value	uncertainty σ	mg/kg reported value	uncertainty σ		
Near Cochiti	1.32	0.125	1.88	0.19	0.61	35

DER and RPD were calculated for uranium measurements because the reported values were close to 10 times σ. In the case of the sample at Near Cochiti the RPD indicates the sample difference is unacceptable and the DER indicates an acceptable difference.

Isotopic uranium activity to mass conversion for Near Cochiti sample

$$\text{U234} \quad \frac{0.44 * 10^{-12}\,\text{Ci/g}}{6.25 * 10^{-3}\,\text{Ci/g}} = 7.04 * 10^{-5}\,\frac{\text{mg}}{\text{kg}}$$

$$\text{U235} \quad \frac{0.03 * 10^{-12}\,\text{Ci/g}}{2.16 * 10^{-6}\,Ci/g} = 1.39 * 10^{-2}\,\frac{\text{mg}}{\text{kg}}$$

$$\text{U238} \quad \frac{0.44 * 10^{-12}\,\text{Ci/g}}{3.35 * 10^{-7}\,\text{Ci/g}} = 1.31 * 10^{0}\,\frac{\text{mg}}{\text{kg}}$$

$$\text{Total uranium in mass} = 1.32\,\frac{\text{mg}}{\text{kg}}$$

Figure A-8. Duplicate Error Ratio, Relative Percent Difference, and Uranium Activity to Mass Calculation Example

LOCATION	Date Collected	NMED Beryllium (mg/kg)	LANL Beryllium (mg/kg)	NMED Lead (mg/kg)	LANL Lead (mg/kg)	NMED Pu-238 (pCi/g)	NMED counting uncertainties[c] 2σ	LANL Pu-238 (pCi/g)	LANL counting uncertainties[d] 2σ	NMED Pu-239/240 (pCi/g)	NMED counting uncertainties 2σ	LANL Pu-239/240 (pCi/g)	LANL counting uncertainties 2σ
REGIONAL													
Near Cochiti	03/25/96	0.5	0.43	9.0	8.32	0.00	0.01	0.001	0.002	0.01	0.01	0.006	0.004
Bernalillo	03/25/96	NA[e]	0.55	NA	10.90	0.00	0.01	0.004	0.004	0.01	0.01	0.005	0.004
Jemez	03/25/96	0.6	0.46	7.5	8.96	0.00	0.01	0.002	0.002	0.01	0.01	0.012	0.006
Mean (+/- 2 SD)[f]		0.55[k] (0.07)	0.49 (0.28)	8.25 (1.06)	9.44 (5.42)	0.00 (0.00)		0.002 (0.002)		0.01(0.00)		0.010 (0.009)	
RSRL[g]			0.74		14.4			0.008				0.028	
SAL[h]			0.9		500			27				24	
PERIMETER													
North Mesa	03/20/96	0.7	0.65	13	11.70	NA		0.002	0.002	NA		0.026	0.004
Near TA-8 (GT Site)	03/21/96	<0.5[i]	0.511	10	11.50	0.00	0.01	0.002	0.002	0.01	0.01	0.025	0.004
Near TA-49	03/21/96	0.7	0.695	14	11.90	0.00	0.01	0.000	0.002	0.02	0.01	0.022	0.004
White Rock (East)	03/20/96	NA	1.100[m]	18[m]	16.05[m]	NA		0.001	0.002	NA		0.007	0.002
Tsankawi	03/20/96	0.9[m]	0.906[m]	17[m]	15.5[m]	NA		0.001	0.002	NA		0.009	0.002
Mean (+/- 2 SD)		0.636[k] (0.275)	0.869[k] (0.409)	14.4[k] (1.4)	13.31[k] (9.20)	0.00 (0.00)		0.002 (0.002)		0.015[k] (0.007)		0.048[m] (0.162)	
ON-SITE													
TA-21 (DP Site)	03/20/96	0.7	0.827[m]	25[m]	38.9[m]	0.00	0.02	0.004	0.004	0.01	0.01	0.015	0.006
East of TA-53	03/20/96	0.5	0.452	11	10.00	0.00	0.02	0.002	0.002	0.02	0.01	0.025	0.006
West of TA-53	03/20/96	0.7	0.651	12	11.10	0.00	0.02	0.001	0.002	0.02	0.01	0.026	0.006
Two Mile Mesa	03/21/96	0.6	0.499	14	8.95	0.00	0.05	0.001	0.002	0.01	0.01	0.017	0.004
R Site Rd. (East)	03/21/96	0.9[m]	0.869[m]	17[m]	12.00	0.01[m]	0.01	0.000	0.002	0.02	0.01	0.012	0.004
Potrillo Drive	3/96[p]	<0.5	0.463	11	9.32	0.01[m]	0.01	0.001	0.002	0.02	0.01	0.015	0.004
S-Site (TA-16)	03/21/96	0.8	0.825[m]	10	9.31	0.01[m]	0.01	0.001	0.002	0.02	0.01	0.025	0.004
Near Test Well DT-9	03/21/96	0.8	0.873[m]	9.6	10.10	0.00	0.02	0.002	0.002	0.03[m]	0.01	0.013	0.004
Mean (+/- 2 SD)		0.656[k] (0.206)	0.656[k] (0.349)	13.7[k] (5.2)	13.13[k] (16.88)	0.004[k] (0.005)		0.002 (0.002)		0.02[k] (0.01)		0.027[k] (0.050)	

[a]Radiochemical and Trace Metal Analysis reported on a dry weight basis (i.e. pCi/g dry or mg/kg dry)
[b]Metals were digested following SW-846 Method 3050A and analyzed following Method 6010A. Radioisotopes digested with hydrofloric acid and analyzed by alpha spectroscopy
[c]Total Propagated Uncertainty, reported by Paragon Analytics, Inc. as 2 x sigma
[d]Uncertainty reported in LANL 1996 ESR as 2 x sigma
[e]NA indicates analysis not requested (not analyzed)
[f]LANL Mean +/- 2SD are the means presented in the 1996 ESR, NMED means are calculated form data presented in this table
[g]Regional Statistical Reference Levels; upper limit background concentration, from Fresquez et. al. (1996a).
[h]SALs; (Los Alamos National Laboratory Screening Actions Level) from Fresquez et. al. (1996a).
[i]Means that exceed background averages presented in 1996 ESR as Regional Means +/- 2 SD
[m]Any level, mean or individual measurement, that exceed it's RSRL
[n]< indicates not detected at or above the reporting limit. To calculate means, 1/2 reporting limit value used.
[p]Collection date not recorded in field records

LOCATION	Date Collected	NMED U 234 (pCi/g)	NMED counting uncertainties 2σ	NMED U-235 (pCi/g)	NMED counting uncertainties 2σ	NMED U-238 (pCi/g)	NMED counting uncertainties 2σ	NMED Total U[f] mg/kg	NMED counting uncertainties 2σ	LANL Total U[g] mg/kg	LANL counting uncertainties 2σ
REGIONAL											
Near Cochiti	03/25/96	0.44	0.08	0.03	0.02	0.44	0.08	1.32	0.25	1.88	0.38
Bernalillo	03/25/96	0.56	0.09	0.03	0.02	0.67	0.10	2.01	0.31	2.35	0.46
Mean (+/- 2 SD)[f]								1.67 (0.98)		2.32 (0.95)	
RSRL[g]										4.05	
SAL[h]										29	
PERIMETER											
North Mesa	03/20/96	0.95	0.14	0.03	0.02	1.04	0.15	3.11	0.46	3.91	0.76
White Rock (East)	03/20/96	0.87	0.13	0.05	0.02	0.82	0.12	2.46	0.37	2.77	0.56
Tsankawi	03/20/96	1.37	0.19	0.06	0.03	1.49	0.20	4.46[m]	0.61	4.36[m]	0.88
Mean (+/- 2 SD)								3.43[k] (2.04)		3.44[k] (1.84)	
ON-SITE											
East of TA-53	03/20/96	0.88	0.11	0.03	0.02	0.80	0.12	2.39	0.37	2.49	0.5
Two Mile Mesa	03/21/96	0.91	0.14	0.04	0.02	0.95	0.14	2.85	0.43	3.71	0.74
R Site Rd. (East)	03/21/96	1.39	0.19	0.07	0.03	1.50	0.21	4.50[m]	0.64	4.42[m]	0.88
Potrillo Drive	3/96[p]	0.68	0.11	0.03	0.02	0.65	0.10	1.95	0.31	2.62	0.52
S-Site (TA-16)	03/21/96	1.40	0.20	0.07	0.03	1.45	0.20	4.35[m]	0.61	5.13[m]	1.02
Mean (+/- 2 SD)								2.99[k] (1.42)		3.27[k] (1.68)	

[a]Radiochemical and Trace Metal Analysis reported on a dry weight basis (i.e. pCi/g dry or mg/kg dry)
[b]Metals were digested following SW-846 Method 3050A and analyzed following Method 6010A, or equivalent methods. Radioisotopes digested with hydrofloric acid and analyzed by alpha spectroscopy
[c]Total Propagated Uncertainty, reported by Paragon Analytics, Inc. as 2 x sigma
[d]Uncertainty reported in LANL 1996 ESR as 2 x sigma
[e]NA indicates analysis not requested (not analyzed)
[f]LANL Mean +/- 2 standard deviations (SD) are the means presented in the 1996 ESR, NMED means are calculated form data presented in this table
[g]Regional Statistical Reference Levels; upper limit background concentration, from Fresquez et. al. (1996a).
[h]SALs; (Los Alamos National Laboratory Screening Actions Level) from Fresquez et. al. (1996a).
[i]Means that exceed background averages presented in 1996 ESR as Regional Means +/- 2 SD
[m]Any level, mean or individual measurement, that exceed its RSRL
[n]< indicates not detected at or above the reporting limit. To calculate means, 1/2 reporting limit value used.
[p]Collection date not recorded in field records
[q]NMED Total Uranium data calculated from Uranium isotopic measurements
[r]LANL Total Uranium measurements are measured by Kinetic Phosphorescence Analysis

Figure A-9. NMED/LANL radiochemical and trace metal analysis of soils from the LANL area during 1996[a,b]