APR 6 1998

SANDIA REPORT

SAND98-0612 • UC-630

Unlimited Release

Printed March 1998

RECEIVED

APR 09 1998

OSTI

The Role of Data Analysis in Sampling Design of Environmental Monitoring

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

Lih-Jenn Shyr, Heidi Herrera, Rick Haaker

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of
Energy under Contract DE-AC04-94AL85000.

Approved for public release; further dissemination unlimited.

Sandia National Laboratories

MASTER

Issued by Sandia National Laboratories, operated for the United States Department of Energy by Sandia Corporation.

NOTICE: This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, nor any of their contractors, subcontractors, or their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government, any agency thereof, or any of their contractors or subcontractors. The views and opinions expressed herein do not necessarily state or reflect those of the United States Government, any agency thereof, or any of their contractors.

Printed in the United States of America. This report has been reproduced directly from the best available copy.

Available to DOE and DOE contractors from
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Prices available from (615) 576-8401, FTS 626-8401

Available to the public from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Rd
Springfield, VA 22161

NTIS price codes
Printed copy: A04
Microfiche copy: A01

DISCLAIMER

**Portions of this document may be illegible
electronic image products. Images are
produced from the best available original
document.**

SAND98-0612
Unlimited Release
Printed March 1998

Distribution
Category UC-630

THE ROLE OF DATA ANALYSIS IN SAMPLING DESIGN OF ENVIRONMENTAL MONITORING

**Lih-Jenn Shyr
Heidi Herrera
Rick Haaker**

Environmental and Emergency Management Department

Sandia National Laboratories
P.O. Box 5800
Albuquerque, NM 87185-0854

ABSTRACT

The report is intended to address the need for data analysis in environmental sampling programs. Routine environmental sampling has been conducted at Sandia National Laboratories/New Mexico (SNL/NM) to ensure that site operations have not resulted in undue risk to the public and the environment. Over the years, large amounts of data have been accumulated. The richness of the data should be fully utilized to improve sampling design and prioritize sampling needs for a technically-sound, yet cost-effective sampling design. The report presents a methodology for analyzing environmental monitoring data and demonstrates the application by using SNL's historical monitoring data. Recommendations for sampling design modification were derived based on the results of the analyses.

TABLE OF CONTENTS

	<u>Page</u>
Table of Contents.....	ii
List of Tables.....	iv
List of Figures.....	vi
Abbreviations.....	vii
1.0 INTRODUCTION.....	1-1
1.1 Sampling Locations.....	1-1
1.2 Sample Collection & Analysis.....	1-2
2.0 STATISTICAL ANALYSIS METHODOLOGY.....	2-1
2.1 Comparison to Background Concentrations.....	2-2
2.2 Trend Analysis.....	2-4
2.3 Comparison of Upgradient to Downgradient.....	2-5
2.4 Statistical Software.....	2-6
3.0 ANALYSIS OF TERRESTRIAL SURVEILLANCE.....	3-1
3.1 Terrestrial Radiological Results.....	3-1
3.1.1 Vegetation Results - Radiological.....	3-1
3.1.2 Soil Results - Radiological.....	3-2
3.1.3 Sediment Results - Radiological.....	3-10
3.1.4 Surface Water Results - Radiological.....	3-10
3.1.5 Environmental Thermoluminescent Dosimeters (TLD) Results.....	3-13
3.2 Terrestrial Non Radiological Results.....	3-14
3.2.1 Soil Results - Metals.....	3-16
3.2.2 Sediment Results - Metals.....	3-22
3.2.3 Surface Water Results - Metals.....	3-24
3.2.3 Surface Water Results - Metals.....	3-24
4.0 COMPARISON OF MAY AND AUGUST SAMPLING PERIODS.....	4-1
4.1 Checking for Normality.....	4-1
4.2 Wilcoxon Two Sample Test.....	4-1
4.3 Radiological Results.....	4-2
4.3.1 Vegetation.....	4-3
4.3.2 Soil.....	4-3
4.3.3 Sediment.....	4-4
4.3.4 Filtered Water.....	4-4
4.3.5 Unfiltered Water.....	4-4
4.3.6 Filters.....	4-4
4.4 Non radiological Results.....	4-4
4.4.1 Soil.....	4-4
4.4.2 Sediment.....	4-5
4.4.3 Filtered Water.....	4-5
4.4.4 Unfiltered Water.....	4-5
4.4.5 Filters.....	4-6

TABLE OF CONTENTS *(Concluded)*

	<u>Page</u>
5.0 SAMPLING ENHANCEMENTS	5-1
5.1 Suggested Modifications.....	5-1
5.1.1 Modification of the ICP-20 Metals List.....	5-1
5.1.2 Vegetation Sampling.....	5-1
5.1.3 Replicate Sampling Locations.....	5-1
5.1.4 TCLP Analysis.....	5-2
5.1.5 Discontinuation of Hydrofluoric Acid Dissolution.....	5-3
5.2 Follow-up Investigations.....	5-3
5.2.1 TCLP Analysis - Location 20.....	5-3
5.2.2 "As Received Condition" - Location 64.....	5-3
 6.0 SPLIT COMPARISON ANALYSIS AND RESULTS.....	 6-1
6.1 Site Selection Methodology	6-1
6.2 Selection of Laboratory Used for Split Comparison.....	6-1
6.3 Results of the Split Comparison.....	6-1
6.3.1 Soil Results.....	6-2
6.3.2 Sediment Results.....	6-2
6.3.3 Vegetation Results.....	6-5
6.3.4 Filtered Water Results.....	6-5
6.3.5 Unfiltered Water Results.....	6-6
6.3.6 Filter Results	6-7
6.4 Lessons Learned.....	6-8
6.4.1 Performance Evaluation Samples.....	6-9
6.4.2 EPA and EML Cross Check.....	6-10
6.4.3 Analysis Template.....	6-10
6.4.4 Gamma Spectroscopy System.....	6-10
6.4.5 Minimal Detectable Activities/Minimal Detectable Limits.....	6-11
 7.0 KEY PEAKS IDENTIFICATION	 7-1
7.1 Vegetation	7-1
7.2 Soil	7-2
7.3 Sediment.....	7-3
7.4 Filtered Water.....	7-4
7.5 Unfiltered Water.....	7-5
7.6 Filters.....	7-5
 8.0 PERFORMANCE EVALUATION SAMPLES.....	 8-1
8.1 Performance Evaluation Sample Results	8-1
8.2 Performance Evaluation Program Continuation.....	8-4

LIST OF TABLES

<u>Table</u>	<u>Page</u>
1-1	SNL/NM terrestrial surveillance locations and sample types.....1-5
1-2	Terrestrial surveillance sampling and analysis matrix.....1-8
2-1	Analysis categories for radiological results2-1
2-2	Calculation of the test statistic using an ANOVA table.....2-3
2-3	Differences in data values needed for computing Mann-Kendall test statistic.....2-4
3-1	Summary statistics for concentrations of tritium in vegetation, 1991- 1995.....3-2
3-2	Summary statistics for concentrations of soil radionuclides, 1991- 19953-3
3-3	Analysis categories for Cs-137, H-3, and U _{tot} concentrations.....3-4
3-4	Concentrations of sediment radionuclides, 1991- 1995.....3-11
3-5	Concentrations of surface-water radionuclides, May 19953-12
3-6	Concentrations of surface-water radionuclides, August 19953-13
3-7	Summary of termoluminescent dosimeter measurements for 1995.....3-14
3-8	Summary statistics for metal concentrations in soil, May 19953-17
3-9	Summary statistics for metal concentrations in soil, August 1995.....3-19
3-10	Locations with metal concentrations classified by category.....3-21
3-11	Concentrations of metal sediments3-23
3-12	Concentrations of surface-water metals, May 1995.....3-24
3-13	Concentrations of surface-water metals, August 19953-26
3-14	Metals concentrations at onsite location 33 which were above offsite concentrations3-28
4-1	Summary statistics for tritium by sampling period.....4-3
4-2	Summary statistics for tritium by sampling period without locations of known contamination.....4-3
4-3	Summary statistics for soil by sampling period.....4-5
4-4	Summary statistics for filtered water by sampling period.....4-5
4-5	Summary statistics for unfiltered water by sampling period.....4-6
5-1	Current and revised list of ICP-20 metals.....5-2
6-1	Summary statistics for ratio of soil concentrations.....6-3
6-2	Summary statistics for ratio of sediment concentrations.....6-4
6-3	Summary statistics for ratio of vegetation concentration.....6-5
6-4	Summary statistics for ratio of filtered water concentrations.....6-6
6-5	Summary statistics for ratio of unfiltered water concentrations.....6-7
6-6	Summary statistics for ratio of filter concentrations.....6-8
6-7	Performance evaluation sample results for Core Laboratories - water.....6-9
6-8	Performance evaluation sample results for Core Laboratories - soil.....6-10
7-1	Key peaks observed in 1995 vegetation samples.....7-2
7-2	Key peaks observed in 1995 soil samples.....7-3
7-3	Key peaks observed in 1995 sediment samples.....7-4

LIST OF TABLES *(Concluded)*

<u>Table</u>		<u>Page</u>
7-4	Key peaks observed in 1995 filter water samples.....	7-4
7-5	Key peaks observed in 1995 unfiltered water samples.....	7-5
7-6	Key peaks observed in 1995 water filter samples.....	7-5
8-1	Performance evaluation sample results for water, March 1995.....	8-2
8-2	Performance evaluation sample results for water, August 1995.....	8-2
8-3	Performance evaluation sample results for soil, March 1995.....	8-3
8-4	Performance evaluation sample results for soil, August 1995.....	8-3

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1-1	Onsite and perimeter monitor locations.....	1-3
1-2	Offsite terrestrial monitoring locations.....	1-4
3-1	SNL/NM soil location with increasing trend for Cs-137.....	3-5
3-2	Onsite/Perimeter soil locations with increasing total uranium.....	3-6
3-3	SNL/NM soil locations with increasing total uranium for the first time.....	3-7
3-4	Soil locations with increasing total uranium for 2 years.....	3-8
3-5	Perimeter soil locations showing increasing total uranium concentrations over time.....	3-9
3-6	Mean thermoluminescent dosimeter dose estimate by year.....	3-15

ABBREVIATIONS

Acronyms

ANOVA	A one-way analysis of variance
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DOE	Department of Energy
DPA	Kinetic-phosphorescent Analysis
EPA	Environmental Protection Agency
ICP-AES	Inductively Coupled Plasma-Atomic Emission
KAFB	Kirtland Air Force Base
MDA	minimum detectable activity
MDL	minimum detection limit
NIST	National Institute of Science and Technology
PE	performance evaluation
QA	Quality Assurance
QAPP	Quality Assurance Program Plan
RCRA	Resource Conservation and Recovery Act
SMO	Sample Management Office
SNL/NM	Sandia National Laboratories, New Mexico
TA-II	Technical Area II
TA-III	Technical Area III
TCLP	toxicity characteristic leaching procedure
TLD	Thermoluminescent dosimeter

Units of Measure

$\mu\text{g}/\text{filt comp}$	micrograms per filter composite	mg/L	milligrams per liter
$\mu\text{g}/\text{g}$	micrograms per gram	pCi/g	pico curies per gram
$\mu\text{g}/\text{L}$	micrograms per liter	pCi/mL	pico curies per milliliter
mg/kg	milligrams per kilograms	ppm	parts per million

Elements and Isotopes

Al	aluminum	Ni	nickel
Ba	barium	K	potassium
Be	beryllium	Si	silicon
Cd	cadmium	Ag	silver
Ca	calcium	Sr	strontium
Cr	chromium	Ti	titanium
Co	cobalt	V	vanadium
Cu	copper	Zn	zinc
Fe	iron	U_{tot}	uranium total
Pb	lead	H-3	tritium
Mg	magnesium	Cs-137	cesium-137
Mn	manganese		

1.0 INTRODUCTION

This report is intended to address the need for data analysis in environmental sampling programs. Routine environmental sampling has been conducted at Department of Energy (DOE) sites to ensure that site operations have not resulted in undue risk to the public and the environment. Over the years, various environmental monitoring programs have accumulated large amounts of data. The richness of the data should be fully utilized to improve sampling design and prioritize sampling needs for a technically-sound, yet cost-effective sampling design.

In this study, the terrestrial surveillance activity of the environmental monitoring programs at Sandia National Laboratories, New Mexico (SNL/NM) was used to demonstrate the role of data analysis in improving sampling design. An introduction of the terrestrial surveillance program is followed by a discussion of the data analysis strategy and the results of data analysis. Based on current and historical data, modifications to the sampling design are proposed. Results from split samples analyzed by different labs are also compared to establish the necessary data link in trend analysis.

SNL/NM has performed environmental radiological surveillance sampling since 1959. Non radiological surveillance sampling began in May, 1993, which marked the first year that metals analysis was performed. Terrestrial surveillance also determines the background levels of radionuclides and metals present in community (off site) areas, which are used as a baseline for data comparison.

Surveillance monitoring at regular intervals allows SNL/NM to detect the possible migration of contaminated material to off site (community) locations and also to determine potential impacts (if any) of site-related activities to the off site population and the surrounding environment. Surveillance monitoring includes sampling of soil, vegetation, water, and sediment samples.

1.1 SAMPLING LOCATIONS

The Terrestrial Surveillance program staff collected soil, arroyo/stream and river sediment, surface water, and vegetation samples in May and August 1995. The sampling stations are located in three distinct areas: on SNL/NM property (on site), at site perimeter, and in the surrounding community (off site). On site sampling locations are near areas of known contamination or potential sources of contamination, or are in areas where contamination, if present, would be expected to accumulate. The perimeter locations are used to monitor the SNL/NM boundaries for migration of potential SNL/NM site-related contamination to off site receptors. The community locations are off site and unrelated to SNL/NM activities. Data collected at off site locations serve as a background reference for

comparison with samples collected from SNL/NM perimeter and on site locations. Thermoluminescent dosimeters (TLDs) used to measure ambient levels of external gamma radiation, are also located at on site, perimeter, and off site locations.

Figures 1-1 shows on site and perimeter sample locations located within SNL/NM property. Figure 1-2 shows off site sampling locations. Table 1-1 lists the SNL/NM terrestrial surveillance locations, specifies the types of samples collected at each location, and indicates whether the location is utilized for TLD monitoring. There are a total of 73 fixed sampling locations: 40 on site (at SNL/NM), 17 distributed around the site perimeter, and 16 off- site in and around Albuquerque within a 50 mile (80 km) radius of SNL/NM. Over the past years, new monitoring locations have been added, as necessary, to monitor new facilities and operations, or to supplement existing data. Seven new locations (74 through 80), for example, were added in 1995 based on a study of existing environmental restoration (ER) sites and present sampling locations. This study was conducted to determine optimum positions for the new sampling locations relative to topographical features (i.e. drainage basins), wind directions and the locations of other sampling points in the vicinity of particular ER sites (Shyr and Thelen 1995).

1.2 SAMPLE COLLECTION & ANALYSIS

Environmental samples were collected and analyzed in accordance with the Quality Assurance Project Plan (SNL 1993c) and the Operating Procedure for Terrestrial Surveillance (SNL 1994d). Native vegetation (usually grasses due to their fast growing cycle), soil, sediment, and surface water samples were collected biannually: once early in the growing season (May) and once toward the end of the growing season (August). TLDs were exchanged every calendar quarter (January, April, July, and October). Surface water samples were collected by grab sampling. Unfiltered surface water (Total Water), filtered surface water, and suspended solids (sediments > 0.45 micron [μm]) were analyzed for radiological and non radiological constituents. Table 4-2 shows the sampling matrix for the types of analysis performed on each type of media.

Figure 1-1. Onsite and Perimeter Monitor Locations

Figure 1-2. Offsite Terrestrial Monitoring Locations

Table 1-1. SNL/NM terrestrial surveillance locations and sample types.

Location Number	Sampling Location	Location Type*	Sample Type ^a
1	Pennsylvania Avenue	S	V,S,T
2NW	Mixed Waste Landfill	S	V,S,T
2NE ^b	Mixed Waste Landfill	S	V,S
2SE	Mixed Waste Landfill	S	V,S
2SW	Mixed Waste Landfill	S	V,S
3	Coyote Canyon Control	S	V,S,T
4	Isleta Reservation Gate	P	V,S,T
5	McCormick Gate	P	V,S,T
6	Technical Area III, east of water tower	S	V,S,T
7 ^b	North of Technical Area V, arroyo	S	V,S,T
8	Corrales Bridge (upgradient of Rio Grande)	C	V,S,W,A
9	Sedillo Hill, I-40, east of Albuquerque	C	V,S
10	Oak Flats	C	V,S,T
11 ^b	Isleta Pueblo, Rio Grande (downgradient)	C	V,S,T,W,A
12	NE Perimeter	P	V,S
16	Four Hills	P	V,S,T
18	North Perimeter Road	P	T
19	Seismic Center Gate	P	V,S,T
20	Technical Area IV, SW	S	V,S,T
21	Bernalillo Fire Station 10, Tijeras	C	T
22	Los Lunas Fire Station	C	T
23	Rio Rancho Fire Station, 19th Avenue	C	T
24	Corrales Fire Station	C	T
25	Placitas Fire Station	C	V,S,T
26	Albuquerque Fire Station 9, Menaul NE	C	T
27	Albuquerque Fire Station 11, Southern SE	C	T
28	Albuquerque Fire Station 2, High SE	C	T
29	Albuquerque Fire Station 7, 47th NW	C	T

Note: NW = northwest; NE = northeast; SE = southeast; SW = southwest.

*Location types: S = on site SNL/NM; P = perimeter of SNL/NM; and C = community (off site).

^aSample types: V = vegetation, S = soil, W = surface water, A = sediment, and T = TLD (thermoluminescent dosimeter).

^bReplicate sampling sites

{ S and V: 2NE, 7, 11, and 53.
W: 11.
A: 11 and 73.

Table 1-1. SNL/NM terrestrial surveillance locations and sample types (Continued).

Location Number	Sampling Location	Location Type*	Sample Type [†]
30	Albuquerque ^b Fire Station 6, Griegos NW	C	T
31	Technical Area II Guard Gate	S	T
32S	Technical Area II, Building 935 (south bay door)	S	S
32E	Technical Area II, Building 935 (east personnel door)	S	S
33	Coyote Spring	S	V,S,W
34	Lurance Canyon (Burn Site)	S	V,S
35	Chemical Waste Disposal Site	S	V,S
39	NW U.S. Department of Energy Complex	P	T
40	Technical Area I, NE, by Building 852	P	T
41	Technical Area V, NE fence	S	V,S,T
42	Technical Area V, east fence	S	V,S,T
43	Technical Area V, SE fence	S	V,S,T
45	Technical Area III, Radioactive and Mixed Waste Management Facility Site, NW corner	S	V,S,T
45E	Technical Area III, Radioactive and Mixed Waste Management Facility Site, east fence	S	T
46	Technical Area II, south corner	S	V,S,T
47	Tijeras Canyon east of TA-IV	S	T
48	Tijeras Canyon NE of TA-IV	S	T
49	Near the Explosives Components Facility Site	S	V,S
51	Technical Area V, north of culvert	S	V,S
52	Technical Area III, NE of Buildings 6716/6717	S	V,S
53 ^b	Technical Area III, south of Long Sled Track	S	V,S
54	Technical Area III, Building 6630	S	V,S
55	Large-Scale Melt Facility, Building 9939	S	V,S
56	Technical Area V, west Building 6588	S	S
57	Technical Area IV, NE of Building 970	S	S

Note: NW = northwest; NE = northeast; SE = southeast; SW = southwest.

*Location types: S = on site SNL/NM; P = perimeter of SNL/NM; and C = community (off site).

[†]Sample types: V = vegetation, S = soil, W = surface water, A = sediment, and T = TLD (thermoluminescent dosimeter).

^bReplicate sampling sites

{	S and V: 2NE, 7, 11, and 53.
	W: 11.
	A: 11 and 73.

Table 1-1. SNL/NM terrestrial surveillance locations and sample types (Concluded).

Location Number	Sampling Location	Location Type [*]	Sample Type ^a
58	North Base housing	P	V,S
59	Zia Park/SE	P	V,S
60	Tijeras Arroyo (downgradient)	P	V,S,A
61	Albuquerque International Sunport (west end)	P	V,S
62	East resident	C	V,S
63	No Sweat Boulevard	P	V,S
64	North Manzano	P	V,S
65	Sandia Research Park	P	V,S
65E	Tijeras Arroyo East (upgradient 1)	P	V,S,A
66	Kirtland Underground Munitions Storage Complex	S	V,S
68	Las Huertas	C	W,A
72	Arroyo del Coyote (mid-arroyo)	S	A
73 ^b	Tijeras Arroyo (upgradient 2)	P	A
74	Technical Area IV, Tijeras Arroyo mid-stream	S	A
75	Arroyo del Coyote (downgradient)	S	A
76	North Thunder Range	S	V
77	South Thunder Range	S	V,S
78	School House Mesa	S	V,S
79	Arroyo del Coyote (upgradient)	S	A
80	Maderas Canyon	P	V,S

73 total

Note: NW = northwest; NE = northeast; SE = southeast; SW = southwest.

^{*}Location types: S = on site SNL/NM; P = perimeter of SNL/NM; and C = community (off site).^aSample types: V = vegetation, S = soil, W = surface water, A = sediment, and T = TLD (thermoluminescent dosimeter).

^bReplicate sampling sites

{	S and V: 2NE, 7, 11, and 53.
	W: 11.
	A: 11 and 73.

Table 1-2. Terrestrial surveillance sampling and analysis matrix.

Matrix	Gross Alpha	Gross Beta	Gamma Spec	ICP-20 Metals	Tritium	Total Uranium	Percent H ₂ O
Soil			✓	✓	✓	✓	✓
Sediment			✓	✓	✓	✓	✓
Vegetation			✓		✓		✓
Filtered H ₂ O	✓	✓	✓	✓	✓	✓	
Unfiltered H ₂ O	✓	✓	✓	✓	✓	✓	
Water Filters	✓	✓	✓	✓		✓	

2.0 STATISTICAL ANALYSIS METHODOLOGY

To meet the objectives of the terrestrial surveillance program (i.e. determine contaminant presence/migration), data from on site and perimeter locations over the last five years (August 1991 through August 1995) were compared to those from community locations to identify locations with concentrations higher than background. (Data from 1991 to present were selected, since during this time period, the same analytical laboratory was used and therefore, provided consistent analytical procedures [Shyr and Skipper 1995].) In addition, data from soil and vegetation samples gathered over the last 5 years were analyzed by location to determine if a trend (either increasing or decreasing) was observed.

Results of both analyses were then combined to determine how a location should be categorized (i.e. "Category 1" to "Category 4") for further investigation (Table 2-1).

Table 2-1. Analysis categories for radiological results.

Category Type	Higher than Off site?	Trend Increasing?	Priority for further investigation
Category 1	Yes	Yes	1st priority
Category 2	Yes	No	2nd priority
Category 3	No	Yes	3rd priority
Category 4	No	No	No concern.

Only those locations listed under Categories 1, 2, or 3 were discussed in the data analysis report. This analysis identified locations with abnormal concentrations based on statistical procedures and the results were further compared to federal/state regulation limits and U.S. Soil average concentrations.

Data from surface water and sediment samples were analyzed using the same approach with additional comparisons between upgradient and downgradient river and arroyo samples to determine contribution from SNL/NM and/or Albuquerque and the surrounding areas.

2.1 COMPARISON TO BACKGROUND CONCENTRATIONS

In order to determine whether migration has occurred from on site locations or perimeter locations to background (community) locations, a one-way analysis of variance was performed. If the test was significant, Dunnett's test was used as a comparison of mean values to see if there was a difference between community means and on site means and community means and perimeter locations.

A one-way analysis of variance (ANOVA) was the statistical procedure used to test the equality of means for several populations simultaneously. In this case, the three populations being tested were on site, perimeter, and background. Assumptions for using the ANOVA include: 1) analyte concentrations in each population are assumed to be normally distributed and 2) the standard deviations of analyte concentrations are assumed to be equal. A testing situation including a null hypothesis (H_0) and an alternative hypothesis (H_a) are set up such that when H_0 is rejected it leads to the alternative hypothesis.

H_0 : There is no difference between analyte concentrations, or
 H_0 : $\mu_1 = \mu_2 = \mu_3$.

H_a : At least one of the means is difference than the other means, or
 H_a : One μ_i is different.

The null hypothesis is rejected if the observed test statistic tends to be large. Calculation of the test statistic is most easily done utilizing an ANOVA table. ANOVA problems have an underlying F-distribution. The observed F-statistic (calculation is seen in Table 2-2) is compared to a table containing values calculated from the F-distribution. If the observed value is greater than the table value, the null hypothesis is rejected and at least one of the means is different. Since statistical software was used to perform this test (see section 2.4), the p-value was used to determine if the test should be rejected. The p-value is the probability of observing a test statistic as large as or greater than the value observed. If the p-value is small (usually less than 0.05), the test statistic is considered statistically significant and a difference among the population means is said to exist. Please note that the test only tells you that a difference exists, it does not tell you where the difference is.

If the null hypothesis is rejected, i.e., at least one of the means is different, a multiple-comparison test called Dunnett's Test, is performed. Dunnett's Test is specifically used to compare the mean of the background (community) concentrations to the mean of the on site or perimeter concentrations. This test is only performed after the ANOVA is done, to determine if the difference detected in the ANOVA is due to the on site concentrations or the perimeter concentrations being different (usually greater than) the background concentrations. Dunnett's Test calculates the difference between on site concentrations and background concentrations and the difference between perimeter

Table 2-2. Calculation of the test statistic using an ANOVA table.

Source of Variation	Sums of Squares (SS)	Degrees of Freedom (df)	Mean Squares (MS)	F
Between Populations	SSB	k - 1	MSB = SSB/(k-1)	MSB / MSW
Within Populations	SSW	N - k	MSW = SSW/(N-k)	
Total	SST	N - 1		

- n_i = Number of analyte concentrations in the i th population
 X_i = Mean of i th population as estimated by the sample
 s_i = Standard deviation of i th population
 k = Number of populations, in our case $k = 3$
 N = Number of analyte concentrations in all populations combined
 s = Standard deviation of all analyte concentrations

$$\begin{aligned}
 \text{SSB} &= \frac{\sum n_i X_i^2 - (\sum n_i X_i)^2}{N} \\
 \text{SSW} &= \sum (n_i - 1) s_i^2 \\
 \text{SST} &= (N - 1) s^2
 \end{aligned}$$

concentrations and background concentrations. The differences calculated are then compared to a mathematical expression containing known values of Dunnett's Test. For example to compare the difference between on site values to the background values, the difference between on site values and background values ($X_o - X_b$) is compared to the following expression:

$$d_{\alpha}(a-1, N-k) \sqrt{MSW \left(\frac{1}{n_o} + \frac{1}{n_b} \right)}$$

where X_o is the average on site concentration, X_b is the average background concentration, $d_{\alpha}(a-1, N-k)$ is the known Dunnett's value for the specified level of significance (usually $\alpha = 0.05$), a is the number of treatments (in our case there are 3), and $(N-k)$ is the degrees of freedom associated with the Within Population Sums of Squares, MSW is the Mean Squares for Within Populations, n_o is the number of analyte concentrations for on site values and n_b is the number of analyte concentrations for background. If $(X_o - X_b)$ is greater than Dunnett's expression, it is said that on site concentration levels are greater than background concentrations. This same comparison process is done for perimeter concentrations substituting the appropriate values for perimeter instead of on site.

2.2 TREND ANALYSIS

Data from August 1991 to August 1995, were tested for increasing trend using the Mann-Kendall test for trend (Gilbert 1987, pp. 208-210). The data are ordered over time (in this case data was ordered from 1991 to 1995). The change from each data point to each subsequent data point is then determined. The Mann-Kendall test statistic is the difference of the number of changes in a positive direction (i.e., if the difference between two data points is positive) and the number of changes in a negative direction. If there is an increasing trend, the Mann-Kendall test statistic will be a large positive number. This test statistic is then compared to the "Probabilities for the Mann-Kendall Non-Parametric Test for Trend" (Gilbert 1987, p. 272). If the probability of observing the test statistic is small (usually less than 0.05) the test statistic is considered statistically significant and an increasing trend is apparent. Table 2-3 shows an example of how to calculate the Mann-Kendall test for trend for the time frame of August 1991 to August 1995.

Table 2-3. Differences in data values needed for computing Mann-Kendall test statistic.

Time Frame							# of + Signs	# of - Signs
8/91	5/92	8/92	5/93	8/93		5/95		
X_1	X_2	X_3	X_4	X_5		X_9		
	$X_2 - X_1$	$X_3 - X_1$	$X_4 - X_1$	$X_5 - X_1$		$X_9 - X_1$		
		$X_3 - X_2$	$X_4 - X_2$	$X_5 - X_2$		$X_9 - X_2$		
			$X_4 - X_3$	$X_5 - X_3$		$X_9 - X_3$		
				$X_5 - X_4$		$X_9 - X_4$		
								
						$X_9 - X_8$		
							Sum of + Signs	Sum of - Signs

Mann-Kendall Test Statistic:

$$S = (\text{Sum of + Signs}) - (\text{Sum of - Signs})$$

If S is a large positive number, the measurements taken later in time tend to be larger than those taken earlier, indicating an increasing trend.

The Mann-Kendall test statistic is then compared to values in the "Probabilities for the Mann-Kendall Non-Parametric Test for Trend" (Gilbert 1987, p. 272) table using n and S where n is the number of time periods and S is the Mann-Kendall test statistic. If the value of the probability observed in the table is less than a pre-specified value (usually 0.05) then the Mann-Kendall test is significant and the data is said to be increasing over time.

2.3 COMPARISON OF UPGRAIDENT TO DOWNGRAIDENT

In order to determine whether there was a difference between upgradient locations to downgradient locations, a two-sample t-test was performed. The two-sample t-test compares the average concentration of the upgradient location with the average concentration of the downgradient position. Data from August 1991 to August 1995 was used in this analysis.

Assumptions for the two-sample t-test include 1) upgradient and downgradient concentrations are normally distributed, and 2) standard deviations for upgradient and downgradient concentrations are equal (i.e., equality of variances).

A testing situation including a null hypothesis (H_0) and an alternative hypothesis (H_a) are set up such that if H_0 is rejected it leads to the alternative hypothesis.

H_0 : There is no difference between upgradient and downgradient concentrations, or

H_0 : $u_{up} = u_{down}$.

H_a : There is difference between upgradient and downgradient concentrations, or

H_a : $u_{up} \neq u_{down}$.

The null hypothesis is rejected if the observed test statistic tends to be large. Calculation of the test statistic is done using the following formula:

$$t_{obs} = \frac{X_{up} - X_{down}}{sp \sqrt{\left(\frac{1}{n_{up}} + \frac{1}{n_{down}}\right)}}$$

where X_{up} is the mean concentration for upgradient locations, X_{down} is the mean concentration for downgradient concentrations, n_{up} is the number of concentrations up the upgradient locations, n_{down} is the number of concentrations for the downgradient locations and s_p is the pooled standard deviation computed in the following manner -

$$s_p = \sqrt{\frac{(n_{up} - 1)s_{up}^2 + (n_{down} - 1)s_{down}^2}{n_{up} + n_{down} - 2}}$$

A two-sample t-test has an underlying t-distribution. The observed t-statistic is compared to a table containing values calculated from the t-distribution. If the observed value is greater than the table value, the null hypothesis is rejected and one of the means is greater than the other.

determine if the test should be rejected. The p-value is the probability of observing a test statistic as large as or greater than the value observed. If the p-value is small (usually less than 0.05), the test statistic is considered statistically significant and the upgradient location is either greater than or less than the downgradient location.

2.4 STATISTICAL SOFTWARE

The statistical package used to analyze the Terrestrial Surveillance data was SAS, by the SAS Institute in Cary, North Carolina. Several procedures within SAS were used to perform the above statistical analysis. Sample statistics could be generated using PROC MEANS. Testing for normality was done using PROC UNIVARIATE. PROC GLM was utilized to perform analysis of variance. The Mann-Kendall test for trend was performed using code written by Heidi Herrera and submitted through SAS.

3.0 ANALYSIS OF TERRESTRIAL SURVEILLANCE DATA

As described in the previous section, results were labeled as Category 1, 2, 3, or 4 based on the presence of higher/lower than off site and increasing and decreasing trends. Because Category 4 is of no environmental concern (i.e., not higher than off site and not increasing), only categories 1, 2, and 3 will be discussed in the below subsections. The discussion presented in this section is divided into radiological and non radiological results. Each section is then further divided to discuss each matrix in detail.

3.1 TERRESTRIAL RADIOLOGICAL RESULTS

The radiological results of the statistical analysis described in this section are from data collected during sampling events from August 1991 through August 1995. Data from this period were selected since the same analytical laboratory was used, and therefore provided consistent analytical procedures (Shyr and Skipper, 1995)

3.1.1 Vegetation Results - Radiological

Table 3-1 presents the summary statistics for tritium (H-3) concentrations in vegetation samples taken in May and August of 1995. H-3 concentrations in vegetation at on site locations are skewed toward smaller values as indicated by the small median compared to the mean. Location 63 showed an unusually high H-3 concentration (16 pCi/mL) in the May 1994 sampling and was considered in the *1994 SNL/NM Site Environmental Report* as a possible measurement error based on historical data. The 1995 data did not show an elevated concentration. The terrestrial surveillance staff will continue to monitor this location for increasing tritium values.

There were no Category 1 or Category 3 locations observed for H-3 concentrations at either perimeter or on site locations. The only Category 2 location was 2NE, which reported a higher than background H-3 level; but no increasing trend. The elevated H-3 concentration at this location was the primary reason causing a higher mean for the on site H-3 concentrations (Table 3-1).

Table 3-1. Summary statistics for concentrations of tritium in vegetation, 1991 - 1995.

Radionuclide	Units	Location Type	Sample Size	Raw Data			
				Median	Mean	Standard Deviation	Range
Tritium (Oxide)	pCi/ml	SNL/NM	223	0.060	0.789	2.692	-0.260 26.000
Tritium (Oxide)	pCi/ml	Perimeter	111	0.040	0.216	1.545	-0.190 16.000
Tritium (Oxide)	pCi/mL	Off site	54	0.015	0.031	0.108	-0.150 0.450

Note: pCi/mL = pico curies per milliliter.

3.1.2 Soil Results - Radiological

Table 3-2 presents the summary statistics for Uranium-total (U_{tot}), Cesium-137 (Cs-137), and H-3 concentrations in soil samples taken in May and August of 1995. Concentrations of H-3 in soil from on site locations are skewed toward smaller values as indicated by the small median compared to the mean.

Cesium-137 - Last year an increasing trend was detected for Cs-137 at on site location 6 in TA-III. However, with the 1995 data, that trend was no longer noted at this location (Figure 3-1).

Uranium - The background (off site) U_{tot} concentrations showed a larger variation among locations and showed a higher mean concentration level than did on site and perimeter locations. This trend has been observed consistently over the years and most of the high U_{tot} values were associated with locations on the east side of the city, near the mountain areas, where the granite rock formations may contribute to the high U_{tot} values (Shyr, et al. 1996). Last year, increasing trends were detected for U_{tot} at locations 20, 46, and 64, (SNL 1995). However, with the addition of the 1995 data, the increasing U_{tot} trends were no longer detected (Figure 3-2).

Tritium - The value of 2300 pico curies per milliliter (pCi/mL) for H-3 in the soil sample taken at location 32S during May 1995 had an impact on the statistics for on site locations as indicated by the adjusted statistics when the value is excluded. Location 32S is within the controlled area of TA-II and has shown an elevated H-3 concentration in past years.

Table 3-2. Summary statistics for concentrations for soil radionuclides, 1991 - 1995.

Radionuclide	Units	Location Type	Sample Size	Raw Data				Range
				Median	Mean	Standard Deviation		
Uranium, total	ug/g	SNL/NM	257	1.100	1.237	0.663	0.100	4.200
	ug/g	Perimeter	111	1.300	1.796	4.765	0.200	51.000
	ug/g	Off site	54	1.600	1.719	0.735	0.100	3.700
Tritium (Oxide)	pCi/ml	SNL/NM	257	0.130	26.664	188.972	-0.190	2300.000
	pCi/ml	SNL/NM*	247	0.120	2.845	10.567	-0.190	97.00
	pCi/ml	Perimeter	111	0.060	0.167	0.824	-0.600	8.600
	pCi/mL	Off site	54	0.050	0.088	0.180	-0.110	0.860
Cesium-137**	pCi/g	SNL/NM	245	0.200	0.307	0.296	-0.030	1.800
	pCi/g	Perimeter	105	0.370	0.495	0.479	-0.020	1.900
	pCi/g	Off site	53	0.200	0.336	0.317	0.000	1.200

Note:

µg/g = micrograms per gram; pCi/g = picocuries per gram; pCi/mL = picocuries per milliliter

*There are 3 locations within SNL/NM with known tritium contamination and are not considered representative of tritium values across SNL/NM. The adjusted statistics indicates the impact of the values greater than 100 which were seen at these three locations.

**Cesium-137 sample sizes reflect only the results reported by lab (i.e. Cs-137 was not detected in samples from several locations).

Table 3-3 shows the results of the statistical analysis for Cs-137, H-3, and U_{tot} concentrations.

Table 3-3 Discussion

Cs-137 - An increasing trend was observed for the first time in 1995 for two on site locations, 2NW and 45, although, the concentrations were not higher than background levels. Monitoring on these locations will continue. The Cs-137 concentrations at on site location 34 and perimeter locations 12 and 64 were higher than the background values, but no increasing trend was detected. The Cs-137 concentrations at locations 34, 12, and 64 ranged from 0.4 to 1.9 pCi/g over the past five years (Shyr, et. al. 1996). Even though these values were higher than those from off site locations, they were still within the range of background Cs-137 concentrations in the vicinity of Albuquerque (Hostak 1995). The SNL/NM surveillance staff plans to investigate if the variation in background values was the only reason for the elevated concentrations. Figure 3-1 depicts locations with an increasing trend for Cs-137.

Table 3-3. Analysis categories for Cs-137, H-3, and U_{tot} concentrations.

Radionuclide	Category	On site Location No.	Perimeter Locations No.
Cs-137	Category 1	None	None
	Category 2	34	12, 64
	Category 3	2NW, 45	None
H-3	Category 1	None	None
	Category 2	2NE, 32E, 32S	None
	Category 3	33, 43, 46	None
U _{tot}	Category 1	None	None
	Category 2	None	None
	Category 3	1, 3, 32S, 42, 43, 49, 51, 55, 66	4, 5, 12, 19, 58, 60

H-3 - All perimeter locations showed no trend and there were no detected differences from background levels. Three on site locations, 33, 43, and 46, showed an increasing trend for the first time, although the concentrations were not higher than the background values (Category 3). Monitoring at these locations will continue. Three on site locations, 2NE, 32E, and 32S, showed higher concentrations than background (Category 2) and are associated with identified ER sites in controlled areas. The major exposure pathway for H-3 is through food/crop intake (DOE 1993) and, clearly, this is not a possible exposure scenario at these controlled locations. These elevated concentrations will be addressed by the Environmental Restoration program and the facility owners.

Uranium-total - There were no on site and perimeter locations that showed higher concentrations of U_{tot} as compared to off site (background) values. However, a number of locations (Figure 3-2) showed an increasing trend. Among these were samples from locations 3, 49, 51, and 55, which showed an increasing trend for the first time (Figure 3-3). On site locations, 1, 32S, 42, 43, and 66, have showed an increasing trend for two consecutive years, 1994 and 1995 (Figure 3-4), even though the 1995 concentrations were declining. Out of the six perimeter locations, only one location, 58, showed an increasing trend for two consecutive years (Figure 3-5).

For all three radionuclides (Cs-137, U_{tot}, and H-3), no location was classified as a Category 1.

As seen in Figures 3-1 to 3-5 a trend can be observed for a particular location due to one value higher than usually seen and/or data fluctuations as a result of variations in sampling conditions and analysis. Therefore, locations that continue to show an increasing trend for two consecutive

Figure 3-1. SNL/NM Soil Location Where Increasing Trend for Cesium-137 Was Observed in 1994, but No Trend Observed With Addition of 1995 Data.

Figure 3-2. Onsite and Perimeter Soil Locations Where Increasing Trend for Total Uranium Was Observed in 1994, but No Trend Observed With Addition of 1995 Data.

Figure 3-3. SNL/NM Soil Locations with Increasing Total Uranium Concentrations For The First Time.

Figure 3-4. SNL/NM Soil Locations with Increasing Total Uranium Concentrations For Two Consecutive Years (1994 and 1995)

Figure 3-5. Perimeter Soil Locations Showing Increasing Total Uranium Concentrations Over Time.
Locations 4, 5, 12, 19, and 60 Showed No Trend Previously

years should receive a higher priority for further investigation. If a trend has been observed in the past, but does not show a trend for the current year or the following year, it will not be further discussed in subsequent reports.

3.1.3 Sediment Results - Radiological

Table 3-4 summarizes the data for water deposited sediment samples taken from the Rio Grande, Las Huertas Creek, and on site arroyos in May and August of 1995. Trend analyses (for Cs-137, U_{tot} , and H-3) were performed for all locations using data from 1991 to 1995. No trend was detected at any location and on site and perimeter concentrations were not statistically different from off site values. In addition to this analysis, data from upgradient and downgradient samples taken from the following locations were compared to determine potential contribution from SNL/NM and/or Albuquerque and the surrounding areas.

Tijeras Arroyo - Location 73 is on the site perimeter by TA-II where the Tijeras Arroyo intersects SNL/NM property. Location 60, also taken from the arroyo, is downgradient from TA-I, II, and IV. Data from 1991 through 1995 showed there was no statistically significant difference between upgradient and downgradient radionuclide concentrations (Shyr, et al. 1996).

Rio Grande - Location 8 is off site at the Corrales Bridge, just north of Albuquerque. This location is upgradient of both SNL/NM and the city, although it is located downgradient of Corrales Village, and Rio Rancho, two outlying suburbs. Downgradient samples were taken from the Rio Grande at location 11, on the Isleta Pueblo Indian Reservation, south of Albuquerque. No statistically significant difference in isotope concentrations were detected based on data from the past five years.

Arroyo del Coyote - Since locations 79 and 75, upgradient and downgradient of Arroyo del Coyote, are new locations added in 1995, a trend analysis cannot be performed at this time. The upgradient, mid arroyo, and downgradient concentrations did not appear to be very different; a statistical analysis will be performed when more data become available.

3.1.4 Surface Water Results - Radiological

Tables 3-5 and 3-6 summarize the data for surface water taken from three off site locations 8, 11, and 68, and one on site location 33 in May and August 1995. No trend was detected for any location based on the data collected from the past five years. Location 33 (Coyote Springs) was the only Category 2 location as discussed below.

Uranium-total - Using the 1991 to 1995 data set, on site location 33 at Coyote Spring showed statistically higher concentrations for U_{tot} than off site results, and was therefore classified as Category 2 for Total Water, Filtered Water, and Suspended Solids. The concentrations of U_{tot} in water (~ 0.005 mg/L) at this location were about 25 percent of the maximum federal standard for drinking water (0.02 mg/L).

Table 3-4. Concentrations of sediment radionuclides, 1991 - 1995.

Sediment Type	Loc No.	Location Type	Total Uranium ($\mu\text{g/g}$)	Tritium (pCi/mL)	Cesium-137 (pCi/g)
May, 1995					
Arroyo del Coyote	79	Upgradient	2.50	0.11	0.05
	72	Mid-arroyo	1.70	0.20	0.08
	75	Downgradient	1.30	0.30	NR
Tijeras Arroyo	65E	Upgradient1	2.30	0.25	0.19
	73	Upgradient2	2.10	0.00	NR
	74	Mid-arroyo	1.80	0.12	NR
	60	Downgradient	1.80	-0.04	0.08
River/Stream	8	River upgradient	1.11	0.04	0.19
	68	Stream	0.97	0.03	0.04
	11	River downgradient	0.97	0.18	0.09
August, 1995					
Arroyo del Coyote	79	Upgradient	1.60	-0.06	0.12
	72	Mid-arroyo	1.20	-0.07	0.05
	75	Downgradient	1.20	0.20	NR
Tijeras Arroyo	65E	Upgradient1	1.30	0.11	NR
	73	Upgradient2	1.60	0.12	NR
	74	Mid-arroyo	1.30	0.11	NR
	60	Downgradient	1.40	0.52	0.05
River/Stream	8	River upgradient	1.20	0.10	0.15
	68	Stream	2.00	0.12	0.07
	11	River downgradient	0.73	0.08	0.07

Note:

$\mu\text{g/g}$ = micrograms per gram; pCi/mL = pico curies per milliliter; pCi/g = pico curies per gram; NR = Cesium-137 concentrations were not detected at these locations.

Locations 65E, 75 and 79 are a new locations for data collection in 1995 and no comparison of data over years was made.

Table 3-5. Concentrations of surface-water radionuclides, May 1995.

Analysis (Units)	Location Type	Loc No.	Total Water	Filtered Water	Suspended Solids
Gross Alpha (pCi/L)	River upgradient	8	1	1	-3.24
	River downgradient	11	2	1	-0.59
	On site	33	16	32	-3.53
	Stream	68	-1	0	-0.59
Gross Beta (pCi/L)	River upgradient	8	4	3	-1.18
	River downgradient	11	6	3	1.18
	On site	33	44	66	-7.35
	Stream	68	-1	1	-0.29
Uranium-total (mg/L)	River upgradient	8	0.0018	0.0016	0.0002
	River downgradient	11	0.0019	0.0017	0.0001
	On site	33	0.0052	0.0062	*0.0000
	Stream	68	0.0011	0.0012	0.0001
Tritium (pCi/mL)	River upgradient	8	-0.03	0.03	NA
	River downgradient	11	0.06	-0.10	NA
	On site	33	-0.02	0.02	NA
	Stream	68	0.02	0.01	NA

Note: pCi/L = picocuries per liter; mg/L = milligrams per liter; pCi/mL = picocuries per milliliter; NA = filters were not analyzed for tritium. * Numerical rounding result.

Gross Alpha - concentrations over the past 5 years, at on site location 33, were also higher than off site values for Suspended Solids and were therefore classified as Category 2. The 1995 Gross Alpha activities at location 33 were higher than the off site locations, and exceeded the federal drinking water standard (15 pCi/L). Location 33 (Coyote Springs) is on site and has been controlled for access. It has also been posted as "Not a Source for Drinking Water."

Gross Beta and H-3 - Based on data from the past 5 years, Gross Beta and H-3 from location 33 did not show concentrations that were statistically significant from the background concentrations.

Table 3-6. Concentrations of surface-water radionuclides, August 1995.

Analysis (Units)	Location Type	Loc No.	Total Water	Filtered Water	Suspended Solids
Gross Alpha (pCi/L)	River upgradient	8	2	3	0.29
	River downgradient	11	2	1	0
	On site	33	38	28	-0.09
	Stream	68	NR	NR	NR
Gross Beta (pCi/L)	River upgradient	8	5	7	0.29
	River downgradient	11	8	5	0.88
	On site	33	51	28	-0.29
	Stream	68	NR	NR	NR
Uranium, total (mg/L)	River upgradient	8	0.0019	0.0018	*
	River downgradient	11	0.0019	0.0018	0.0001
	On site	33	0.0059	0.0060	0.0000
	Stream	68	NR	NR	NR
Tritium (pCi/mL)	River upgradient	8	0.11	0	NA
	River downgradient	11	0.04	0	NA
	On site	33	-0.13	0.02	NA
	Stream	68	NR	NR	NA

Note: pCi/L = picocuries per liter; mg/L = milligrams per liter; pCi/mL = picocuries per milliliter; NA = filters were not analyzed for tritium. NR = No sample was taken at location 68 because the stream bed was dried up. * Sample was not analyzed for U_{tot}.

Upgradient versus Downgradient - Location 8 is on the Rio Grande upgradient of SNL/NM and Albuquerque; location 11 is downgradient. In addition to the trend analysis, data from upgradient and downgradient samples taken from the Rio Grande were compared to determine potential contributions from Albuquerque and the surrounding areas. The results showed there was no statistically significant difference between the upgradient and downgradient locations (Shyr, et al. 1996).

3.1.5 Environmental Thermoluminescent Dosimeters (TLD) Results

Table 3-7 summarizes the 1995 annual dose equivalent estimates for the on site, perimeter, and off site locations. These estimates include total external gamma measurements from both natural

Table 3-7. Summary of thermoluminescent dosimeter measurements for 1995.

Location	Number of Locations	Mean	Annual External Dose Equivalent (mrem/year)	
			Standard Deviation	Range
On site- SNL/NM (S)	14	99.74	4.07	93.10 - 107.70
Perimeter (P)	7	98.51	11.60	88.50 - 120.02
Off site- Community (C)	11	97.86	8.28	89.10 - 114.20

background (e.g., cosmic rays) and man-made sources (e.g., facility contributions, if any). One datum point was excluded from the summary statistics because the TLD from one off site location (24) was not recovered during the fourth quarter in 1995. Because the mean and the standard deviation, and the range were similar for on site, perimeter, and off site locations, the individual sites were not compared to the mean of the off site locations as is the approach used for all other radiological data. Instead, the means of the three location groups were compared to detect any difference using a one-way analysis of variance (Shyr, et al. 1996). It appears that for the 13 years worth of data (1983 - 1995), on site locations for TLD measurements are slightly higher than background locations. There is no statistical difference between measurements taken at perimeter and background locations.

In addition to the comparison of means for the three location types, TLD data from 1983 to 1995 were analyzed to detect any trend (Shyr, et al., 1996). TLD measurements from on site, perimeter, and off site locations were consistent over the past 13 years, although measurements from on site locations were approximately 9 percent higher than measurements from perimeter and off site locations during the period from 1986 through 1989 (Figure 3-6). No trend was detected.

3.2 TERRESTRIAL NON RADIOLOGICAL RESULTS

Beginning in 1993, the scope of the terrestrial surveillance program was broadened to include sample analysis for metals in soil. Samples were analyzed for the following 20 metals:

aluminum (Al)	barium (Ba)	beryllium (Be)
cadmium (Cd)	calcium (Ca)	chromium (Cr)
cobalt (Co)	copper (Cu)	iron (Fe)
lead (Pb)	magnesium (Mg)	manganese (Mn)
nickel (Ni)	potassium (K)	silicon (Si)
silver (Ag)	strontium (Sr)	titanium (Ti)
vanadium (V)	zinc (Zn)

Figure 3-6. Mean Thermoluminescent Dosimeter Dose Estimate by Year

As was done for radiological results, a trend comparison was performed to determine if concentrations were increasing for any on site/perimeter location over the years. Next, metal concentrations from these locations were compared to community (background) concentrations. The same classification scheme (Categories 1-4) used for radiological comparisons was used for non radiological results.

All soil and sediment samples were analyzed by Environmental Protection Agency (EPA) method 6010 A, "Inductively Coupled Plasma-Atomic Emission Spectroscopy (ICP-AES)." Samples were first prepared using EPA method 3050 A, which does not allow for complete dissolution of metals and therefore, only provides a measure of the concentration of metals in soil that can be leached and remain dissolved in the digestion solution (Shyr, et al. 1996).

There are numerous soil types on Kirtland Air Force Base (KAFB) and composition and mineralogy differences among these different soil types are to be expected (USDA 1977). Funding has not been available to match on site, perimeter, and off site sampling locations by soil type.

Aluminum, calcium, iron, magnesium, potassium, and silicon occur in abundance within the soil as naturally occurring components of minerals (e.g., calcite, feldpars, quartz, and clays). They have a low health impact and there are no primary drinking water standards or Resource Conservation and Recovery Act (RCRA) toxicity characteristics established for these metals. Due to these reasons, the above metals are not discussed further within the context of this report. The data for individual sample locations are reported in the *1995 Environmental Surveillance Data Analysis Report* (Shyr, et al. 1996).

3.2.1 Soil Results - Metals

Tables 3-8 and 3-9 provide summary statistics of soil samples. Qualitatively, on site concentrations for all the metals except lead and titanium were lower than off site values which also showed relatively larger variations among locations. Table 3-10 lists the categorization for metal analysis for on site and perimeter locations.

Table 3-8. Summary statistics for metal concentrations in soil, May 1995.

Metal	Units	Description	Count	Median	Mean	Stand Dev.	Range	
Barium	mg/kg	SNL/NM	31	90.00	96.03	25.28	68	to 170
	mg/kg	Perimeter	14	103.00	113.21	35.26	64	to 190
	mg/kg	Off site	6	170.00	163.33	44.12	110	to 230
Beryllium	mg/kg	SNL/NM	31	0.50*	0.55	0.14	0.5	to 1.1
	mg/kg	Perimeter	14	0.50*	0.53	0.07	0.5	to 0.7
	mg/kg	Off site	6	0.65	0.62	0.10	0.5	to 0.7
Cadmium	mg/kg	SNL/NM	31	0.50*	0.59	0.30	0.5	to 1.9
	mg/kg	Perimeter	14	0.50*	0.50	0.00	0.5	to 0.5
	mg/kg	Off site	6	0.50*	0.50	0.00	0.5	to 0.5
Chromium	mg/kg	SNL/NM	31	30.00	28.44	12.87	4.7	to 60
	mg/kg	Perimeter	14	20.50	23.57	8.35	12	to 39
	mg/kg	Off site	6	28.50	28.50	9.09	17	to 42
Cobalt	mg/kg	SNL/NM	31	3.60	3.86	0.88	2.6	to 5.9
	mg/kg	Perimeter	14	4.85	5.13	1.99	2.6	to 8.8
	mg/kg	Off site	6	5.75	5.45	2.34	2.4	to 8.7
Copper	mg/kg	SNL/NM	31	9.10	9.51	2.87	5.4	to 18
	mg/kg	Perimeter	14	11.00	10.74	3.35	5.2	to 18
	mg/kg	Off site	6	14.00	17.15	10.96	5.9	to 33
Lead	mg/kg	SNL/NM	31	13.00	463.19	2512.33	5	to 14000**
	mg/kg	Perimeter	14	11.00	12.71	4.01	8	to 19
	mg/kg	Off site	6	14.00	21.83	20.88	5	to 62
Manganese	mg/kg	SNL/NM	31	170.00	182.90	50.41	110	to 320
	mg/kg	Perimeter	14	275.00	276.43	130.36	120	to 570
	mg/kg	Off site	6	350.00	373.33	158.07	190	to 560
Nickel	mg/kg	SNL/NM	31	8.00	8.35	2.33	4	to 15
	mg/kg	Perimeter	14	8.50	8.29	2.67	4	to 12
	mg/kg	Off site	6	11.50	11.00	6.00	4	to 20
Silver	mg/kg	SNL/NM	31	0.50*	0.51	0.02	0.5	to 0.6
	mg/kg	Perimeter	14	0.50*	0.53	0.07	0.5	to 0.7
	mg/kg	Off site	6	0.50*	0.50	0.00	0.5	to 0.5
Strontium	mg/kg	SNL/NM	31	26.00	37.90	29.11	14	to 140
	mg/kg	Perimeter	14	35.50	60.21	71.73	12	to 290
	mg/kg	Off site	6	75.50	86.00	51.53	33	to 180

Table 3-8. Summary statistics for metal concentrations in soil, May 1995 (Concluded).

Metal	Units	Description	Count	Median	Mean	Stand Dev.	Range
Titanium	mg/kg	SNL/NM	31	210.00	233.87	82.69	100 to 470
	mg/kg	Perimeter	14	240.00	271.43	147.80	100 to 560
	mg/kg	Off site	6	104.50	111.50	23.81	82 to 140
Vanadium	mg/kg	SNL/NM	31	15.00	16.19	4.21	11 to 29
	mg/kg	Perimeter	14	17.00	18.71	6.22	9.9 to 32
	mg/kg	Off site	6	22.50	20.17	6.18	12 to 27
Zinc	mg/kg	SNL/NM	31	31.00	33.94	10.87	20 to 72
	mg/kg	Perimeter	14	37.50	40.79	17.11	20 to 78
	mg/kg	Off site	6	45.50	43.00	11.76	24 to 57

Note: *Analytical laboratory reported results at detection limit because results fell below the detection limit.

**The high lead concentration (14,000 ppm) at location 20 had a significant impact on the mean value. The mean for SNL/NM would be 11.97 if location 20 was excluded from analysis.

mg/kg = milligrams per kilogram.

Table 3-9. Summary statistics for metal concentrations in soil, August 1995.

Metal	Units	Description	Count	Median	Mean	Stand Dev.	Range	
Barium	mg/kg	SNL/NM	31	79.00	87.90	25.45	58	to 160
	mg/kg	Perimeter	13	115.00	122.08	35.35	56	to 190
	mg/kg	Off site	6	165.00	161.67	40.70	110	to 210
Beryllium	mg/kg	SNL/NM	31	0.50*	0.53	0.10	0.5	to 1.0
	mg/kg	Perimeter	13	0.50*	0.56	0.09	0.5	to 0.7
	mg/kg	Off site	6	0.75	0.70	0.17	0.5	to 0.9
Cadmium	mg/kg	SNL/NM	31	0.50*	0.59	0.30	0.5	to 1.9
	mg/kg	Perimeter	13	0.50*	0.51	0.03	0.5	to 0.6
	mg/kg	Off site	6	0.50*	0.50	0.00	0.5	to 0.5
Chromium	mg/kg	SNL/NM	31	15.00	16.06	3.36	8	to 23
	mg/kg	Perimeter	13	18.50	19.00	4.26	14	to 30
	mg/kg	Off site	6	22.00	22.67	3.14	19	to 28
Cobalt	mg/kg	SNL/NM	31	3.95	4.24	0.95	2.9	to 6.4
	mg/kg	Perimeter	13	5.60	5.48	1.83	2.7	to 8.0
	mg/kg	Off site	6	5.65	5.47	2.12	2.9	to 8.1
Copper	mg/kg	SNL/NM	31	8.00	8.74	2.24	6	to 13
	mg/kg	Perimeter	13	10.50	10.92	4.27	5	to 21
	mg/kg	Off site	6	12.00	11.67	5.47	5	to 20
Lead	mg/kg	SNL/NM	31	11.00	18.32	41.21	7	to 240
	mg/kg	Perimeter	13	12.50	13.46	4.12	7	to 23
	mg/kg	Off site	6	13.00	15.17	8.70	7	to 32
Manganese	mg/kg	SNL/NM	31	170.00	190.00	52.85	120	to 320
	mg/kg	Perimeter	13	290.00	287.69	137.00	130	to 590
	mg/kg	Off site	6	395.00	370.00	124.58	200	to 500
Nickel	mg/kg	SNL/NM	31	7.00	8.16	2.25	6	to 15
	mg/kg	Perimeter	13	8.50	9.23	3.14	4	to 13
	mg/kg	Off site	6	10.50	11.00	5.40	4	to 19
Silver	mg/kg	SNL/NM	31	0.50*	0.52	0.06	0.5	to 0.8
	mg/kg	Perimeter	13	0.50*	0.52	0.06	0.5	to 0.7
	mg/kg	Off site	6	0.50*	0.50	0.00	0.5	to 0.5
Strontium	mg/kg	SNL/NM	31	25.50	36.42	29.95	13	to 150
	mg/kg	Perimeter	13	45.00	53.92	45.99	10	to 180
	mg/kg	Off site	6	68.50	71.17	22.46	40	to 99

Table 3-9. Summary statistics for metal concentrations in soil, August 1995 (concluded).

Metal	Units	Description	Count	Median	Mean	Stand Dev	Range
Titanium	mg/kg	SNL/NM	31	140.00	191.10	126.60	58 to 460
	mg/kg	Perimeter	13	255.00	267.69	196.42	51 to 820
	mg/kg	Off site	6	230.00	208.33	64.94	120 to 280
Vanadium	mg/kg	SNL/NM	31	17.50	18.65	5.33	12 to 29
	mg/kg	Perimeter	13	23.50	23.54	6.39	10 to 37
	mg/kg	Off site	6	32.00	28.83	9.28	15 to 39
Zinc	mg/kg	SNL/NM	31	32.00	33.71	12.29	21 to 75
	mg/kg	Perimeter	13	40.50	41.46	15.50	20 to 74
	mg/kg	Off site	6	39.00	37.17	11.62	23 to 51

Note: *Analytical laboratory reported results at detection limit because results fell below the detection limit.

mg/kg = milligrams per kilogram.

Table 3-10 Discussion

Cadmium - Concentrations at location 20 were above the background concentration levels, but no trend was detected. The current concentration levels of cadmium (~2 ppm) were about an order of magnitude lower than the concentration that would show RCRA toxicity characteristics (Shyr, et al. 1996). It should be noted that cadmium was below the detection limit for most locations. When a metal concentration was below the detection limit, the result was recorded by the analytical laboratory as at the detection limit. As a result, any deviation from the detection limit was detected as statistically significant. This example demonstrated the need of a closer examination of the data for an appropriate interpretation of "statistically significant" results.

Cobalt - An increasing trend for cobalt at on site location 35 was observed, although, the concentration levels were below background concentration levels. Monitoring at this location will continue. Perimeter location 64 was noted for having cobalt concentrations (along with cobalt, manganese, and zinc) above the background concentrations, but no trend was present. The maximum concentration level of cobalt (14 ppm) was at least two orders of magnitude lower than the proposed RCRA action limit (4800 ppm), and was within the range of U.S. Surface Soil background cobalt concentrations (3-50 ppm).

Table 3-10. Locations with metal concentrations classified by category.

Note: barium, beryllium, nickel, silver, vanadium, strontium, and chromium did not occur in Category 1,2, or 3.

Radionuclide	Category	On site Location No.	Perimeter Locations No.
Cadmium	Category 1	None	None
	Category 2	20	None
	Category 3	None	None
Cobalt	Category 1	None	None
	Category 2	None	64
	Category 3	35	None
Copper	Category 1	None	None
	Category 2	None	None
	Category 3	2SE	None
Lead	Category 1	None	None
	Category 2	20	None
	Category 3	55	None
Manganese	Category 1	None	None
	Category 2	None	64
	Category 3	None	None
Titanium	Category 1	None	None
	Category 2	None	16
	Category 3	None	None
Zinc	Category 1	None	None
	Category 2	None	64
	Category 3	None	None

Copper - On site location 2SE was the only location observed to have an increasing trend for copper concentrations, however, concentration levels were not statistically different from the background values. Monitoring at this location will continue.

Lead - On site location 55 showed an increasing trend for lead concentration, but was less than the background concentration levels. Monitoring at this location will continue. On site location 20 had concentration levels greater than the community average over time. Location 20 is adjacent to the KAFB skeet shooting range. The higher concentrations of lead at this location are most likely due to the presence of lead shot within the sample. If that is the case, the high soil

lead values might not meet the RCRA lead toxicity characteristics. Soils from this location may be analyzed by EPA method 1311, "Toxic Compound Leaching Procedure," to determine whether the lead value exceeds the maximum concentration specified in 40 CFR 261.24, Table 1.

Manganese and Zinc - Perimeter location 64 showed concentration levels for manganese and zinc above the community level, but did not show an increasing trend. The maximum concentrations for manganese and zinc at location 64, were 760 parts per million (ppm) and 110 ppm, respectively. Although these concentrations were higher than the community values, they were still within the range of U.S. Surface Soil background levels which are 20-3000 ppm for manganese and 13-300 ppm for zinc (CRC 1992). The zinc concentration, 110 ppm, was at least two orders of magnitude lower than the proposed RCRA Subpart S action level, 23,000 ppm; however, the manganese concentration, 760 ppm, was higher than the RCRA action level, 400 ppm. Both manganese and zinc are considered non-carcinogenic. Monitoring at this location will continue.

Titanium - Concentrations were statistically higher at perimeter location 16 as compared to background concentrations. However, there was no increasing trend for titanium concentrations at this or any other location. Although location 16 showed titanium concentrations higher than background, the concentrations were still in the range of U.S. Surface Soil concentrations (50 - 1000 ppm).

3.2.2 Sediment Results - Metals

Table 3-11 summarizes the data for sediment samples taken from the Rio Grande, Las Huertas Creek, and two arroyos in May and August of 1995. Trend analysis and comparison to off site (background) locations were performed for all locations using data from 1993 to 1995. There were no Category 1 locations observed for sediment samples. Perimeter location 60 showed titanium concentrations above the off site (background) values and was classified as Category 2. Perimeter location 73 had an increasing trend for lead concentration and was classified as Category 3. No other metal concentrations were observed as Category 2 or Category 3.

Location 73 is in the Tijeras Arroyo, on the east side of KAFB where it enters the site perimeter; location 60 is at the perimeter on the west side of KAFB where the Tijeras Arroyo leaves the KAFB boundary, downgradient from SNL/NM. Data from 1993 to 1995 were used to determine if there was any statistically significant differences between upgradient and downgradient metal concentrations in the Tijeras Arroyo; the results showed no statistically significant difference (Shyr, et al. 1996). Location 8 is on the Rio Grande upgradient of SNL/NM and Albuquerque; location 11 is on the river downgradient from the site. No statistically significant difference was detected based on the past three years of data.

Table 3-11. Concentrations of metal in sediments. Samples, from May and August 1995.

Sediment Type	Location Description	Loc No.	Ba	Be	Cd	Cr	Co	Cu (mg/kg or ppm)	Pb	Mn	Ni	Ag	Ti	V	Zn
<u>May, 1995</u>															
Tijeras Arroyo	Upgradient 1	65E	44.00	0.50	0.50	61.00	4.60	9.10	6.00	170.00	6.00	0.50	860.00	16.00	22.00
Tijeras Arroyo	Upgradient 2	73	55.00	0.50	0.50	20.00	4.60	8.00	7.00	200.00	4.00	0.50	500.00	13.00	26.00
Tijeras Arroyo	Mid-arroyo	74	140.00	0.50	0.50	34.00	5.30	7.30	10.00	220.00	6.00	0.50	660.00	30.00	26.00
Tijeras Arroyo	Downgradient	60	110.00	0.50	0.50	19.00	4.20	8.00	9.00	230.00	6.00	0.50	450.00	16.00	29.00
Arroyo del Coyote	Upgradient	79	89.00	0.50	0.50	42.00	2.80	7.60	7.00	250.00	10.00	0.50	59.00	13.00	28.00
Arroyo del Coyote	On site	72	120.00	0.50	0.50	47.00	4.90	12.00	16.00	270.00	10.00	0.50	230.00	22.00	34.00
Arroyo del Coyote	Downgradient	75	39.00	0.50	0.50	30.00	4.10	8.20	5.00	190.00	8.00	0.50	430.00	15.00	22.00
River/Stream	River upgradient	8	200.00	0.50	0.50	36.00	3.60	8.30	7.00	180.00	5.00	0.50	160.00	15.00	25.00
River/Stream	Stream	68	350.00	0.50	0.50	28.00	2.80	5.70	8.00	410.00	9.00	0.50	160.00	13.00	29.00
River/Stream	River downgradient	11	180.00	0.50	0.50	56.00	3.50	7.30	7.00	250.00	7.00	0.50	140.00	19.00	26.00
<u>August, 1995</u>															
Tijeras Arroyo	Upgradient 1	65E	53.00	0.50	0.50	28.00	4.10	7.00	7.00	220.00	5.00	0.50	920.00	18.00	26.00
Tijeras Arroyo	Upgradient 2	73	47.00	0.50	0.60	21.00	5.10	8.00	7.00	200.00	4.00	0.50	620.00	18.00	25.00
Tijeras Arroyo	Mid-arroyo	74	190.00	0.50	0.50	20.00	5.80	11.00	10.00	260.00	7.00	0.60	650.00	28.00	34.00
Tijeras Arroyo	Downgradient	60	93.00	0.50	0.50	26.00	4.80	8.00	7.00	220.00	7.00	0.50	740.00	24.00	26.00
Arroyo del Coyote	Upgradient	79	100.00	0.50	0.60	14.00	2.90	6.00	7.00	290.00	8.00	0.50	44.00	13.00	31.00
Arroyo del Coyote	On site	72	74.00	0.50	0.50	18.00	4.50	10.00	10.00	240.00	9.00	0.50	170.00	20.00	33.00
Arroyo del Coyote	Downgradient	75	38.00	0.50	0.50	20.00	4.40	9.00	5.00	200.00	7.00	0.50	440.00	20.00	22.00
River/Stream	River upgradient	8	160.00	0.50	0.50	33.00	4.40	11.00	31.00	260.00	8.00	0.50	260.00	21.00	36.00
River/Stream	Stream	68	180.00	0.70	0.50	36.00	5.30	10.00	12.00	330.00	12.00	0.50	340.00	28.00	35.00
River/Stream	River downgradient	11	180.00	0.50	0.50	22.00	3.10	6.00	6.00	170.00	5.00	0.50	190.00	19.00	25.00

3.2.3 Surface Water Results - Metals

Tables 3-12 and 3-13 summarize the data for surface water taken from three off site locations, 8, 11, and 68, and one on site location 33, in May and August 1995. Only two years of data (1994 and 1995) from surface waters were used for metal concentration analysis because the 1993 water samples were not analyzed for metals. Using the data from the past two years, no trend was detected.

Table 3-12. Concentrations of surface-water metals, May 1995.

Analysis (Units)	Location Type	Loc No.	Total Water	Filtered Water	Suspended Solids
Barium (mg/L)	River upgradient	8	0.08	0.06	0.016
	River downgradient	11	0.09	0.06	0.014
	On site	33	0.05	0.05	0.003
	Stream	68	0.12	0.09	0.013
Beryllium (mg/L)	River upgradient	8	0.005	0.005	0.000
	River downgradient	11	0.005	0.005	0.000
	On site	33	0.006	0.005	0.000
	Stream	68	0.005	0.005	0.000
Cadmium (mg/L)	River upgradient	8	0.005*	0.005*	0.001
	River downgradient	11	0.005*	0.005*	0.000
	On site	33	0.005*	0.005*	0.000
	Stream	68	0.005*	0.005*	0.001
Chromium (mg/L)	River upgradient	8	0.005*	0.005*	0.001
	River downgradient	11	0.005*	0.005*	0.001
	On site	33	0.005*	0.005*	0.000
	Stream	68	0.005*	0.005*	0.001
Cobalt (mg/L)	River upgradient	8	0.005*	0.005*	0.010
	River downgradient	11	0.005*	0.005*	0.007
	On site	33	0.007	0.009	0.003
	Stream	68	0.005*	0.005*	0.006
Copper (mg/L)	River upgradient	8	0.005	0.005	0.003
	River downgradient	11	0.005	0.005	0.002
	On site	33	0.005	0.005	0.001
	Stream	68	0.005	0.005	0.002
Lead (mg/L)	River upgradient	8	0.05*	0.05*	0.003*
	River downgradient	11	0.05*	0.05*	0.003*
	On site	33	0.05*	0.05*	0.003*
	Stream	68	0.05*	0.05*	0.003*
Manganese (mg/L)	River upgradient	8	0.083	0.005*	0.053
	River downgradient	11	0.120	0.005*	0.047
	On site	33	1.200	1.300	0.002
	Stream	68	0.043	0.005*	0.022

Table 3-12. Concentrations of surface-water metals, May 1995 (Concluded).

Analysis (Units)	Location Type	Loc No.	Total Water	Filtered Water	Suspended Solids
Nickel (mg/L)	River upgradient	8	0.02	0.02	0.001
	River downgradient	11	0.02	0.02	0.001
	On site	33	0.03	0.04	0.001
	Stream	68	0.02	0.02	0.001
Silver (mg/L)	River upgradient	8	0.005*	0.005*	0.000*
	River downgradient	11	0.005*	0.005*	0.000*
	On site	33	0.005*	0.005*	0.000*
	Stream	68	0.005*	0.005*	0.000*
Strontium (mg/L)	River upgradient	8	0.27	0.27	NA
	River downgradient	11	0.27	0.26	NA
	On site	33	1.30	1.30	NA
	Stream	68	0.17	0.16	NA
Titanium (mg/L)	River upgradient	8	0.05	0.01*	NA
	River downgradient	11	0.07	0.01*	NA
	On site	33	0.01	0.01*	NA
	Stream	68	0.05	0.01*	NA
Vanadium (mg/L)	River upgradient	8	0.006	0.005*	0.003
	River downgradient	11	0.009	0.005*	0.002
	On site	33	0.005*	0.005*	0.000
	Stream	68	0.005*	0.005*	0.001
Zinc (mg/L)	River upgradient	8	0.010	0.005*	0.010
	River downgradient	11	0.013	0.005*	0.005
	On site	33	0.051	0.056	0.001
	Stream	68	0.008	0.005*	0.004

Note: pCi/L = picocuries per liter; mg/L = milligrams per liter; pCi/mL = picocuries per milliliter; NA = filters were not analyzed for tritium. *Analytical laboratory reported results at detection limit because results fell below the detection limit.

Table 3-13. Concentrations of surface-water metals, August 1995.

Analysis (Units)	Location Type	Loc No.	Total Water	Filtered Water	Suspended Solids
Barium (mg/L)	River upgradient	8	0.08	0.07	0.019
	River downgradient	11	0.08	0.07	0.016
	On site	33	0.05	0.05	0.006
	Stream	68	NR	NR	NR
Beryllium (mg/L)	River upgradient	8	0.005	0.005	0.001
	River downgradient	11	0.005	0.005	0.001
	On site	33	0.005	0.005	0.001
	Stream	68	NR	NR	NR
Cadmium (mg/L)	River upgradient	8	0.005*	0.005*	0.001
	River downgradient	11	0.005*	0.005*	0.001
	On site	33	0.005*	0.005*	0.001
	Stream	68	NR	NR	NR
Chromium (mg/L)	River upgradient	8	0.005*	0.005*	0.001
	River downgradient	11	0.005*	0.005*	0.002
	On site	33	0.005*	0.005*	0.001
	Stream	68	NR	NR	NR
Cobalt (mg/L)	River upgradient	8	0.005*	0.005*	0.001*
	River downgradient	11	0.005*	0.005*	0.001*
	On site	33	0.007	0.007	0.001*
	Stream	68	NR	NR	NR
Copper (mg/L)	River upgradient	8	0.005	0.005	0.004
	River downgradient	11	0.005	0.005	0.004
	On site	33	0.006	0.005	0.002
	Stream	68	NR	NR	NR
Lead (mg/L)	River upgradient	8	0.05*	0.05*	0.006*
	River downgradient	11	0.05*	0.05*	0.006*
	On site	33	0.05*	0.05*	0.006*
	Stream	68	NR	NR	NR
Manganese (mg/L)	River upgradient	8	0.075	0.005*	0.118
	River downgradient	11	0.058	0.009	0.076
	On site	33	1.300	1.200	0.004
	Stream	68	NR	NR	NR

Table 3-13. Concentrations of surface-water metals, August 1995 (Concluded).

Analysis (Units)	Location Type	Loc No.	Total Water	Filtered Water	Suspended Solids
Nickel (mg/L)	River upgradient	8	0.02	0.02	0.002*
	River downgradient	11	0.02	0.02	0.002*
	On site	33	0.02	0.02	0.002*
	Stream	68	NR	NR	NR
Silver (mg/L)	River upgradient	8	0.005*	0.005*	0.001*
	River downgradient	11	0.005*	0.005*	0.001*
	On site	33	0.005*	0.005*	0.001*
	Stream	68	NR	NR	NR
Strontium (mg/L)	River upgradient	8	0.28	0.28	NA
	River downgradient	11	0.29	0.29	NA
	On site	33	1.30	1.30	NA
	Stream	68	NR	NR	NA
Titanium (mg/L)	River upgradient	8	0.02	0.01*	NA
	River downgradient	11	0.02	0.01*	NA
	On site	33	0.01*	0.01*	NA
	Stream	68	NR	NR	NA
Vanadium (mg/L)	River upgradient	8	0.005*	0.005*	0.002
	River downgradient	11	0.007	0.005*	0.002
	On site	33	0.005*	0.005*	0.001
	Stream	68	NR	NR	NR
Zinc (mg/L)	River upgradient	8	0.005*	0.006	0.013
	River downgradient	11	0.007	0.006	0.011
	On site	33	0.052	0.052	0.004
	Stream	68	NR	NR	NR

Note: pCi/L = picocuries per liter; mg/L = milligrams per liter; pCi/mL = picocuries per milliliter; NR = No results for location 68 in August 1995 because stream bed was dried up. *Analytical laboratory reported results at detection limit because results fell below the detection limit.

Coyote Springs - On site location 33 at Coyote Springs was a Category 3 location with a few metal concentrations higher than the background (Table 3-14). The maximum concentration of strontium in water (1.4 mg/L) at location 33 was an order of magnitude lower than the RCRA proposed action level (21 mg/L). The maximum concentration of manganese in water (1.3 mg/L) at location 33 exceeded all federal and state drinking water standards which range from 0.05 to 0.2 mg/L. This location is on site and had controlled access and was posted as "Not a Drinking Water Source."

Table 3-14. Metals concentrations at on site location 33 which were above off site concentrations.

Metal	Total Water	Filtered Water	Suspended Solids
Manganese	✓	✓	-
Strontium	✓	✓	-

Data from 1994 and 1995 were used to determine whether there was a statistically significant difference between upgradient and downgradient metal concentrations in the Rio Grande. Location 8 is at the river upgradient of SNL/NM and Albuquerque; location 11 is downgradient, south of Albuquerque. The results showed no statistically significant difference (Shyr, et al. 1996).

4.0 COMPARISON OF MAY AND AUGUST SAMPLING PERIODS

Sampling events have occurred twice a year since 1992; once in May and once in August. During 1991, only one sampling event was performed for the year (August). May is the start of the growing season and August is towards the end of the growing season. Results from the May and August sampling periods were compared to determine if there were any differences and to determine if annual sampling was sufficient. Data from August 1991 to May 1995 were used in this analysis. Data from 1991 to present were selected, since during this time period, the same analytical laboratory was used and therefore, provided consistent analytical procedures [Shyr and Skipper 1995].

4.1 Checking for Normality

A two-sample t-test was the first statistical test of choice to test whether there was a difference in results from the May and August sampling periods. A two sample t-test assumes that the data are normally distributed and the variances between the two sampling periods are equal.

Data was checked for normality using the Kolmogorov test statistic under PROC UNIVARIATE in SAS. Several radionuclides and metals did not meet the normality assumptions (these were primarily radionuclides or metals that had many values close to the detection limit). PROC TTEST, the two-sample t-test in SAS, also tested for equality of variances. In several cases, this assumption was not met.

4.2 Wilcoxon Two Sample Test

Due to the fact that normality of the data values was questionable and that there was the issue of non-equality of the variances, the Wilcoxon (also known as Mann-Whitney) test was used. The Wilcoxon test is a non-parametric test based on the ranks of the combined sample results. The Wilcoxon test statistic is the sum of the ranks for the sample. If the sum of the ranks is different for one sample when compared to the other sample the test is rejected and it is said that there is a difference between the two samples.

Hypothesis Statement:

H₀: There is no difference between the May and August sampling periods.

H_a: There is a difference between the May and August sampling periods.

This hypothesis was assumed for each analyte (radiological and non radiological). Wilcoxon test results that showed a difference between the sampling periods are discussed in further detail below.

Test Statistic:

The Wilcoxon test statistic which is used to evaluate the test is based on the number of samples and the sum of the ranks. Although the formula for the test statistic looks formidable, it is fairly easy to compute.

$$T_1 = \frac{T - n \frac{N+1}{2}}{\sqrt{\frac{nm}{N(N-1)} \sum_{i=1}^N R_i^2 - \frac{nm(N+1)^2}{4(N-1)}}$$

where:

T₁ represents the Wilcoxon test statistic

T represents the sum of the ranks for the May sampling period

n represents the number of observations in the May sampling period

m represents the number of observations in the August sampling period

N represents the total number of observations for the two sampling periods, and

R_i represents the rank for the ith observation in the two sampling periods.

The test statistic is then compared to a table containing the quantiles of the Mann-Whitney test statistic (Conover, Practical NonParametric Statistics, Table A7, page 448). If the test statistic is greater than the quantile value, the test is rejected and is said that there is a difference between the May and August sampling periods. SAS computes the Wilcoxon test statistic as a sub-procedure under PROC NPARWAY1.

4.3 Radiological Results

The following sections discuss in detail the results of the Wilcoxon test performed to determine if a difference exist between the May and August sampling periods for radiological results. The results are discussed by matrix.

4.3.1 Vegetation

There was no difference between May and August for radiological results for vegetation samples.

4.3.2 Soil

Cesium-137 and total uranium showed no difference between May and August sampling periods. There was a difference detected for tritium results. It appears that May tritium results were slightly higher than August results. Table 4-1 shows the summary statistics for tritium separated for each sampling period.

Table 4-1. Summary statistics for tritium by sampling period.

Sampling Period	Sample Size	Median	Average Result	Standard Deviation
May	188	0.125	18.89	171.28
August	234	0.070	14.20	126.42

Looking at table 4-1, it is seen that the average results are much higher than the median; this is due to locations with known tritium contamination. It was decided to re-do, the analysis of comparing the May and August sampling periods without the locations of known contamination. Table 4-2 shows the summary statistics for tritium concentrations without the locations of known contamination.

Table 4-2. Summary statistics for tritium by sampling period without locations of known contamination.

Sampling Period	Sample Size	Median	Average Result	Standard Deviation
May	175	0.11	0.371	1.055
August	220	0.06	0.414	1.314

Notice that both the mean and standard deviation are greatly decreased by removing those locations of known tritium contamination. The median concentration is fairly consistent with those seen in table 4-1 (all locations). It was determined that even with the more consistent results, the data distributions were not normal. In view of the non-normality of the data, the Wilcoxon test for the differences between two samples was used. This also determined that there is still a difference between the May and August sampling periods. Even though May has a lower average result, it appears that based on the ranks of the observations, May has the higher sum of ranks, indicating that May results are statistically higher than August results. Although this is a statistical difference, this difference is not operationally significant.

4.3.3 Sediment

There was no difference between May and August for radiological results for sediment samples.

4.3.4 Filtered Water

There was no difference between May and August for radiological results for filtered water samples.

4.3.5 Unfiltered Water

There was no difference between May and August for radiological results for unfiltered water samples.

4.3.6 Filters

There was no difference between May and August for radiological results for filter samples.

4.4 Non radiological Results

Non radiological sampling commenced in 1993 for soil and sediment samples. In 1994, water and filters also began to be tested for non radiological components. Because of this, there are fewer samples to test for differences. However, it was still felt that the Wilcoxon test is sensitive enough to test for differences between the May and August sampling periods. The following sections discuss in detail any differences the Wilcoxon test described above may have noted for metals. These differences are discussed by matrix of sample. Section 3.2 contains a list of the metals used for non radiological sampling.

4.4.1 Soil

Table 4-3 shows the summary statistics for the soil non radiological data by sampling period. In all cases, the median was less than the mean indicating that results were skewed towards the right. Looking at the average result, it appears that chromium and titanium show higher concentrations in May, while cadmium shows a higher result for August. Although these metals showed a statistical difference between the May and August sampling periods, the average concentration was within limits as specified by the "Compendium of Regulatory Levels for Sandia National Laboratories, New Mexico", RCRA Corrective Action Remedy Selection/CAMU Workshop" (April 1995).

Table 4-3. Summary statistics for soil by sampling period.

Analyte	Sampling Period	Sample Size	Median	Average Result	Standard Deviation
Cadmium	May	137	0.50	0.54	0.18
	August	130	0.50	0.60	0.46
Chromium	May	137	24.00	25.21	9.00
	August	130	19.00	20.22	5.57
Titanium	May	137	260.00	318.96	202.22
	August	130	220.00	245.96	160.16

4.4.2 Sediment

For non radiological results, there was no difference between the May and August sampling periods for sediment data.

4.4.3 Filtered Water

Table 4-4 shows the summary statistics for filtered water for non radiological results. Sample sizes were small since water was only analyzed for metal concentrations during 1994 and 1995. Although a statistical difference was observed, the average result was well within RCRA limits for these metals.

Table 4-4. Summary statistics for filtered water by sampling period.

Analyte	Sampling Period	Sample Size	Median	Average Result	Standard Deviation
Iron	May	8	0.01	0.013	0.007
	August	7	0.02	0.029	0.021
Nickel	May	8	0.02	0.023	0.007
	August	7	0.05	0.037	0.016

4.4.4 Unfiltered Water

Table 4-5 shows the summary statistics for unfiltered water for non radiological results. Sample sizes are small since water was only analyzed for metal concentrations during 1994 and 1995. Although a statistical difference was observed, the average result was well within RCRA limits for these metals.

Table 4-5. Summary statistics for unfiltered water by sampling period.

Analyte	Sampling Period	Sample Size	Median	Average Result	Standard Deviation
Nickel	May	8	0.020	0.021	0.004
	August	7	0.050	0.037	0.016

4.4.5 Filters

For non radiological results, there was no difference between the May and August sampling periods for filter data.

5.0 SAMPLING ENHANCEMENTS

Based on the analysis results presented in chapter 3.0, modifications to the sampling design and further investigations were identified as follows. A review of the current sampling methodology lead to the following enhancements which will be implemented during the 1996 sampling period.

5.1 Suggested Modifications

5.1.1 Modification of the ICP-20 Metals List

Table 5-1 shows the current list of metal parameters and the list of revised metal parameters. The revised list includes all metals on the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) target metal list. All metals, with the exception of mercury, can be analyzed using 3050 digestion/6010A ICP-AES. It is recommended that mercury be analyzed using method 7471A. Metals such as strontium and titanium were deleted from the current list since they are not on the CERCLA target metal list. Calcium and silicon were deleted since these are abundant, naturally occurring elements.

5.1.2 Vegetation Sampling

All community vegetation sampling will be continued; samples will be analyzed for tritium and gamma spectroscopy. In addition, analysis of vegetation samples will also include ICP-20 metals and total uranium. At on site and perimeter locations, vegetation sampling will be performed only where there is historical evidence of elevated soil results. (Elevated vegetation results are not expected where there is no known soil contamination.) Every on site or perimeter vegetation location that is selected to be sampled will be analyzed for tritium, gamma spectroscopy, ICP-20 metals, and total uranium. This will ensure continuity between community, on site, and perimeter vegetation samples.

5.1.3 Replicate Sampling Locations

Three new replicate sampling locations were added: locations 2NE and 20 are located on site, and location 64 is a perimeter location. All three of these locations were classified as Category 2 or Category 3 during the 1995 survey analysis period. These locations were chosen to supplement the current replicate sampling locations to increase the accuracy of analysis at those locations where high or suspect values have been observed.

Table 5-1. Current and revised list of ICP-20 metals.

Current List of ICP-20 Metals	Revised List of ICP-20 Metals
Aluminum	Aluminum
--	Antimony
--	Arsenic
Barium	Barium
Beryllium	Beryllium
Cadmium	Cadmium
Calcium	--
Chromium	Chromium
Cobalt	Cobalt
Copper	Copper
Iron	Iron
Lead	Lead
Magnesium	Magnesium
Manganese	Manganese
--	Mercury
Nickel	Nickel
Potassium	Potassium
--	Selenium
Silicon	--
Silver	Silver
Strontium	--
--	Thallium
Titanium	--
Vanadium	Vanadium
Zinc	Zinc

5.1.4 TCLP Analysis

Locations that contain elevated soil metal concentrations will be analyzed utilizing EPA test method 1311, "Toxicity Characteristic Leaching Procedure". Samples are said to exhibit the RCRA toxicity characteristic if, Test Method 1311 results in leachate concentrations that exceed the values found in 40 CFR 261.24, Table 1. Only two locations had concentrations of RCRA metals that could possibly cause the RCRA toxicity characteristic to be exceeded. Examination of these two locations using EPA Test Method 1311, will be performed during the 1996 sampling period.

5.1.5 Discontinuation of Hydrofluoric Acid Dissolution

During the 1995 sampling period, metals were also analyzed using hydrofluoric acid dissolution. Since hydrofluoric acid dissolution dissolves, more or less, the entire soil sample, and hydrofluoric acid dissolution is not included in SW-846, it was determined that this method of analysis should be discontinued. Results obtained with the hydrofluoric acid dissolution method were distinctly different than results obtained utilizing EPA Method 6010/A.

5.2 Follow-Up Investigations

Any location which was categorized as Category 2 (higher than off site, but not increasing) or Category 3 (increasing trend, but not higher than off site) in the 1995 analysis will be reviewed during the 1996 analysis of sample results to determine if additional steps should be taken to ensure any contamination is minimized. (Recall that no location was categorized as Category 1 from the statistical analysis detailed in Section 2.) In addition to those locations categorized as Category 2 or Category 3, the following subsections discuss further investigations.

5.2.1 TCLP Analysis - Location 20

TCLP analysis was recommended for location 20 which showed an elevated result for lead. Location 20 is next to the KAFB Skeet Range. It was felt that lead shot from the Skeet Range could have been included in the soil sample. Toxicity characteristic leaching procedure (TCLP) analysis would determine if the lead content in the soil was soluble or insoluble.

5.2.2 "As Received Condition" - Location 64

Perimeter location 64 showed elevated levels of zinc, cobalt, and manganese concentrations for soil. In particular, manganese exceeded the proposed RCRA subpart S action level of 400 ppm. It is recommended that in addition to soil samples collected at location 64, one more sample be taken. This additional sample would be analyzed in "As Received" condition (no grinding of sample). This additional test would provide an indication of whether the elevated result is due to leaching of the mineral content of the soil sample.

6.0 SPLIT COMPARISON ANALYSIS AND RESULTS

Split comparisons are used to determine how well the current analytical laboratory is performing when compared to another analytical laboratory and is also used as a gauge if another analytical laboratory needs to be utilized in the future. During the 1995 sampling period, Core Laboratories was utilized and compared against the current analytical laboratory, Accu-Labs Research.

6.1 Site Selection Methodology

Sampling locations were selected to meet two objectives. First, the data will cover the whole range of values at on site and off site locations. Second, the number of samples will be sufficient for statistical comparison of the split samples and to establish the relationship between Accu-Labs Research and Core Laboratories values.

6.2 Selection of Laboratory Used for Split Comparison

The analytical laboratory selected to compare results was Core Laboratories: Core Denver was utilized to analyze all samples for metal concentrations while Core Casper was responsible to analyze all samples for radio chemistry concentrations. Core Laboratories was selected from several laboratories possible that were able to perform the types of analysis needed. The use of Core Laboratories was recommended to the Terrestrial Surveillance project by SNL/NM's Sample Management Office (SMO). Unfortunately, several issues in utilizing a new analytical laboratory were not addressed prior to sending samples to Core Laboratories. These issues will be addressed below as lessons learned.

6.3 Results of the Split Comparison

A direct comparison of the analytical results of several analytes were not possible due to varying differences in sample preparation and analysis methods between the two laboratories. Appendix C contains a more detailed analysis of the differences between the two laboratories and their sample preparation and analysis methods. For the analytical results that could be compared, a ratio of the sample results was calculated. The ratio was computed as analytical result for Accu-Labs Research over the analytical result for Core Laboratories. A ratio of one (1.00) would be expected if the analytical results of the two laboratories were in perfect agreement. A ratio between 0.70 and 1.30 would be considered acceptable. These values were selected as

laboratories use a ± 30 percent when performing Quality Assurance (QA) checks in the data. Each type of matrix is discussed below with a table showing summary statistics of the computed ratios.

6.3.1 Soil Results

Table 6-1 shows the summary statistics for the computed ratios for all analytical soil results. Particularly for metals and uranium, analytical results were in good agreement. Only chromium and potassium showed ratios greater than 1.30. Ratios for gamma spectroscopy and tritium were more variable. Lead-212 (Pb-212), Thorium-231 (Th-231), Thorium-234 (Th-234), and Tritium (H-3) all showed small ratios indicating that Core Laboratories gave larger analytical result values. Potassium-40 (K-40) showed a larger than acceptable ratio of 1.76 indicating that Core Laboratories results were smaller.

6.3.2 Sediment Results

Table 6-2 shows the summary statistics for the computed ratios for all analytical sediment results. Particularly for metals and uranium analytical results were in good agreement. Similar to soil results, chromium and potassium showed ratios greater than 1.30. Silver showed a low ratio indicating larger Core Laboratories analytical results. Ratios for gamma spectroscopy and tritium were more variable. Cesium-137 (Cs-137), Lead-212 (Pb-212), Thorium-231 (Th-231), Thorium-234 (Th-234), and Tritium (H-3) all showed small ratios indicating that Core Laboratories gave larger analytical result values. Potassium-40 (K-40) showed a larger than acceptable ratio of 2.70 indicating that Core Laboratories results were smaller.

Table 6-1. Summary statistics for ratio of soil concentrations.

Analyte Type	Analyte	Units	Count	Median	Average	Std Dev	Min	Max
Gamma Spec	AC-228	pCi/g	10	0.75	1.10	0.86	0.61	3.48
Gamma Spec	CS-137	pCi/g	10	1.04	0.99	0.43	0.33	1.62
Gamma Spec	K-40	pCi/g	12	1.76	2.50	1.73	1.06	6.76
Gamma Spec	PB-212	pCi/g	10	0.43	0.54	0.38	0.18	1.27
Gamma Spec	PB-214	pCi/g	26	0.84	1.03	0.74	0.62	3.67
Gamma Spec	TH-231	pCi/g	8	0.33	0.45	0.26	0.12	0.87
Gamma Spec	TH-234	pCi/g	12	0.10	0.10	0.04	0.05	0.18
Metal	Aluminum	mg/kg	16	1.27	1.31	0.30	0.59	1.93
Metal	Barium	mg/kg	16	1.03	1.05	0.12	0.76	1.29
Metal	Beryllium	mg/kg	15	1.20	1.27	0.23	1.00	1.67
Metal	Cadmium	mg/kg	13	1.30	1.30	0.49	0.21	1.67
Metal	Calcium	mg/kg	16	1.12	1.12	0.23	0.71	1.54
Metal	Chromium	mg/kg	16	1.85	2.06	0.59	1.32	3.83
Metal	Iron	mg/kg	16	1.05	1.10	0.22	0.63	1.52
Metal	Lead	mg/kg	16	1.16	1.14	0.23	0.73	1.50
Metal	Magnesium	mg/kg	16	1.01	1.02	0.12	0.76	1.24
Metal	Manganese	mg/kg	16	1.05	1.05	0.11	0.82	1.22
Metal	Nickel	mg/kg	16	1.00	1.05	0.28	0.30	1.65
Metal	Potassium	mg/kg	15	1.73	1.68	0.42	0.61	2.25
Metal	Vanadium	mg/kg	16	1.20	1.21	0.28	0.80	1.92
Metal	Zinc	mg/kg	16	0.73	0.75	0.09	0.60	0.92
Tritium	H-3	pCi/mL	13	0.13	0.63	1.38	0.00	5.08
Uranium	UTOT	µg/g	16	0.88	0.84	0.19	0.34	1.08

Note: pCi/g = picocuries per gram; mg/kg = milligrams per kilogram; pCi/mL = picocuries per milliliter; µg/g = micrograms per gram.

Table 6-2. Summary statistics for ratio of sediment concentrations.

Analyte Type	Analyte	Units	Count	Median	Average	Std Dev	Min	Max
Gamma Spec	AC-228	pCi/g	6	0.73	0.78	0.25	0.46	1.10
Gamma Spec	CS-137	pCi/g	5	0.45	0.49	0.13	0.33	0.64
Gamma Spec	K-40	pCi/g	9	2.70	2.53	1.09	0.93	4.08
Gamma Spec	PB-212	pCi/g	8	0.33	0.38	0.18	0.19	0.66
Gamma Spec	PB-214	pCi/g	18	0.76	1.20	1.20	0.46	4.85
Gamma Spec	TH-231	pCi/g	6	0.42	0.38	0.17	0.15	0.60
Gamma Spec	TH-234	pCi/g	7	0.10	0.12	0.10	0.05	0.34
Metal	Aluminum	mg/kg	10	1.33	1.52	0.62	0.86	2.43
Metal	Barium	mg/kg	10	0.99	1.16	0.56	0.58	2.13
Metal	Beryllium	mg/kg	9	1.25	1.20	0.55	0.01	1.80
Metal	Cadmium	mg/kg	6	0.97	0.87	0.56	0.01	1.67
Metal	Calcium	mg/kg	10	1.24	1.27	0.31	0.88	1.83
Metal	Chromium	mg/kg	10	2.98	3.36	2.48	0.48	9.33
Metal	Iron	mg/kg	10	1.10	1.17	0.49	0.63	2.05
Metal	Lead	mg/kg	10	0.93	1.27	1.41	0.14	5.02
Metal	Magnesium	mg/kg	10	1.20	1.16	0.28	0.77	1.60
Metal	Manganese	mg/kg	10	1.13	1.15	0.33	0.81	1.83
Metal	Nickel	mg/kg	10	0.99	1.03	0.53	0.14	2.18
Metal	Potassium	mg/kg	9	2.55	3.11	2.75	0.94	9.64
Metal	Silver	mg/kg	4	0.20	0.21	0.20	0.01	0.45
Metal	Vanadium	mg/kg	10	1.04	1.33	0.77	0.35	2.62
Metal	Zinc	mg/kg	10	0.65	0.63	0.21	0.31	0.92
Tritium	H-3	pCi/mL	8	0.02	0.14	0.32	-0.03	0.94
Uranium	UTOT	µg/g	10	0.76	0.75	0.17	0.43	0.98

Note: pCi/g = picocuries per gram; mg/kg = milligrams per kilogram; pCi/mL = picocuries per milliliter; µg/g = micrograms per gram.

6.3.3 Vegetation Results

Table 6-3 shows the summary statistics for the computed ratios for all analytical vegetation results. Notice that all ratios for vegetation are very small indicating that analytical results from Core Laboratories were greater than the analytical results from Accu-Labs Research. Particularly with the gamma spectroscopy results, the sample preparation, gamma energy counting systems, count times and calibration methods were different leading to the vastly different results. As a partial fix to the different results, a memo was drafted up indicating methods to be used and Minimal Detectable Activities to be utilized in analyzing any sample sent from this department.

Table 6-3. Summary statistics for ratio of vegetation concentrations.

Analyte Type	Analyte	Units	Count	Median	Average	Std Dev	Min	Max
Gamma Spec	K-40	pCi/g	7	0.15	0.15	0.07	0.06	0.25
Gamma Spec	PB-214	pCi/g	4	0.04	0.04	0.01	0.03	0.04
Gamma Spec	TH-231	pCi/g	7	0.10	0.10	0.04	0.05	0.15
Tritium	H-3	pCi/mL	9	0.01	0.06	0.09	0.00	0.23

Note: pCi/g = picocuries per gram; pCi/mL = picocuries per milliliter.

6.3.4 Filtered Water Results

Table 6-4 shows the summary statistics for the computed ratios for all analytical filtered water results. Ratios were widely scattered for all analytes with approximately 50 percent of ratios being outside of acceptable limits. Also note the smaller sample sizes, fewer water samples were sent as split samples, so a greater amount of variability in the ratio results would be expected. Gamma spectroscopy and tritium ratios were below acceptable limits, indicating that Core Laboratories results were greater than Accu-Labs Research results. Metal results were primarily within acceptable limits. Chromium, Iron, Silver, and Zinc had ratios less than 0.70 and were considered below the acceptable limits. Cadmium showed a ratio greater than 1.30 and was considered above the acceptable limit.

Table 6-4. Summary statistics for ratio of filtered water concentrations.

Analyte Type	Analyte	Units	Count	Median	Average	Std Dev	Min	Max
Gamma Spec	PB-212	pCi/L	2	0.11	0.11	0.06	0.06	0.15
Gamma Spec	TH-231	pCi/L	2	0.45	0.45	0.03	0.43	0.47
Metal	Aluminum	mg/L	2	0.78	0.78	0.06	0.74	0.82
Metal	Barium	mg/L	3	0.97	1.03	0.13	0.95	1.18
Metal	Beryllium	mg/L	1	0.85	0.85		0.85	0.85
Metal	Cadmium	mg/L	1	1.62	1.62		1.62	1.62
Metal	Calcium	mg/L	3	0.99	1.01	0.04	0.98	1.05
Metal	Chromium	mg/L	3	0.64	0.69	0.11	0.61	0.82
Metal	Iron	mg/L	3	0.13	0.90	1.39	0.07	2.51
Metal	Magnesium	mg/L	3	0.95	0.97	0.02	0.95	1.00
Metal	Manganese	mg/L	3	0.74	0.78	0.12	0.69	0.92
Metal	Nickel	mg/L	1	0.82	0.82		0.82	0.82
Metal	Potassium	mg/L	3	1.16	1.07	0.42	0.62	1.44
Metal	Silver	mg/L	1	0.49	0.49		0.49	0.49
Metal	Zinc	mg/L	3	0.04	0.08	0.09	0.01	0.17
Tritium	H-3	pCi/mL	3	0.00	0.05	0.09	0.00	0.15

Note: pCi/L = picocuries per liter; mg/L = milligrams per liter; pCi/mL = picocuries per milliliter..

6.3.5 Unfiltered Water Results

Table 6-5 shows the summary statistics for the computed ratios for all analytical unfiltered water results. Ratios were widely scattered for all analytes with less than 50 percent of ratios being outside of acceptable limits. Also note the smaller sample sizes, fewer water samples were sent as split samples, so a greater amount of variability in the ratio results would be expected. Thorium-234 had one sample with a ratio below acceptable limits indicating that Core Laboratories results were greater than Accu-Labs Research. Two samples of tritium indicated that both ratios were below acceptable limits indicating that Core Laboratories results were greater than Accu-Labs Research results. One sample of total uranium had a ratio greater than acceptable limits indicating that Core Laboratories result was smaller than Accu-Labs Research. Metal results were primarily within acceptable limits. Ratios for chromium, silver, and zinc were less than 0.70 and were considered below the acceptable limits. Aluminum and Iron showed ratios greater than 1.30 and were considered above the acceptable limit.

Table 6-5. Summary statistics for ratio of unfiltered water concentrations.

Analyte Type	Analyte	Units	Count	Median	Average	Std Dev	Min	Max
Gamma Spec	TH-231	pCi/L	2	0.71	0.71	0.04	0.68	0.73
Gamma Spec	TH-234	pCi/L	1	0.11	0.11		0.11	0.11
Gross Alpha	Gross Alpha	pCi/L	3	0.31	1.09	1.37	0.29	2.68
Gross Beta	Gross Beta	pCi/L	3	0.86	0.92	0.26	0.70	1.21
Metal	Aluminum	mg/L	3	3.57	2.82	1.81	0.75	4.12
Metal	Barium	mg/L	3	0.97	1.03	0.10	0.96	1.14
Metal	Beryllium	mg/L	1	0.79	0.79		0.79	0.79
Metal	Calcium	mg/L	3	0.99	0.99	0.02	0.98	1.02
Metal	Chromium	mg/L	1	0.56	0.56		0.56	0.56
Metal	Iron	mg/L	3	2.08	1.78	0.69	0.99	2.27
Metal	Magnesium	mg/L	3	0.98	0.98	0.02	0.96	1.00
Metal	Manganese	mg/L	3	0.98	0.97	0.03	0.93	0.99
Metal	Nickel	mg/L	1	0.74	0.74		0.74	0.74
Metal	Potassium	mg/L	3	1.36	1.27	0.57	0.66	1.79
Metal	Silver	mg/L	1	0.33	0.33		0.33	0.33
Metal	Zinc	mg/L	3	0.03	0.08	0.10	0.03	0.20
Tritium	H-3	pCi/mL	2	0.16	0.16	0.01	0.15	0.17
Uranium	UTOT	mg/L	1	1.97	1.97		1.97	1.97

Note: pCi/L = picocuries per liter; mg/L = milligrams per liter; pCi/mL = picocuries per milliliter.

6.3.6 Filter Results

Table 6-6 shows the summary statistics for the computed ratios for all analytical filter results. Filter results were either very close to zero or very large. There were no ratios within acceptable limits.

Table 6-6. Summary statistics for ratio of filter concentrations.

AnalyteType	Analyte	Units	Count	Median	Average	Std Dev	Min	Max
Gamma Spec	PB-212	pCi/filt comp	1	0.16	0.16	0.16	0.16	
Gamma Spec	PB-214	pCi/filt comp	1	0.13	0.13	0.13	0.13	
Gamma Spec	TH-231	pCi/filt comp	1	0.38	0.38	0.38	0.38	
Gross Alpha	Gross Alpha	pCi/filt comp	3	0.00	0.03	0.12	-0.06	0.17
Gross Beta	Gross Beta	pCi/filt comp	3	0.08	0.05	0.12	-0.08	0.16
Metal	Aluminum	µg/filt comp	3	2.84	2.21	1.23	0.80	3.00
Metal	Arsenic	µg/filt comp	1	3.21	3.21	3.21	3.21	
Metal	Barium	µg/filt comp	3	1.64	2.53	1.83	1.31	4.63
Metal	Beryllium	µg/filt comp	3	2.49	2.55	1.12	1.46	3.70
Metal	Cadmium	µg/filt comp	3	1.42	2.05	2.13	0.31	4.42
Metal	Calcium	µg/filt comp	3	1.02	1.10	0.24	0.90	1.37
Metal	Chromium	µg/filt comp	2	0.94	0.94	1.29	0.03	1.85
Metal	Iron	µg/filt comp	3	1.18	1.19	0.37	0.83	1.57
Metal	Lead	µg/filt comp	1	1.18	1.18	1.18	1.18	
Metal	Magnesium	µg/filt comp	3	1.61	1.45	0.51	0.88	1.86
Metal	Manganese	µg/filt comp	3	1.13	1.05	0.35	0.67	1.35
Metal	Molybdenum	µg/filt comp	1	0.86	0.86	0.86	0.86	
Metal	Nickel	µg/filt comp	1	0.09	0.09	0.09	0.09	
Metal	Silver	µg/filt comp	2	0.88	0.88	0.47	0.55	1.22
Metal	Sodium	µg/filt comp	3	0.88	0.97	0.53	0.49	1.53
Metal	Thallium	µg/filt comp	3	2.69	2.38	1.00	1.26	3.18
Metal	Zinc	µg/filt comp	3	0.52	0.53	0.31	0.24	0.85
Uranium	UTOT	µg/filt comp	2	0.00	0.00	0.00	0.00	0.00

Note: pCi/filt comp = picocuries per filter composite; µg/filt comp = micrograms per filter composite.

6.4 Lessons Learned

In the process of split comparisons several key issues were not addressed prior to using a new analytical laboratory. This section discusses lessons learned in using a new laboratory and items that need to be reviewed or in place prior to using a new laboratory in the future.

6.4.1 Performance Evaluation Samples

As part of the regular split sampling, performance evaluation (PE) samples were prepared and submitted to Core Laboratories. The results of the PE samples indicated that problems existed with the analysis of water and soil samples submitted to Core Laboratories. PE samples were prepared by Yankee Atomic Laboratory for specified values. Table 6-7 and table 6-8 show the values of the PE samples prepared by Yankee Atomic Laboratory and results determined by Core Laboratories.

A ratio of the analytical laboratory result and the Yankee Atomic Laboratory result was computed. If results matched exactly, the ratio would be one. The more perfect the agreement of results, the closer the ratio would be to one.

Table 6-7 shows the results for water; for tritium samples, the ratios were between 0.9 and 1.0, indicating a close match between results. Water samples for total uranium showed ratio values of 0.3, 2.2, and 0.1, indicating a difference in results. It is known that total uranium was analyzed using fluorometric methods instead of Kinetic-phosphorescent Analysis (KPA). KPA was the preferred method of analysis for total uranium. Table 6-8 show the soil results for both tritium and total uranium. Ratios indicate that there was difficulty in analyzing the samples.

If the PE samples had been submitted prior to samples being submitted to Core Laboratories, the differences in tritium and total uranium analysis would have been determined and possible solutions would have been in place prior to split comparison sample submission. It is recommended that PE samples be used in the future when submitting to a new laboratory.

Table 6-7. Performance evaluation sample results for Core Laboratories - water.

Analyte	SNL Contract Value	Units	Yankee Spike Result	Yankee Error (1sd)	Core Labs Result	Core Labs Error (2sd)	Ratio Core Labs/ Yankee
H-3	0.4	pCi/mL	0.413	0.0194	0.370	0.10	0.90
	2.0	pCi/mL	2.017	0.0561	1.990	0.13	0.99
	5.0	pCi/mL	5.010	0.0860	4.440	0.30	0.88
U-tot	0.004	µg/mL	0.003		0.001		0.33
	0.020	µg/mL	0.006		0.014		2.33
	0.002	µg/mL	0.031		0.003		0.10

Note: pCi/mL = picocuries per milliliter; µg/mL = micrograms per milliliter.

Table 6-8. Performance evaluation sample results for Core Laboratories - soil.

Analyte	SNL Contract Value	Units	Yankee Spike Result	Yankee Error (1sd)	Core Labs Result	Core Labs Error (2sd)	Ratio Core Labs/ Yankee
H-3	0.4	pCi/mL	0.413	0.07	4.500	0.60	10.90
	2.0	pCi/mL	2.017	0.10	1.400	0.70	0.69
	5.0	pCi/mL	5.010	0.15	9.700	0.30	1.94
U-tot	0.004	µg/mL	42.38		236.660		5.58
	0.020	µg/mL	59.04		330.850		5.60
	0.002	µg/mL	149.76		807.090		5.39

Note: pCi/mL = picocuries per milliliter; µg/mL = micrograms per milliliter.

6.4.2 EPA and EML Cross Check

Prior to selecting a new laboratory, the intra-laboratory comparisons should be reviewed and checked for any possible problems. This was not done until after samples had been sent to Core Laboratories for analysis.

It is important to get the latest EPA/EML Cross Check results for any new analytical laboratory. These results should be distinguished by media (i.e., soil, vegetation, or water) for easier comparisons. The most current cross check results should be available prior to any samples being submitted to a new analytical laboratory.

6.4.3 Analysis Template

A template or quick reference card, listing the methods to be used for sample analysis, was developed so that new analytical laboratories could see methods preferred by Terrestrial Surveillance personnel. For example, one challenge which occurred was total uranium was analyzed using fluorometry, but the desired method was KPA. Laboratory personnel would know which methods to use for analysis and which ICP-20 metals should be tested.

As an added safeguard, a memo is attached to every Chain of Custody form which requests special or non-routine analysis. This memo ensures that laboratory is aware of any special requests and can call to verify contents of memo if needed.

6.4.4 Gamma Spectroscopy System

After samples were sent to Core Laboratories, it was determined that the gamma spectroscopy system employed was not designed to count low level environmental radio-analytical samples. Core Laboratories gamma spectroscopy system was shown not to be able to meet the minimal detection levels for the Pb-210 energy peak at 46 KeV and Am-241 at 59 KeV. This presented a

difficulty in comparison of samples and analysis because several of the radionuclides of interest at SNL/NM were low level energy emitters. Prior to sending samples to any new lab, a description of the gamma spectroscopy system should be received. This will hopefully determine which laboratory should be utilized and eliminate any future problems. Also, PE gamma spectroscopy samples containing radionuclides of interest at SNL/NM should be analyzed by the laboratory before sending samples.

6.4.5 Minimal Detectable Activities/Minimal Detectable Limits

As result of questions that arose from sending samples to a new analytical laboratory, a list of analytes with appropriate Minimal Detectable Activities (MDA) or Minimal Detectable Limits (MDLs) was developed. This list of MDA's is seen in Appendix D and is now the standard for terrestrial surveillance samples submitted for analysis. This list was developed using currently achievable and desired limits which were verified by SNL/NM staff and other analytical laboratory personnel.

7.0 KEY PEAKS IDENTIFICATION

In the past, only specified radiochemistry results were specified from the lab. For the 1995 sampling period, during both the May and August sampling events, all radiochemistry data was requested. By requesting all radiochemistry results, it is hoped that the presence of any new radionuclide will be detected and corrective actions can be put in place.

It should be noted that the data received from the analytical laboratory contained everything in their radiochemistry library. As a result, much of the data received was below detection limits and was being reported by our request. An algorithm was determined which would look at the viable radionuclides. This algorithm was based on the following criteria:

- 1) Result > 0.5*(MDA)
- 2) Yield > 10%
- 3) IC_Gamma > 0.90

where Result is the analytical laboratory result, MDA is the Minimal Detectable Activity and any value less than MDA is considered a non-detect, Yield is the percentage of transformations producing the photon energy of interest, and IC_Gamma is a number from 0 to 1 which indicate the confidence (i.e., probability) that a peak was observed. An IC_Gamma value of 0.90 or greater is the standard value for peak identification according to laboratory procedures.

In order for the radionuclide to be considered a key peak, all three criteria had to be met. Once a peak was identified as viable, it was marked as a key peak and will be used to compare to future sampling events (1995 data will serve as a baseline for any future identifications).

The sections below briefly describe the key peaks identified. Appendix E contains the full listing of locations and radionuclides identified using the method described above.

7.1 Vegetation

Table 7-1 shows a list of all radionuclides observed in vegetation during the 1995 sample periods. A radionuclide observed could have more than one energy level. Several of these radionuclides are naturally occurring gamma emitting members of either the Uranium-235, Uranium-238, or Thorium-232 decay chain and would be seen in soil or sediment samples. Concentrations for these reported radionuclides is below 1 pCi/g and is not considered out

Table 7-1. Key peaks observed in 1995 vegetation samples.

Radionuclide	Naturally Occuring (in soil/sediment)
Barium-140	
Beryllium-7	Yes
Bismuth-214	Yes
Cerium-141	
Cobalt-60	
Lead-212	Yes
Lead-214	Yes
Mercury-203	
Potassium-40	Yes
Radium-223	Yes
Sodium-22	
Thorium-231	Yes
Thorium-234	Yes
Zinc-65	

of the ordinary. Beryllium-7 and Potassium-40 are not associated with a radioactive decay chain and are usually seen in Terrestrial Surveillance samples.

The other samples which are not listed as naturally occurring were seen infrequently and will be continued to be observed in future sampling events.

7.2 Soil

Table 7-2 shows a list of all radionuclides observed in soil during the 1995 sample periods. A radionuclide observed could have more than one energy level. Several of these radionuclides are naturally occurring gamma emitting members of either the Uranium-235, Uranium-238, or Thorium-232 decay chain and would be seen in soil or sediment samples. Concentrations for these reported radionuclides is below 1 pCi/g and is not considered out of the ordinary. Beryllium-7 and Potassium-40 are not associated with a radioactive decay chain and are usually seen in terrestrial surveillance samples.

The other samples which are not listed as naturally occurring were seen infrequently and will be continued to be observed in future sampling events.

Table 7-2. Key peaks observed in 1995 soil samples.

Radionuclide	Naturally Occuring (in soil/sediment)
Actinium-228	Yes
Barium-140	
Beryllium-7	Yes
Bismuth-212	
Bismuth-214	Yes
Cerium-139	
Cerium-141	
Cobalt-60	
Europium-155	
Lead-212	Yes
Lead-214	Yes
Manganese-54	
Mercury-203	
Potassium-40	Yes
Radium-223	Yes
Sodium-22	
Thallium-208	Yes
Thorium-231	Yes
Thorium-234	Yes
Zinc-65	

7.3 Sediment

Table 7-3 shows a list of all radionuclides observed in sediment during the 1995 sample periods. A radionuclide observed could have more than one energy level. Several of these radionuclide are naturally occurring gamma emitting members of either the Uranium-235, Uranium-238, or Thorium-232 decay chain and would be seen in soil or sediment samples. Concentrations for these reported radionuclides is below 1 pCi/g and is not considered out of the ordinary. Beryllium-7 and Potassium-40 are not associated with a radioactive decay chain and are usually seen in Terrestrial Surveillance samples.

The other samples which are not listed as naturally occurring were seen infrequently and will be continued to be observed in future sampling events.

Table 7-3. Key peaks observed in 1995 sediment samples.

Radionuclide	Naturally Occuring (in soil/sediment)
Actinium-228	Yes
Barium-140	
Beryllium-7	Yes
Bismuth-212	
Bismuth-214	Yes
Cerium-141	
Cobalt-60	
Europium-155	
Lead-212	Yes
Lead-214	Yes
Manganese-54	
Mercury-203	
Potassium-40	Yes
Radium-223	Yes
Thallium-208	Yes
Thorium-231	Yes
Thorium-234	Yes

7.4 Filtered Water

Table 7-4 shows a list of all radionuclides observed in sediment during the 1995 sample periods. A radionuclide observed could have more than one energy level. Several of these radionuclide are naturally occurring gamma emitting members of either the Uranium-235, Uranium-238, or Thorium-232 decay chain and would be seen in soil or sediment samples.

Table 7-4. Key peaks observed in 1995 filtered water samples.

Radionuclide	Naturally Occuring (in soil/sediment)
Cerium-141	
Lead-212	Yes
Lead-214	Yes
Radium-223	Yes
Thorium-231	Yes
Thorium-234	Yes
Zinc-65	

The other samples which are not listed as naturally occurring were seen infrequently and will be continued to be observed in future sampling events.

7.5 Unfiltered Water

Table 7-5 shows a list of all radionuclides observed in sediment during the 1995 sample periods. A radionuclide observed could have more than one energy level. Several of these radionuclide are naturally occurring gamma emitting members of either the Uranium-235, Uranium-238, or Thorium-232 decay chain and would be seen in soil or sediment samples.

Table 7-5. Key peaks observed in 1995 unfiltered water samples.

Radionuclide	Naturally Occuring (in soil/sediment)
Bismuth-214	Yes
Lead-212	Yes
Radium-223	Yes
Thorium-231	Yes
Thorium-234	Yes

7.6 Filters

Table 7-6 shows a list of all radionuclides observed in sediment during the 1995 sample periods. A radionuclide observed could have more than one energy level. Several of these radionuclide are naturally occurring gamma emitting members of either the Uranium-235, Uranium-238, or Thorium-232 decay chain and would be seen in soil or sediment samples.

Table 7-6. Key peaks observed in 1995 water filter samples.

Radionuclide	Naturally Occuring (in soil/sediment)
Cobalt-60	
Lead-212	Yes
Lead-214	Yes
Radium-223	Yes
Thorium-231	Yes

The other samples which are not listed as naturally occurring were seen infrequently and will be continued to be observed in future sampling events.

8.0 PERFORMANCE EVALUATION SAMPLES

Performance evaluation (PE) samples were prepared and submitted to Accu-Labs Research in March and August of 1995. PE samples were prepared by Yankee Atomic Environmental Laboratory for values specified by SNL/NM. The PE sample program is an integral part of the Environmental Monitoring Quality Assurance Program Plan (QAPP). This part of the QAPP is designed to ensure that the radioanalytical laboratory is capable of analyzing the environmental monitoring samples and meeting the Data Quality Objectives outlined in the QAPP. Samples were prepared as outlined under the contract with Yankee Atomic Environmental Laboratory according to the Standard Operating Procedures developed and used by them. Yankee Atomic Environmental Laboratory used radioactive standards traceable to the National Institute of Science and Technology (NIST).

After the sample was prepared by Yankee Atomic Laboratory, it was analyzed using standard methods. A result is yielded and the sample is then shipped to SNL/NM. After the sample is received it is sent to Accu-Labs Research for analysis using normal shipping documents. Accu-Labs Research does not know that the samples received are PE samples. The results from Yankee Atomic Laboratory and Accu-Labs Research are compared to see how closely they are related.

8.1 Performance Evaluation Sample Results

Tables 8-1 through 8-4 show the values of tritium and uranium contained in soil and water samples which were prepared and analyzed by Yankee Atomic Environmental Laboratory. Upon completion, samples were shipped to Accu-Labs Research and analyzed there. A ratio of the analytical results from Accu-Labs and Yankee Atomic Laboratory was determined. If results matched exactly, the ratio would be one. The closer the results were, the closer the ratio would be to one.

Table 8-1 shows that there is fairly good consistency between Accu-Labs Research and Yankee Atomic Laboratory results. For water, tritium results have a ratio from 0.85 to 1.36. There is more correlation between the samples analyzed for total uranium. These ratios ranged from 0.90 to 1.10.

Table 8-2 shows an even closer correlation between the water samples analyzed for tritium and total uranium. For tritium, the ratios ranged from 0.94 to 1.04, while the samples analyzed for total uranium were so close that the ratios were 1.00 for all three samples.

Table 8-1. Performance evaluation sample results for water, March 1995.

Analyte	SNL Contract Value	Units	Yankee Spike Result	Yankee Error (1sd)	Accu-Labs Result	Accu-Labs Error (2sd)	Ratio Accu-Labs/ Yankee
H-3	0.4	pCi/mL	0.4039		0.550		1.36
	2.0	pCi/mL	2.0100		1.700		0.85
	5.0	pCi/mL	5.9000		6.200		1.05
U-tot	0.004	µg/mL	0.0040		0.0039		0.98
	0.020	µg/mL	0.0201		0.0180		0.90
	0.002	µg/mL	0.0020		0.0022		1.10

Note: pCi/mL = picocuries per milliliter; µg/mL = micrograms per milliliter.

Table 8-2. Performance evaluation sample results for water, August 1995.

Analyte	SNL Contract Value	Units	Yankee Spike Result	Yankee Error (1sd)	Accu-Labs Result	Accu-Labs Error (2sd)	Ratio Accu-Labs/ Yankee
H-3	0.4	pCi/mL	0.413	0.0194	0.410	0.21	0.99
	2.0	pCi/mL	2.017	0.0561	2.10	2.10	1.04
	5.0	pCi/mL	5.01	0.0860	4.70	0.32	0.94
U-tot	0.002	µg/mL	0.003		0.003		1.00
	0.004	µg/mL	0.006		0.006		1.00
	0.020	µg/mL	0.031		0.031		1.00

Note: pCi/mL = picocuries per milliliter; µg/mL = micrograms per milliliter.

Soil samples analyzed for the March 1995 time frame are shown in table 8-3. As seen from the table, the ratios for soil samples analyzed for tritium ranged from 0.56 to 0.71. There were some known problems with the preparation of the samples for tritium analysis. The Yankee Atomic Environmental Laboratory Certificate of Content contained a note stating that "The H-3 activity is NOT homogeneously distributed in the soil matrix. For an appropriate performance evaluation the entire sample must be processed without removal of any aliquot." Accu-Labs did not use the entire sample. This information was not passed along to Accu-Labs on the Chain of Custody, since it would have revealed that this sample was a PE sample. Another potential problem with the March 1995 soil samples, is that Yankee Atomic Environment Laboratory interpreted the wording in the SNL contract to mean that no moisture would be added to the samples.

Therefore, the soil used for tritium in soil were washed and dried before the tritium activity standard was added. This meant that the only moisture in the sample is that only provided by the standard addition. Both of these known problems allowed very little opportunity for Accu-Labs to achieve comparable results. Samples analyzed for total uranium showed ratios of 1.00 to 1.13, indicating that the results were fairly consistent.

Table 8-4 shows the results for soil samples prepared in August 1995. There were known problems with the preparation of the soil samples for tritium analysis. The ratios for soil samples analyzed for tritium were 0.08 to 0.56. The results for total uranium showed consistent results with ratios ranging from 0.90 to 1.02.

Table 8-3. Performance evaluation sample results for soil, March 1995.

Analyte	SNL Contract Value	Units	Yankee Spike Result	Yankee Error (1sd)	Accu-Labs Result	Accu-Labs Error (2sd)	Ratio Accu-Labs/Yankee
H-3	0.4	pCi/mL	0.41		0.29		0.71
	2.0	pCi/mL	2.03		1.23		0.61
	5.0	pCi/mL	5.16		2.88		0.56
U-tot	40	µg/g	42.40		43.00		1.07
	60	µg/g	59.40		68.00		1.13
	150	µg/g	149.30		150.00		1.00

Note: pCi/mL = picocuries per milliliter; µg/g = micrograms per gram.

Table 8-4. Performance evaluation sample results for soil, August 1995.

Analyte	SNL Contract Value	Units	Yankee Spike Result	Yankee Error (1sd)	Accu-Labs Result	Accu-Labs Error (2sd)	Ratio Accu-Labs/Yankee
H-3	0.4	pCi/mL	0.413	0.07	0.03	0.54	0.07
	2.0	pCi/mL	2.017	0.10	1.40	1.10	0.70
	5.0	pCi/mL	5.01	0.15	2.80	1.10	0.56
U-tot	40	µg/g	42.38		41.00		0.97
	60	µg/g	59.04		54.00		0.91
	150	µg/g	149.76		150.00		1.00

Note: pCi/mL = picocuries per milliliter; µg/g = micrograms per gram.

8.2 Performance Evaluation Program Continuation

Performance evaluation samples should continue to be a regular part of the environmental monitoring program within Organization 7575. PE samples should be coordinated with the analytical laboratory of choice to ensure quality analysis of environmental samples submitted. PE samples provide a mechanism to ensure that samples are analyzed in a consistent quality oriented manner.

**SANDIA NATIONAL LABORATORIES,
INTERNAL DISTRIBUTION**

3	(MS 0748)	L. J. Shyr, 6413
1	(MS 0854)	H. Herrera, 7575
1	(MS 0854)	R. Haaker, 7575
1	(MS 9018)	Central Technical Files, 8940-2
2	(MS 0899)	Technical Library, 4915
2	(MS 0619)	Review & Approval Desk, 12690 For DOE/OSTI