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Chemical Analyses of Soil Samples Collected from the Sandia National Laboratories/NM, Tonopah Test Range Environs,1994–2005

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Abstract

From 1994 through 2005, the Environmental Management Department of Sandia National Laboratories (SNL) at the Tonopah Test Range (TTR), NV, has collected soil samples at numerous locations on-site, on the perimeter, and off-site for the purpose of determining potential impacts to the environs from operations at TTR. These samples were submitted to an analytical laboratory of metal-in-soil analyses. Intercomparisons of these results were then made to determine if there was any statistical difference between on-site, perimeter, and off-site samples, or if there were increasing or decreasing trends which indicated that further investigation may be warranted. This work provided the SNL Environmental Management Department with a sound baseline data reference against which to compare future operational impacts. In addition, it demonstrates the commitment that the Laboratories have to go beyond mere compliance to achieve excellence in its operations. This data is presented in graphical format with narrative commentaries on particular items of interest.

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Introduction

To establish a baseline for trace metals that exist in the soils of Sandia National Laboratories (SNL) and Tonopah Test Range (TTR) for the purpose of determining potential impacts to the environs from operations at the Laboratories from 1994 through 2005, the SNL Environmental Management Department collected soil samples at numerous locations on-site, on the perimeter, and off-site. The locations are shown in Figures 1 through 7 and tabulated in Tables 1, 2, and 3. Samples were submitted to an analytical laboratory for metal-in-soil analyses (target analyte list [TAL] metals).

These year-to-year soil results were compared to determine if there was any statistical difference between on-site, perimeter, and off-site samples, or if there were increasing or decreasing trends which indicated that further investigation may be warranted to ascertain the cause of the observed anomaly (Shyr, Herrera, and Haaker 1998). This work provided the SNL Environmental Management Department with a sound baseline data reference against which to compare future operational impacts. In addition, it demonstrates the commitment that the Laboratories have to go beyond mere compliance, but to also achieve excellence in its operations. This data is presented in graphical format, with narrative commentaries on particular items of interest.

TABLE 1. On-site TTR Terrestrial Surveillance Locations

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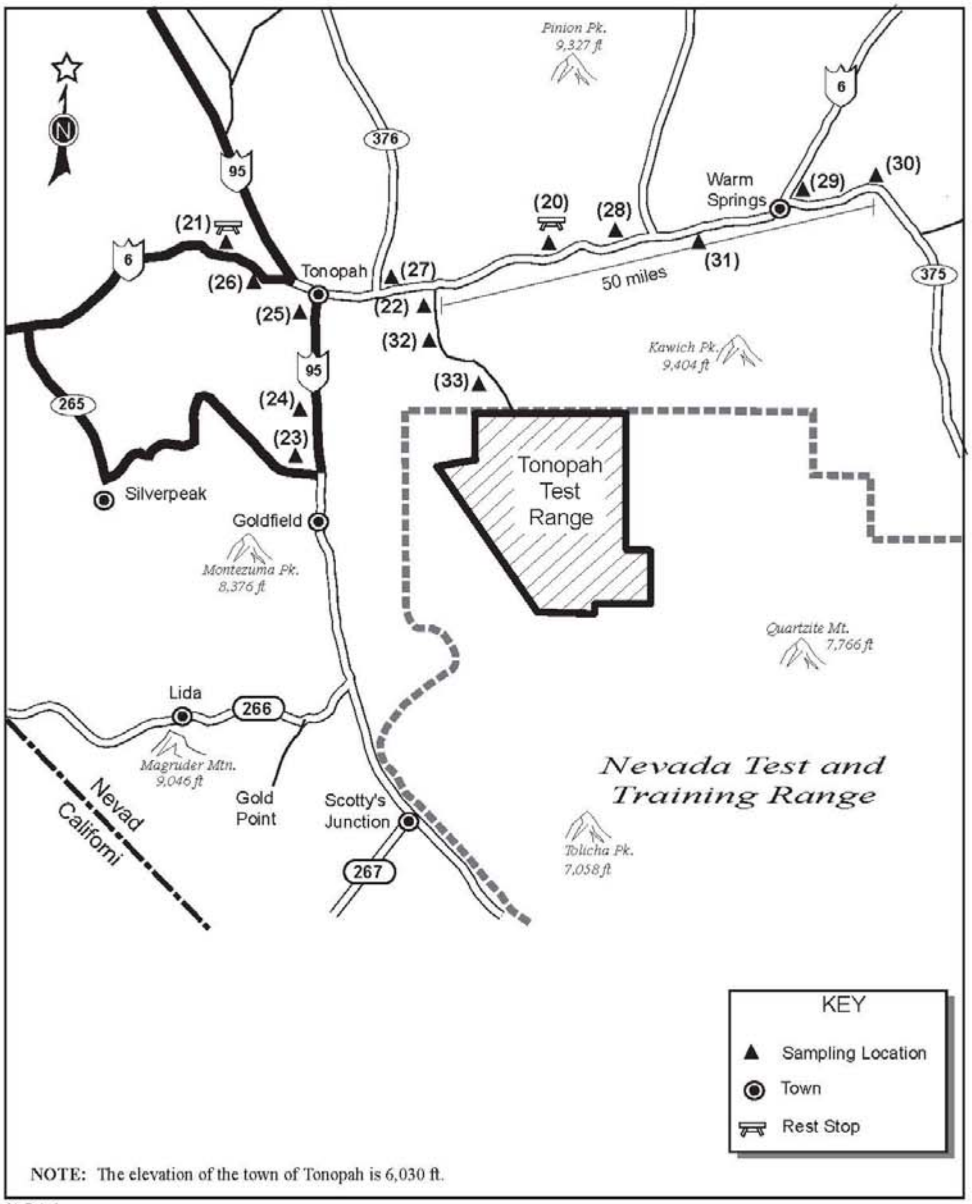
Location Number	***Sample Location***
S-48	N/S Mellan Airstrip – Antelope Tuff
S-49	N/S Mellan Airstrip – SW of S-48
S-50	N/S Mellan Airstrip – sign post
S-51	N/S Mellan Airstrip – NE of S-50
S-52	NE of NW/SE Mellan Airstrip
S-40	Waste Water Monitoring Station
S-41	"Danger Powerline Crossing" Sign
S-42	Main Road/Edward's Freeway
S-43	SW Corner of Sandia Corporation, TTR Operations Center
S-44	NE Corner of Sandia Corporation, TTR Operations Center
S-45	Storage Shelters, 03-38/03-39
S-46	Sand Building
S-47	Generator Storage Area
S-01	Antelope Lake Area Fence, Cultural Area Sign
S-02	N/S Mellan Airstrip (TLD at South fence post)
S-03	TLD at Clean Slate 2
S-04	TLD at Clean Slate 3
S-09	Roller Coaster Decon
S-10	Brownes Road/Denton Freeway
S-13	Area 3 between Bldg. 100 and Caution Sign
S-14	Area 3 CP SW side on fence
S-15	Moody Ave. by cattle guard and entrance to airport and chow hall
S-16	Area 9 by Bldg. 09-08 and LPG storage
S-17	Hard Target area by Bldg. 23-16
S-38	Mellan Hill – Metal Scrap Pile
S-39	Mellan Hill – North
S-53	Main Road/Lake Road SE

TABLE 2. Perimeter TTR Terrestrial Surveillance Locations

Location Number	***Sample Location***
P-05	O&M Complex - Site 4 Entrance Gate
P-06	Cedar Pass Road Guard Station
P-07	On-Base Housing - SW
P-08	On-Base Housing (Main guard gate/power pole CP17)
P-11	Cactus Springs (TLD south of P-35)
P-12	TLD at "US Gov't Property" Sign
P-34	O&M Complex (Owan Drive post)
P-35	Cactus Springs (north fence post)
P-36	On-Base Housing (NE fence line)
P-37	On-Base Housing (guard station)

TABLE 3. Off-site TTR Terrestrial Surveillance Locations

Location Number	***Sample Location***
C-18	Tonopah Old Court House
C-19	Mining Museum, North Goldfield
C-20	State Road 6 Rest Area
C-21	State Road 6/95 Rest Area
C-22	Rocket
C-23	Alkali/Silver Peak Turnoff
C-24	Cattle Guard
C-25	Tonopah Ranger Station
C-26	Gabbs Pole Line Road
C-27	State Roads 6/376 Junction
C-28	Stone Cabin/Willow Creek
C-29	State Roads 6/375 Junction
C-30	State Road 375 Ranch Cattle Gate
C-31	Golden Arrow/Silver Bow
C-32	Five miles south of Rocket
C-33	Nine miles south of Rocket



01_B-1.ai

FIGURE 1. Off-site Soil Sampling Locations
(14 Locations)

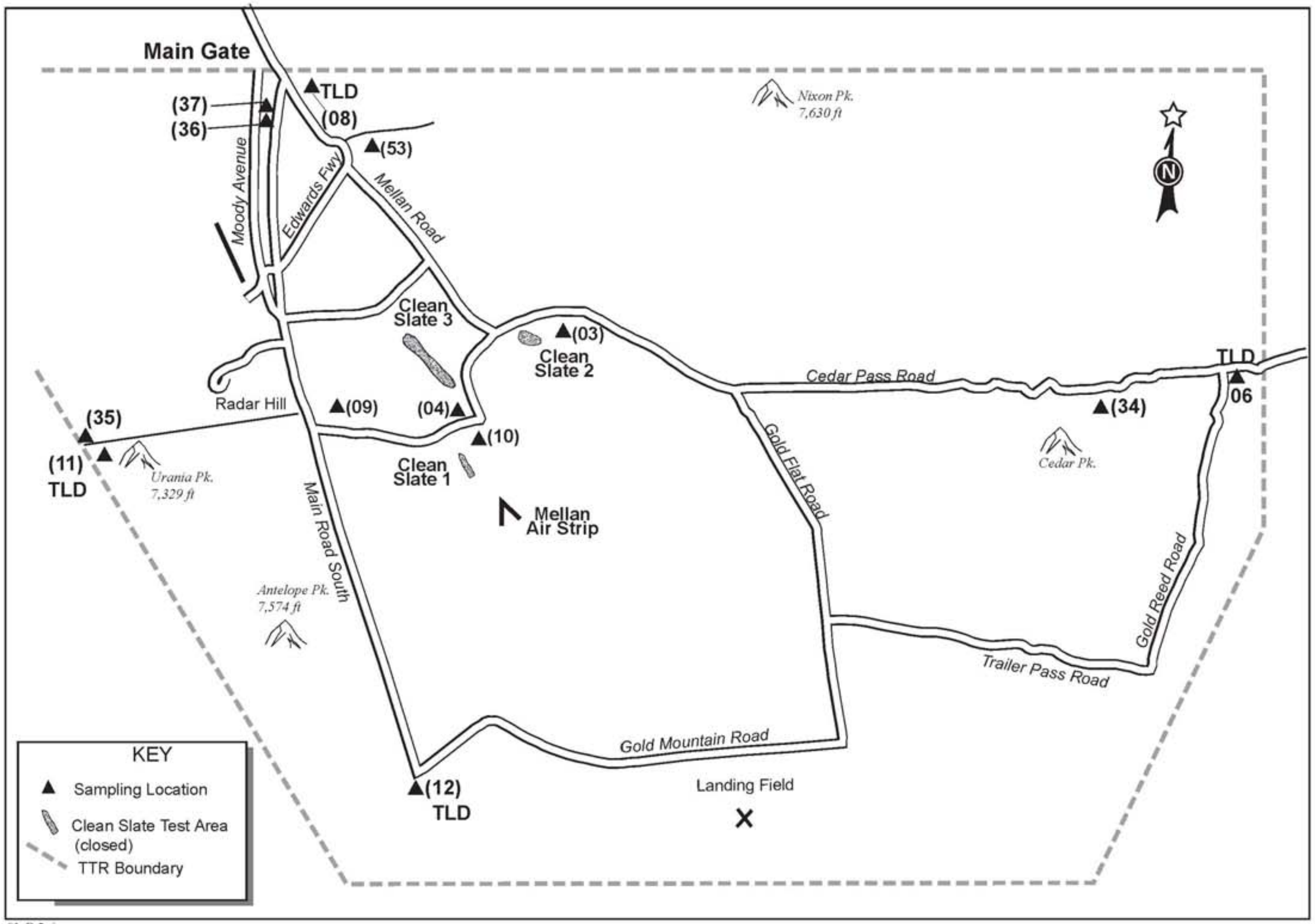


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FIGURE 2. Perimeter Soil Sampling Locations (Eight Locations)

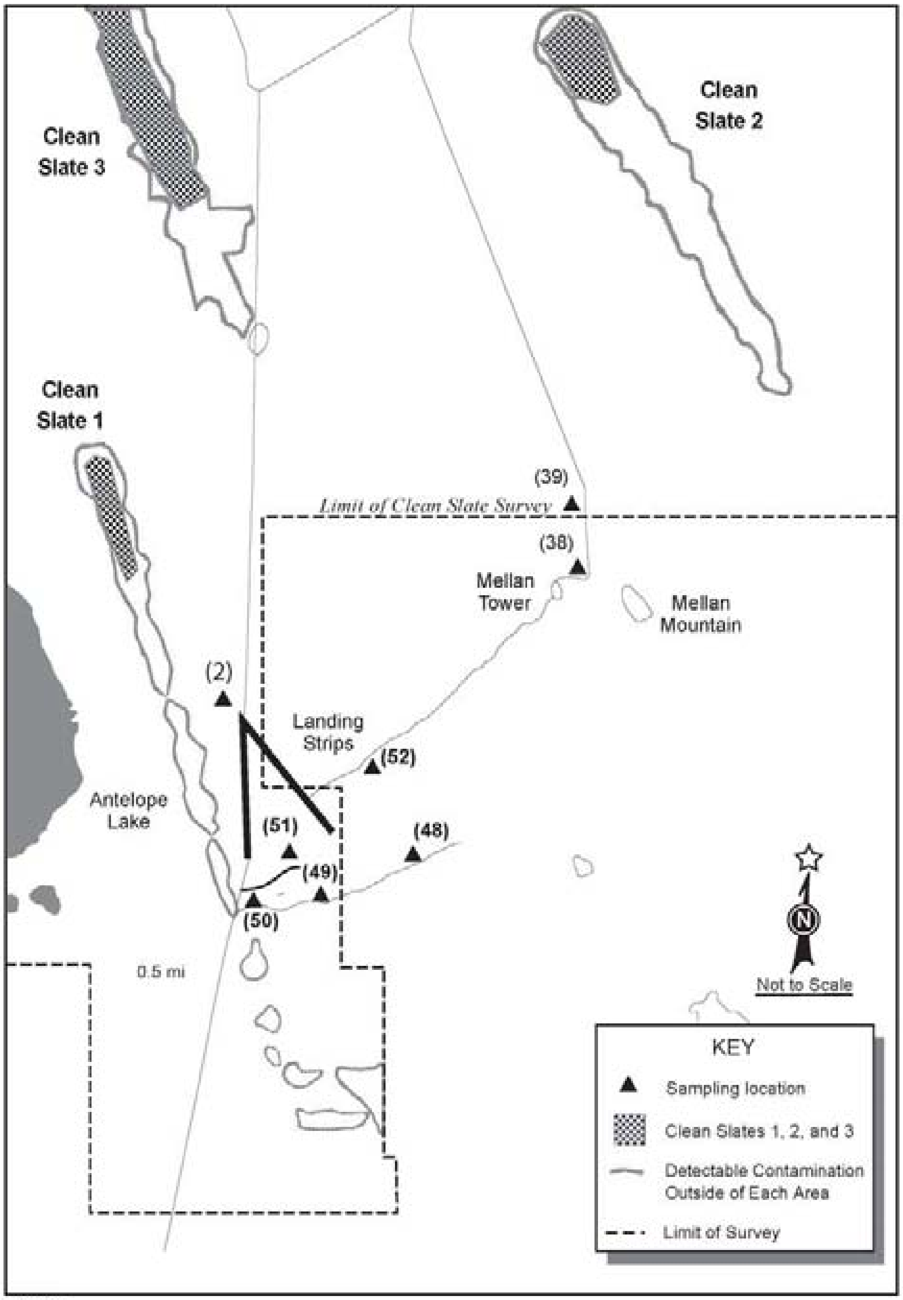
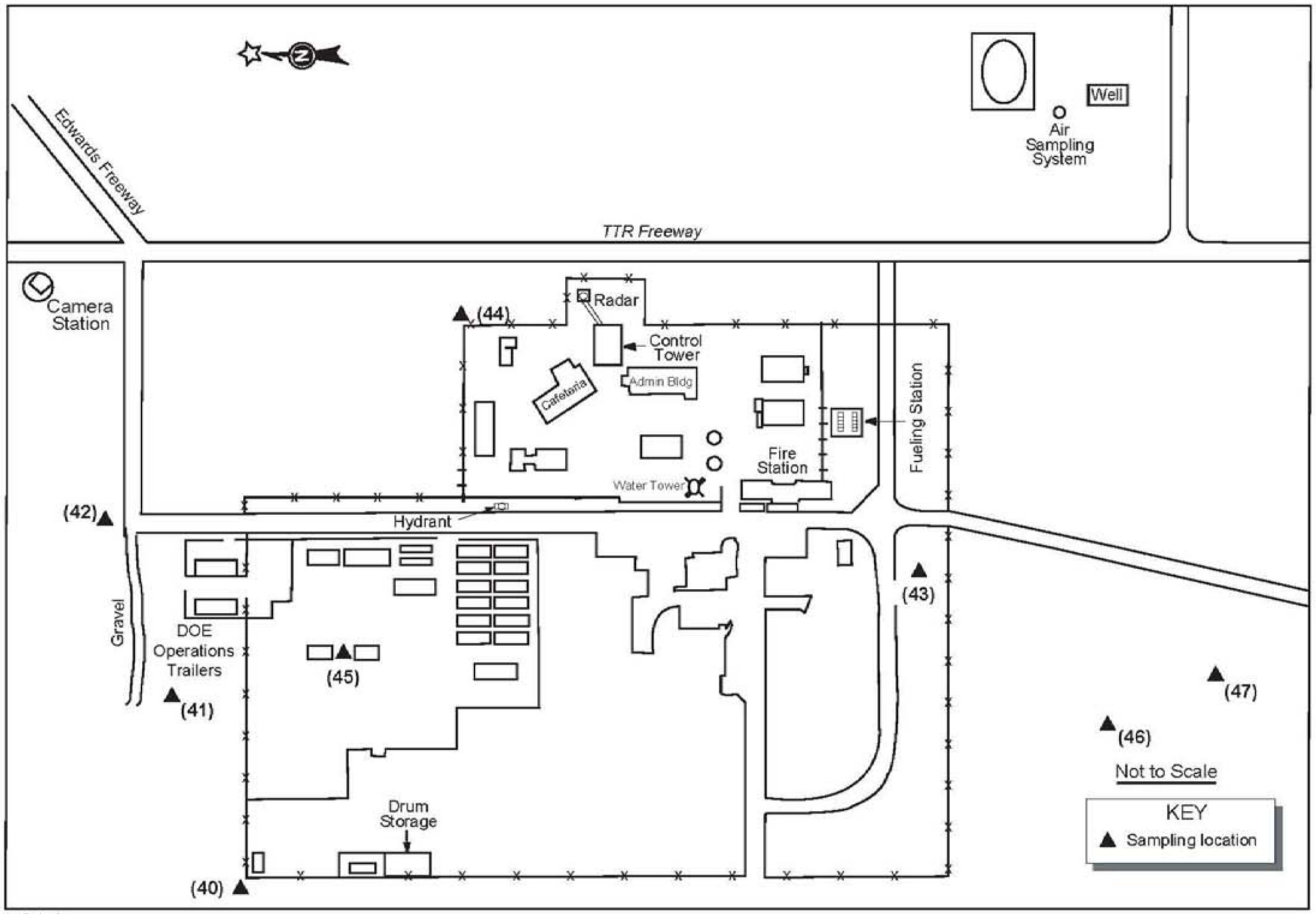


FIGURE 3. Soil Sampling Locations in the South Plume Area (on-site) (Five Locations)



01_B-4a.ai

FIGURE 4. Soil Sampling Locations in the Range Operations Center and Compound (on-site)
(Eight Locations)

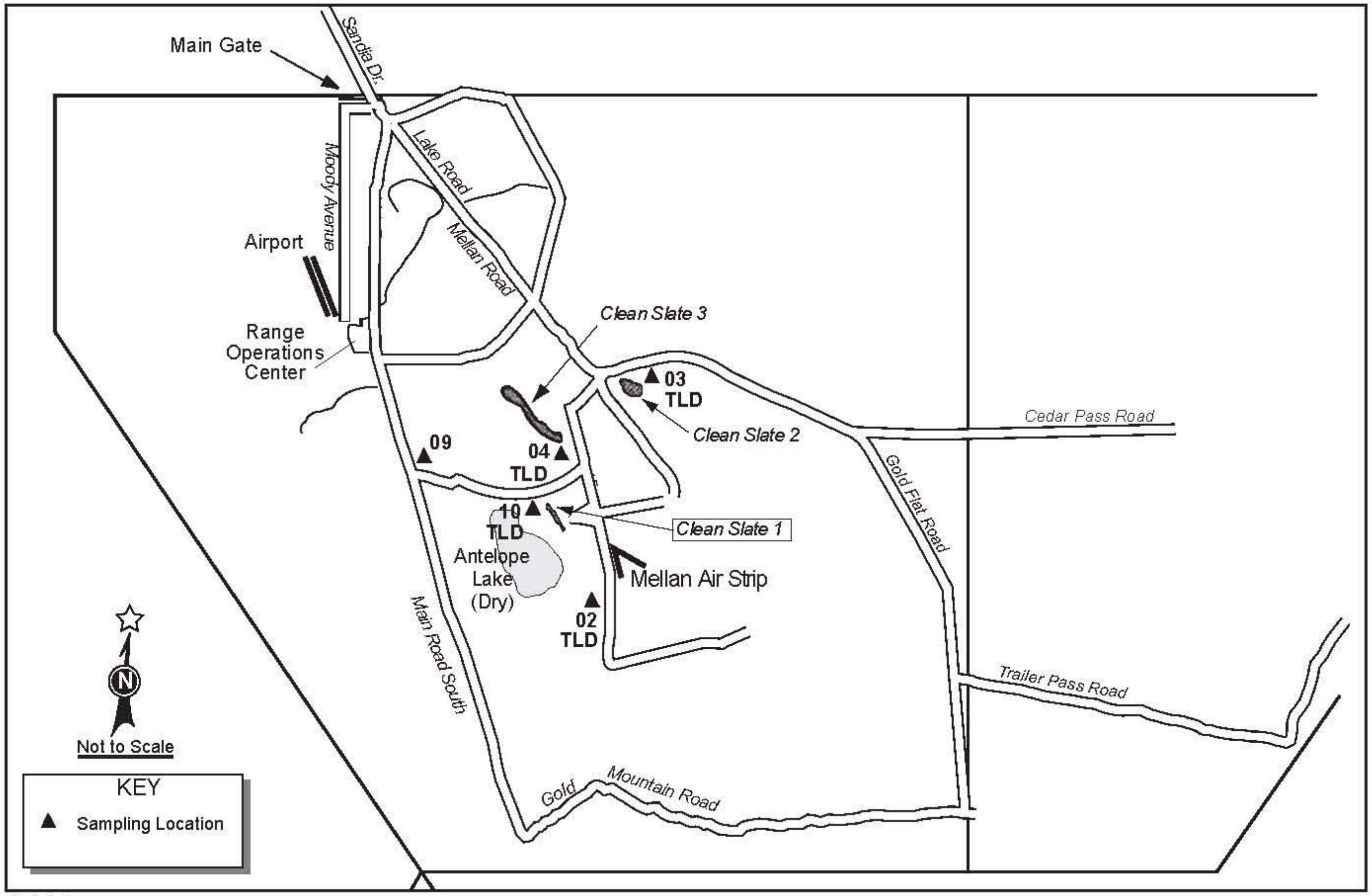


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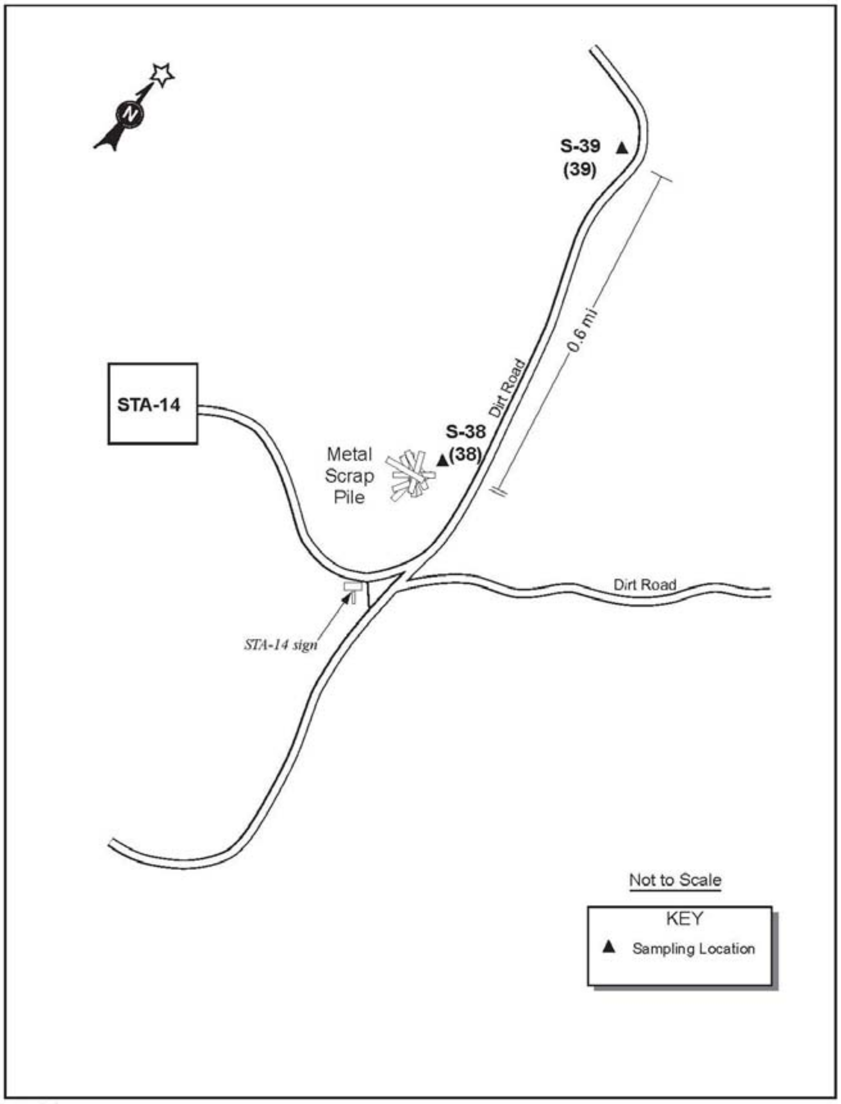
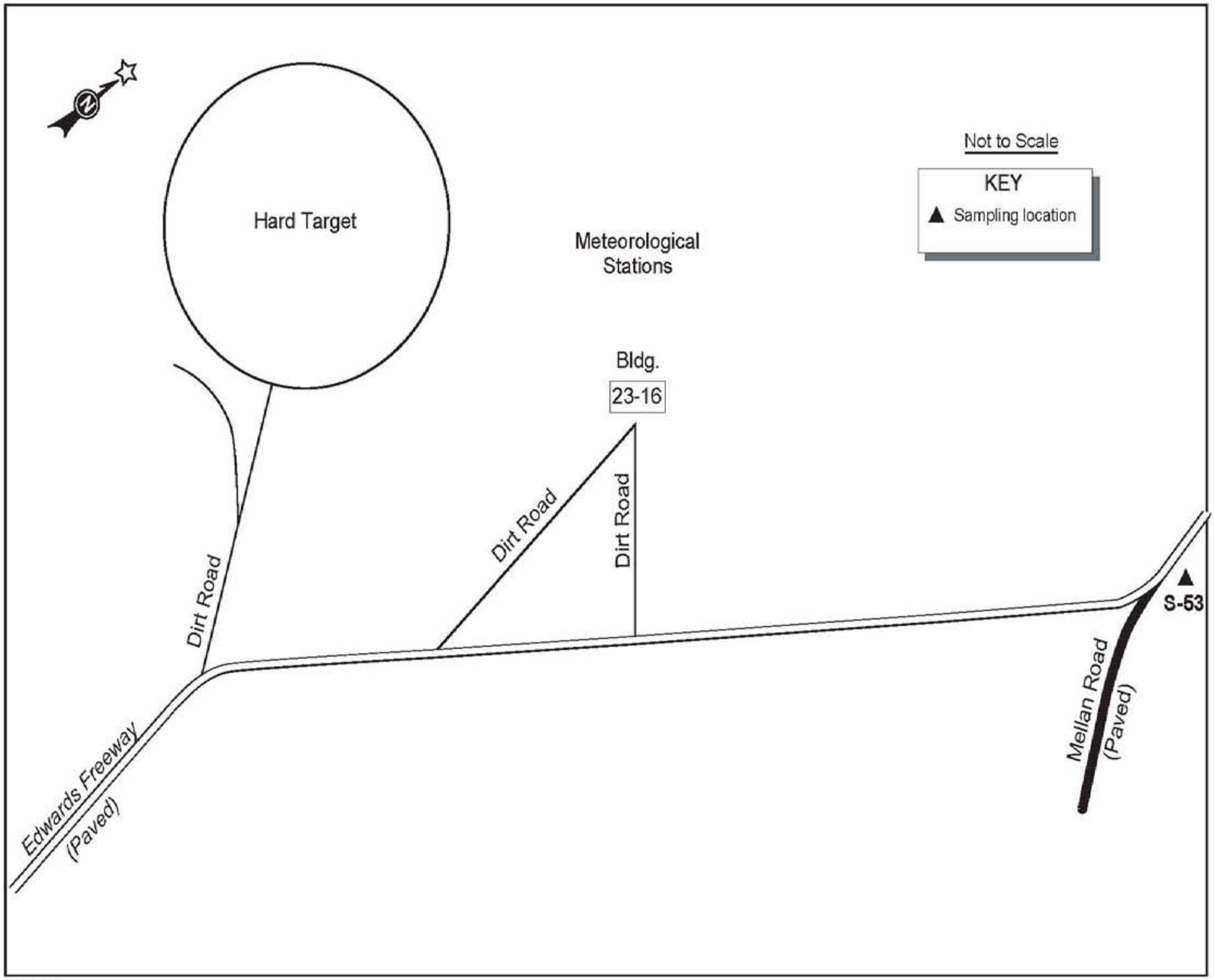
FIGURE 5. Various On-site Soil Sampling Locations
(Five Locations)



01_B-5b.ai

FIGURE 6. Various Soil Sampling Locations at Mellan Hill Area (Two Locations)



01_B-5c.ai

FIGURE 7. Soil Sampling Location Near the Hard Target/Depleted Uranium Area (One Location)

Results of the soil samples were evaluated using probability plotting, which provided a visual representation of the entire data set for all locations and for all times sampled. If the results were similar, or fit a linear distribution when plotted on logarithmic or log-probability scales, then the results were attributable to natural origin. Summary statistics for each element were imbedded in each plot. If any samples indicated concentrations greater than expected from the rest of the sample distribution, further evaluation was conducted to determine if SNL TTR facility operations were possibly responsible for the observed result. Table 4 provides various reference values for metals-in-soil.

Appendix A contains a detailed description of the mechanics of log-normal plotting. Appendix B contains the plots of the soil data, sorted alphabetically by analyte name. Associated with each plot presented are the summary statistics for each analyte. Applicable EPA Region 9 Screening Levels (if available) for Industrial and Residential use are indicated on the graphs.

Table 4.   Various Reference Values for Metals-in-Soil

	NV Soil Concentrations[1]		PA Region 9 PRGs (Soil Screening Levels)[2]		US Soil Concentrations[3]	
lyte	**Lower Limit**	**Upper Limit**	**Residential**	**Industrial**	**Lower Limit**	**Upper Limit**
minum	5,000	100,000	76,000	100,000	4,500	100,000
imony	< 1.0	1.0	31	410	0.25	0.6
enic	2.9	24	0.39	1.6	1	93
ium	150	3,000	5,400	67,000	20	1,500
yllium	ND	5.0	150	1,400	0.04	2.54
lmium	ND	11	37	450	0.41	0.57
cium	600	320,000	n/a	n/a	n/a	n/a
omium	7.0	150	210	450	7	1,500
alt	ND	20	900	1,900	3	50
per	7	150	3,100	41,000	3	300
n	1000	100,000	23,000	100,000	5,000	50,000
d	< 10	700	400	800	10	70
gnesium	300	100,000	n/a	n/a	n/a	n/a
nganese	30	5,000	1,800	19,000	20	3,000
rcury	0.01	0.82	6	62	0.02	1.5
lybdenum	ND	7.0	390	5,100	0.8	3.3
kel	5	50	1,600	20,000	5	150
assium	1,900	63,000	n/a	n/a	n/a	n/a
enium	< 0.1	1.1	390	5,100	0.1	4
a (Silicon)	150,000	440,000	n/a	n/a	24,000	368,000
er	0.5	5	390	5,100	0.2	3.2
ium	500	100,000	n/a	n/a	n/a	n/a
ntium	100	1500	47,000	100,000	7	1,000
llium	n/a	n/a	5.2	67	0.02	2.8
nium	700	5,000	100,000	100,000	20	1,000
nadium	30	150	78	1,000	0.7	98
c	10	2,100	23,000	100,000	13	300

ND = not detectable
n/a = not available

(1) Dragun, James, A. Chiasson, *Elements in North American Soils*, 1991, Hazardous Materials Control Resources Institute, (Used Nevada Soils to determine values).
(2) EPA Region 9 Preliminary Remediation Goals (PRGs), U.S.E.P.A., October 2004.
(3) US Soil Surface Concentrations, Kabata-Pendias, A., Pendias, H., CRC, *Trace Elements in Soils and Plants*, 2nd Edition, 1992

Summary

Soil and sediment samples have been collected from 1994 through 2005 at TTR as one means of monitoring for the potential effects on the environment of facility operations at the Laboratories. The year-to-year results of this sampling effort are reported in the Annual Site Environmental Report (ASER, SNL 2005). The data indicate that TTR operations have made no significant impact to existing concentration of TAL metal is surface soil.

Appendix A - Data Analysis

The data in this report is presented in the form of log-normal probability plots. Such plots are useful tools for conveniently cataloguing and evaluating large amounts of data, as well as providing a first approximation of the similarity (or differences) of the data. The basis for using log-normal plotting is experience which has shown that large quantities of environmental data (many similar analyte/media combinations) yield a straight line when plotted on a log-probability or logarithmic scale (Miller 1977). The presumption of log-normal distribution is never a bad presumption and is never worse than the presumption of arithmetic-normal (Michels 1971). Because the data is represented graphically, the mean, standard deviation, expected upper limits, and any abnormalities can be readily determined visually (Waite 1975).

Characteristics of special importance in the use of log-normal plots are linearity (denoting data from a common population), standard geometric deviation ($\sigma_{g,}$ an indicator of variability or range), and geometric mean (X_g). The unit of slope in a log-normal plot involves a logarithmic increment. Thus, the standard deviation is a multiplier of the geometric mean (Michels 1971). The values for σ_g and X_g can be obtained from the graphs by the ratio of the 84%/50% intercepts and the 50% intercepts, respectively (Miller 1977). Linearity of the graph implies that any potential TTR contribution to the observed concentration is indistinguishable from regional levels of the element. Anomalous results (potentially attributable to TTR operations) must necessarily occur at a higher concentration than would be expected from regional distributions. For convenience, summary statistics for each element was imbedded in each plot. Included in this list is the Upper Tolerance Limit (UTL), which is defined as:

$$95^{th} \text{ UTL} = \bar{X} + K*S$$

Where UTL = Upper Tolerance Limit
X = Sample Arithmetic Mean
S = Sample Standard Deviation
K = One-sided normal tolerance factor

Values for K are commonly determined from tables such as those provided by Lieberman (Leiberman 1958). A typical value of K equal to 1.763 was assigned, which is for sample size of n = 500. The sample size for each element ranged from 200-540. This UTL can be used to estimate a level above which a sample result may not be attributable to naturally occurring “background” levels of the element.

Whenever a particular results appears elevated (on the log-normal plot) compared to the expected concentration based on the population comprised of all the other locations, further investigation to determine if TTR operations are potentially responsible may include (but should not be limited to) the following:

- What is the geographical location of the sample? Is there a detectable pattern to the anomalous observation or is the sample from an area in close proximity to a facility which has the potential for release of the analyte or contaminant?
- Does the location of the sample(s) show elevated levels for other analytes or for the results obtained from the same location in previous years?
- If several locations appear to be elevated, is there a particular year that had the elevated results? How did these compare to perimeter or off-site sample results?

As can be observed in many of the graphs, data at the lower end of the range frequently "falls off" in a manner that suggests that these results do not belong in the distribution being plotted, or are otherwise anomalous. However, in almost all instances, these results represent reported values that were at the extreme lower limit of the analytical method employed at the time of analysis. This is not atypical, since the plotted values do not include the analytical uncertainty or method detection level (MDL) for a given result. Also, the MDL changes (frequently becomes better) over time as the state-of-the-art for analytical science improves, and the aggregated data may include data that actually has a range of MDLs, which only becomes an artifact if the given analyte's concentration is near the MDL. In several of the plots, many of the same reported values appear as a "flat line". These values are typically the "less than" values reported by the laboratory when the analyte was not otherwise detected.

Appendix B contains the plots of the soil/sediment data, sorted alphabetically by analyte name. Any noteworthy anomalies in the plots are discussed by notes within the given plot. Associated with each plot presented in Appendix B are the summary statistics and EPA Region 9 Screening Levels for each analyte.

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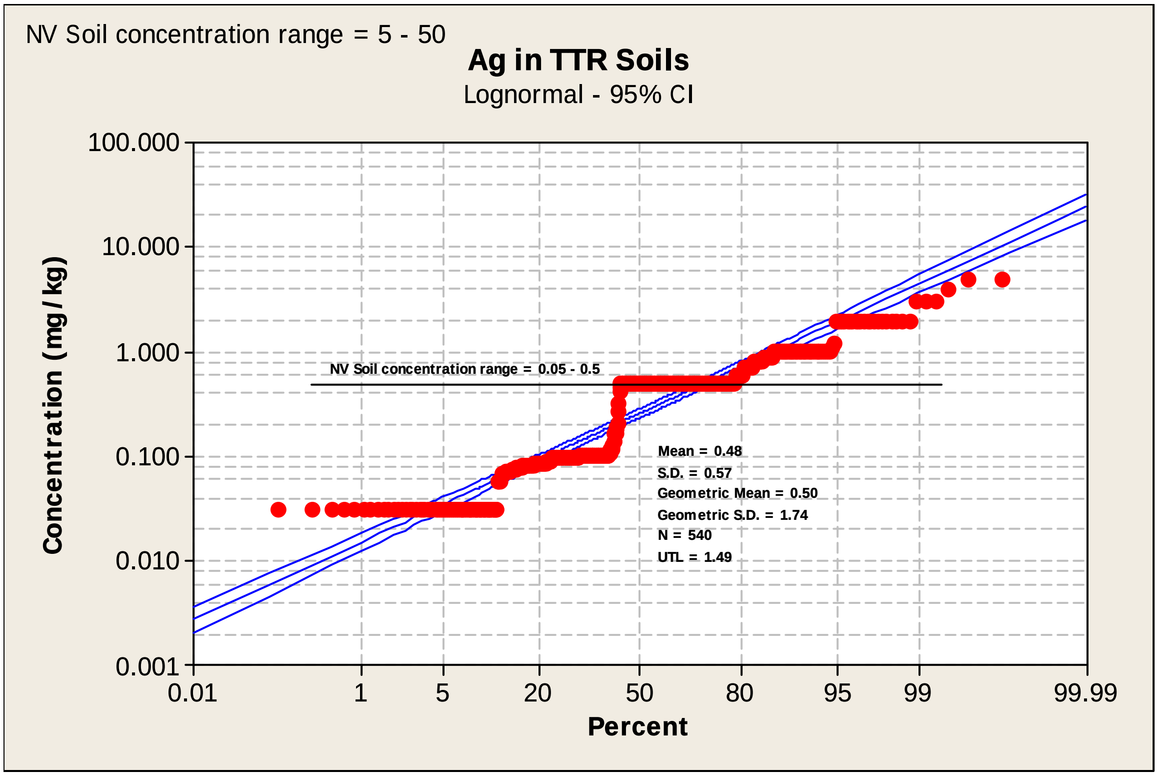
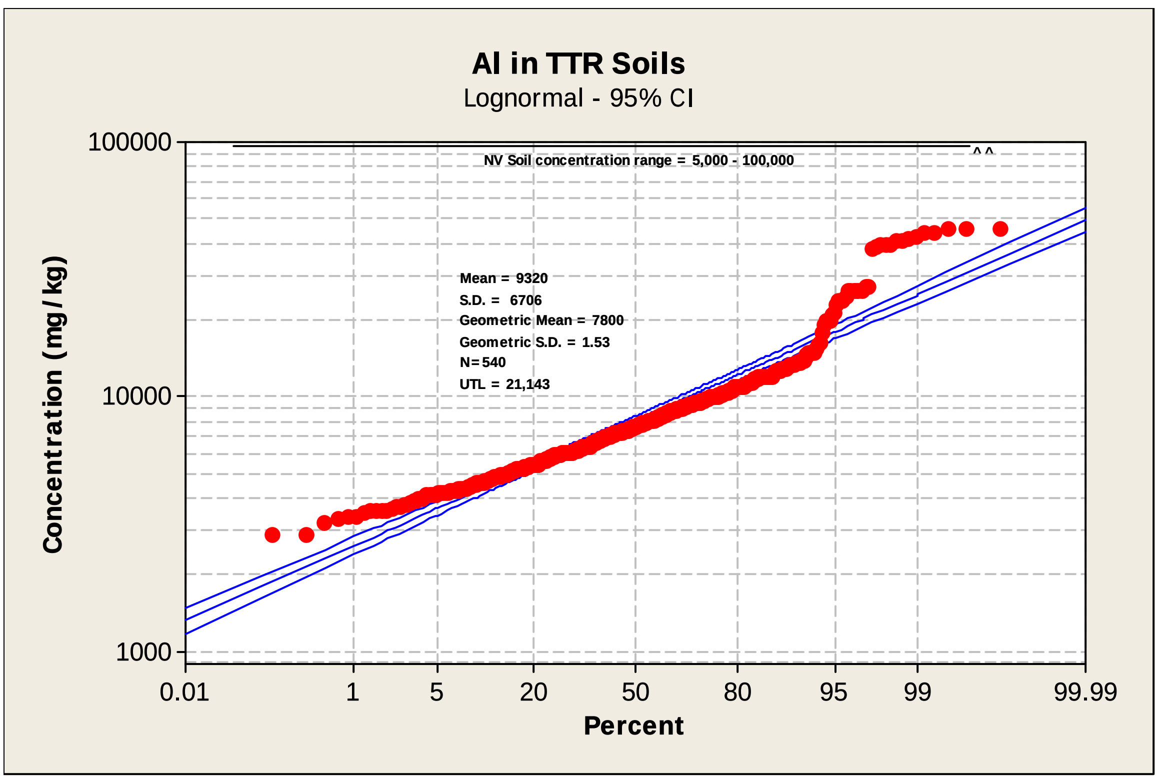
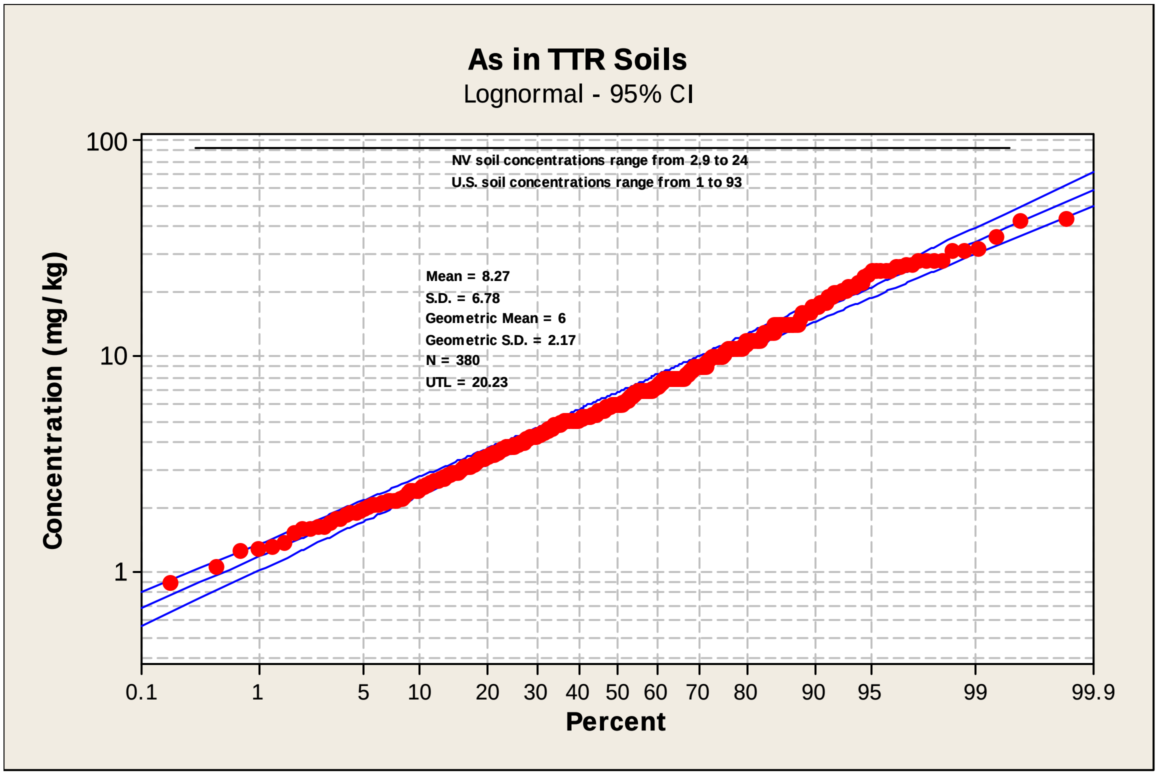
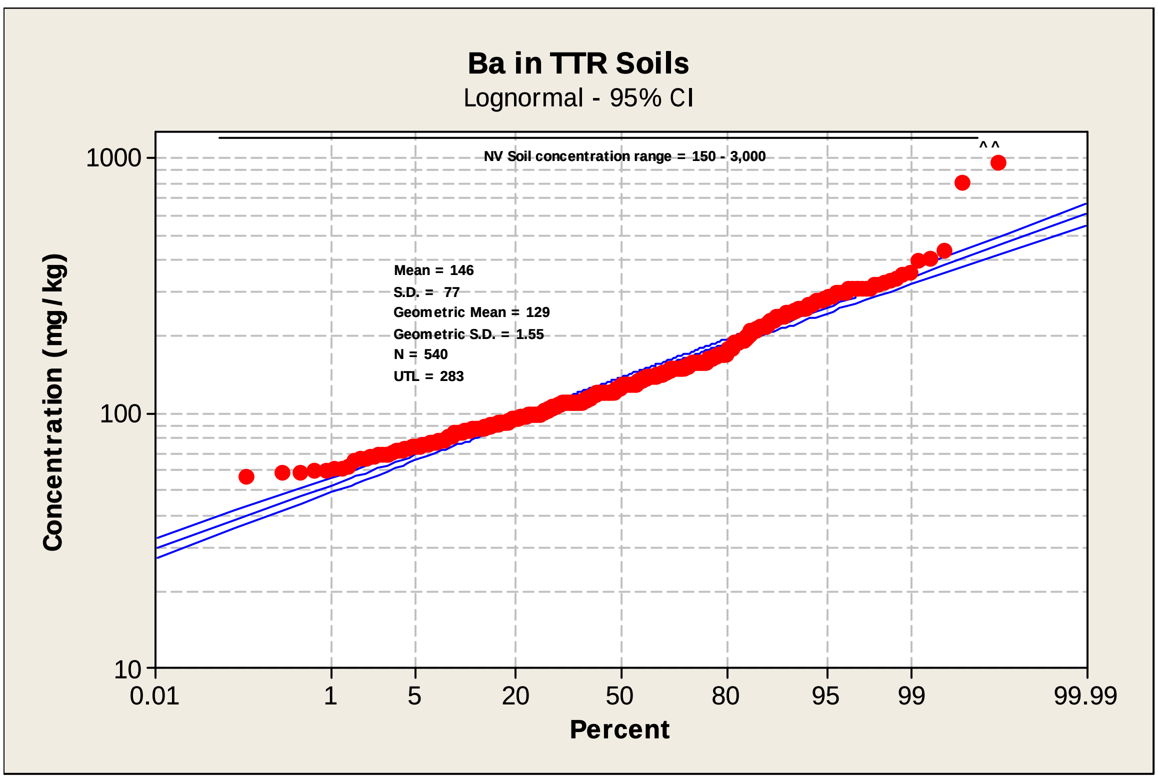
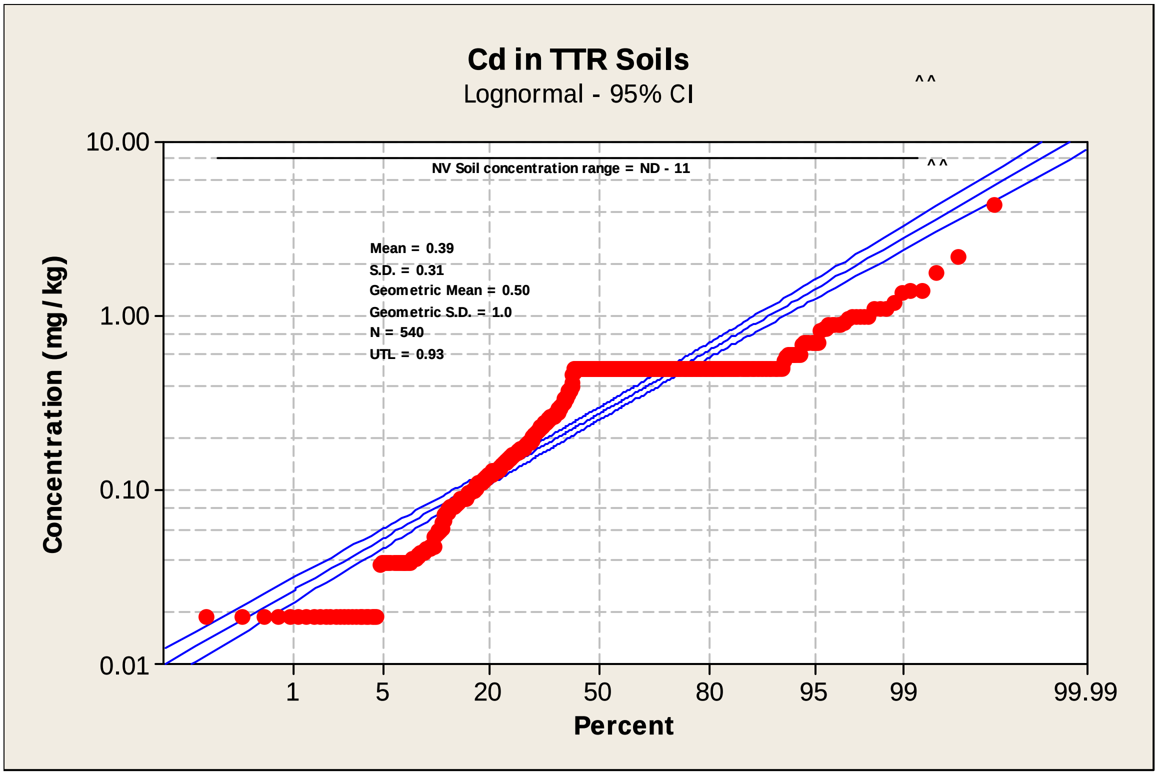
Appendix B – TAL Metals in soil in the TTR Environs

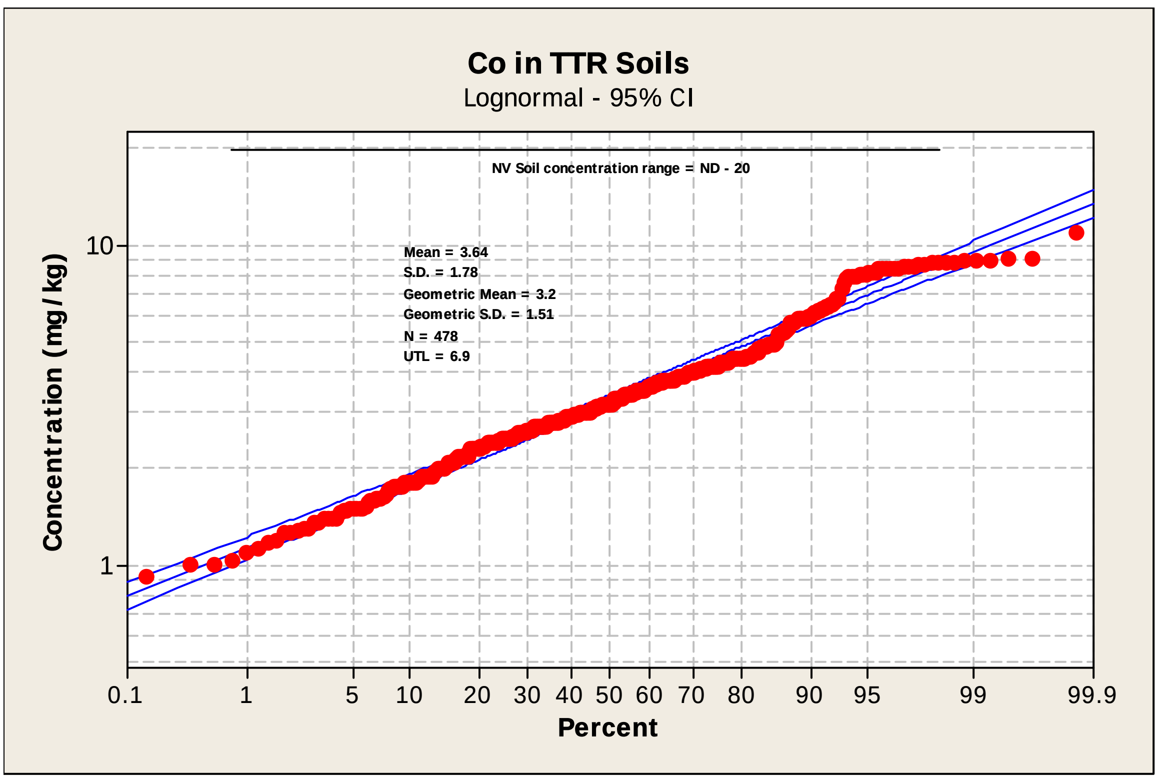


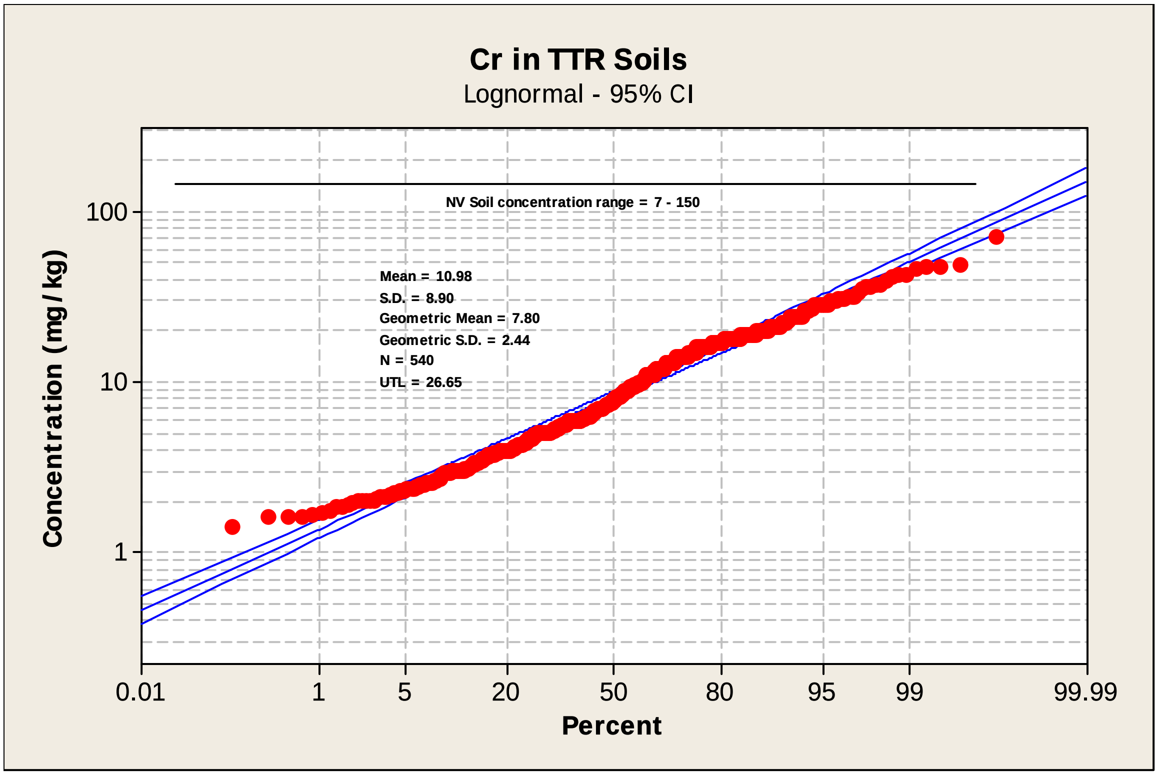


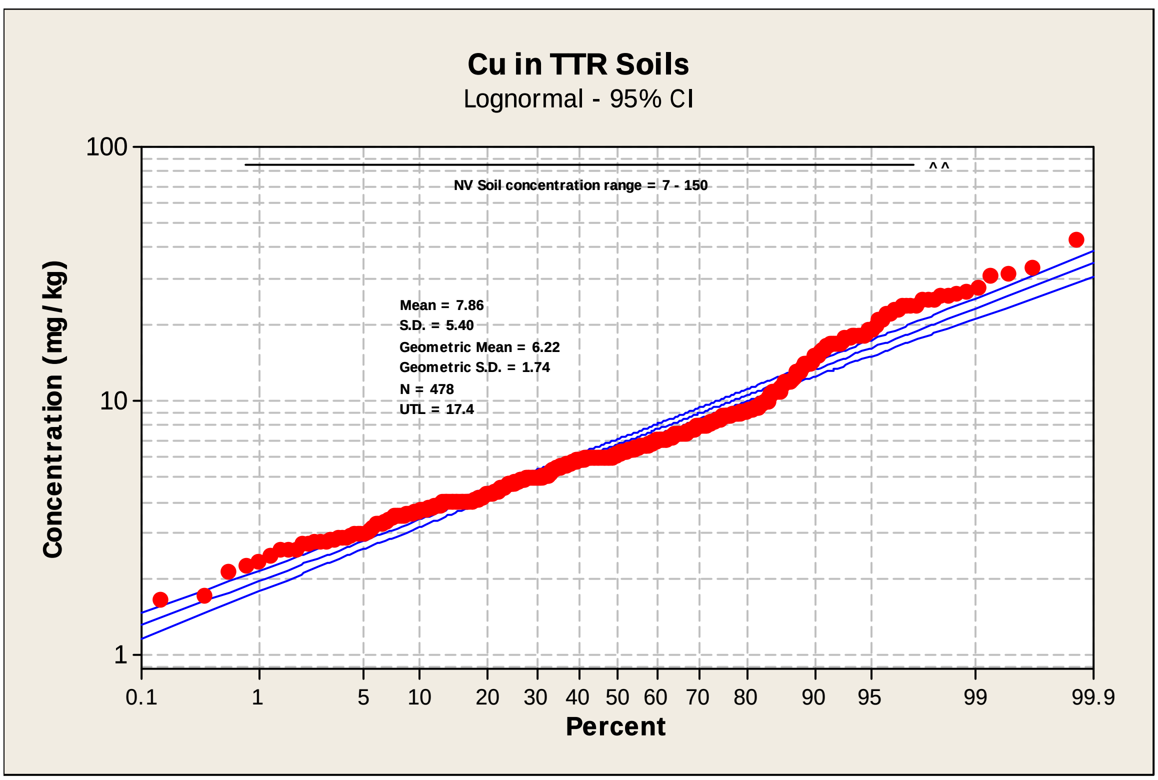

As in TTR Soils
Lognormal - 95% CI
NV soil concentrations range from 2.9 to 24
U.S. soil concentrations range from 1 to 93
Mean = 8.27
S.D. = 6.78
Geometric Mean = 6
Geometric S.D. = 2.17
N = 380
UTL = 20.23
Concentration (mg/kg)
100
10
1
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
Percent

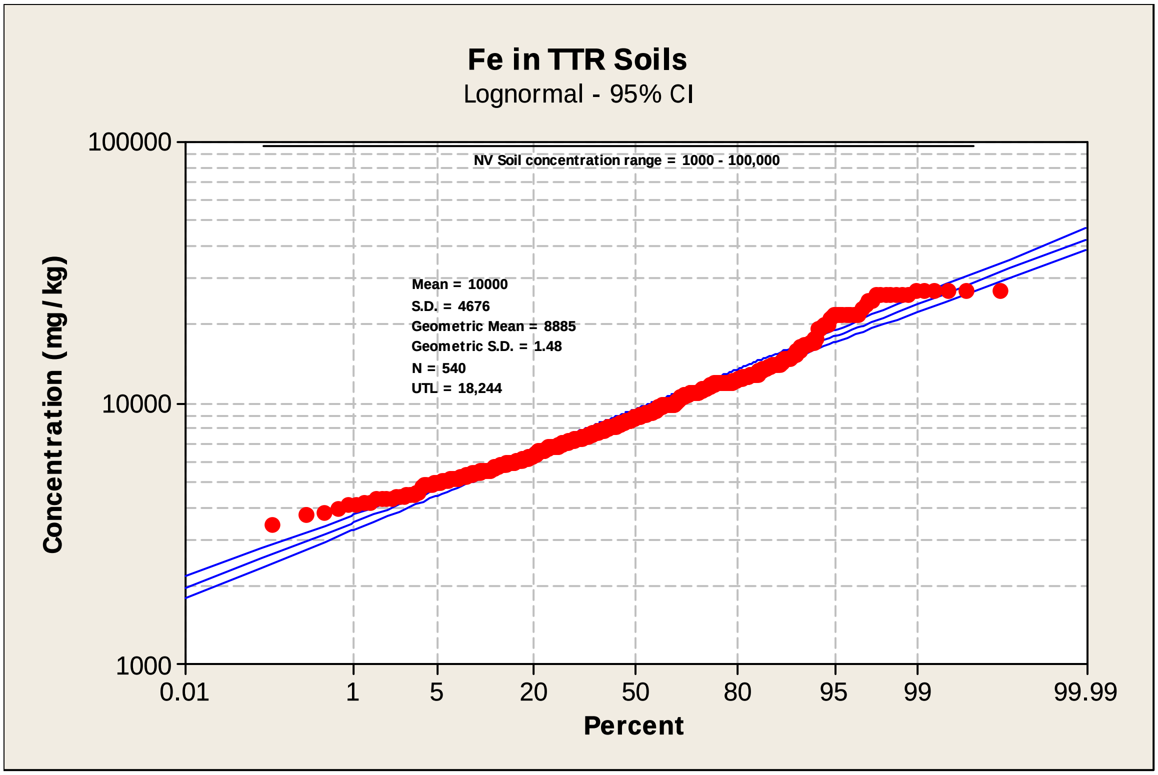

Ba in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 150 - 3,000
^^
Mean = 146
S.D. = 77
Geometric Mean = 129
Geometric S.D. = 1.55
N = 540
UTL = 283
Concentration (mg/kg)
1000
100
10
0.01
1
5
20
50
80
95
99
99.99
Percent


Cd in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = ND - 11
Mean = 0.39
S.D. = 0.31
Geometric Mean = 0.50
Geometric S.D. = 1.0
N = 540
UTL = 0.93
Concentration (mg/kg)
10.00
1.00
0.10
0.01
1
5
20
50
80
95
99
99.99
Percent

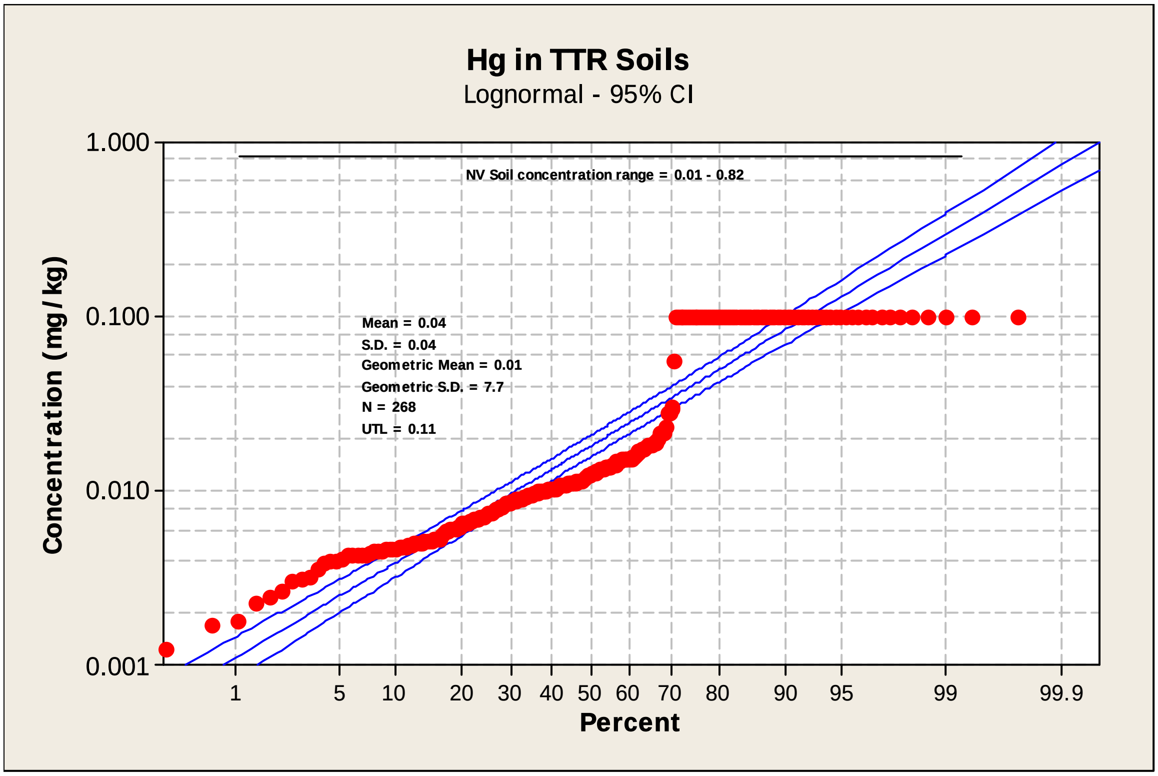

Co in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = ND - 20
Mean = 3.64
S.D. = 1.78
Geometric Mean = 3.2
Geometric S.D. = 1.51
N = 478
UTL = 6.9
Concentration (mg/kg)
10
1
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
Percent


Cr in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 7 - 150
Mean = 10.98
S.D. = 8.90
Geometric Mean = 7.80
Geometric S.D. = 2.44
N = 540
UTL = 26.65
Concentration (mg/kg)
100
10
1
0.01
1
5
20
50
80
95
99
99.99
Percent

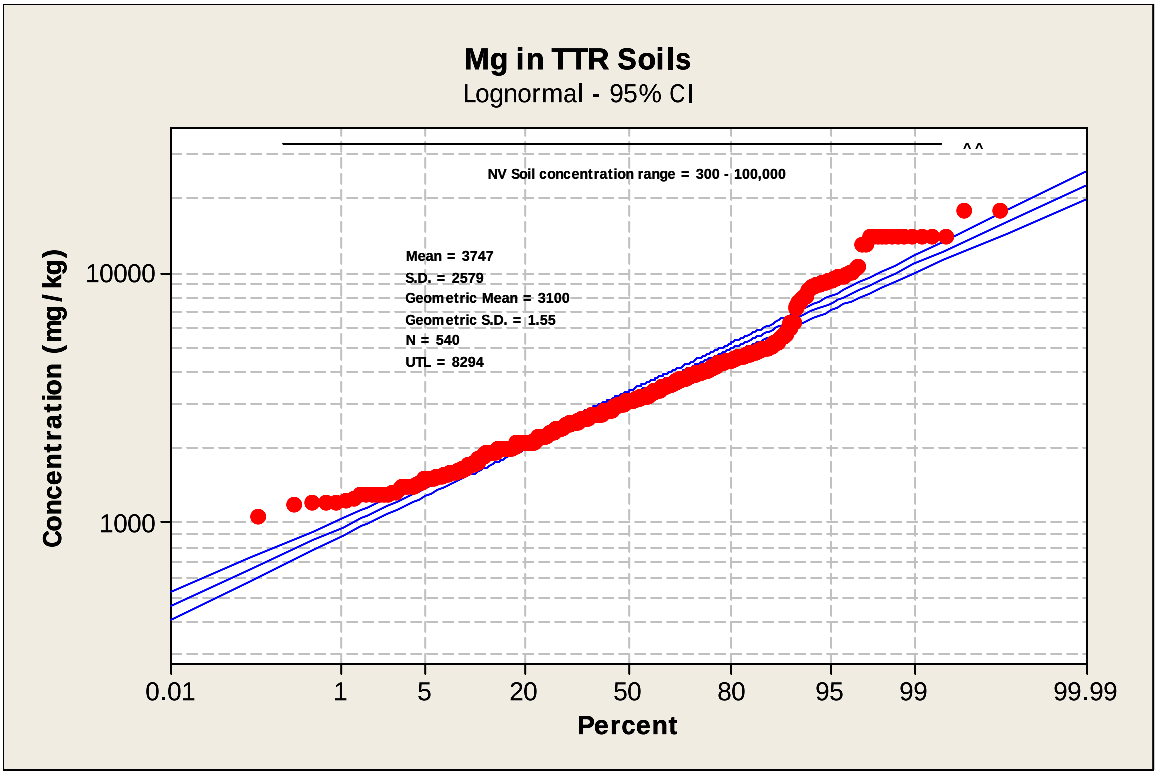

Cu in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 7 - 150
Mean = 7.86
S.D. = 5.40
Geometric Mean = 6.22
Geometric S.D. = 1.74
N = 478
UTL = 17.4
Concentration (mg/kg)
100
10
1
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
Percent

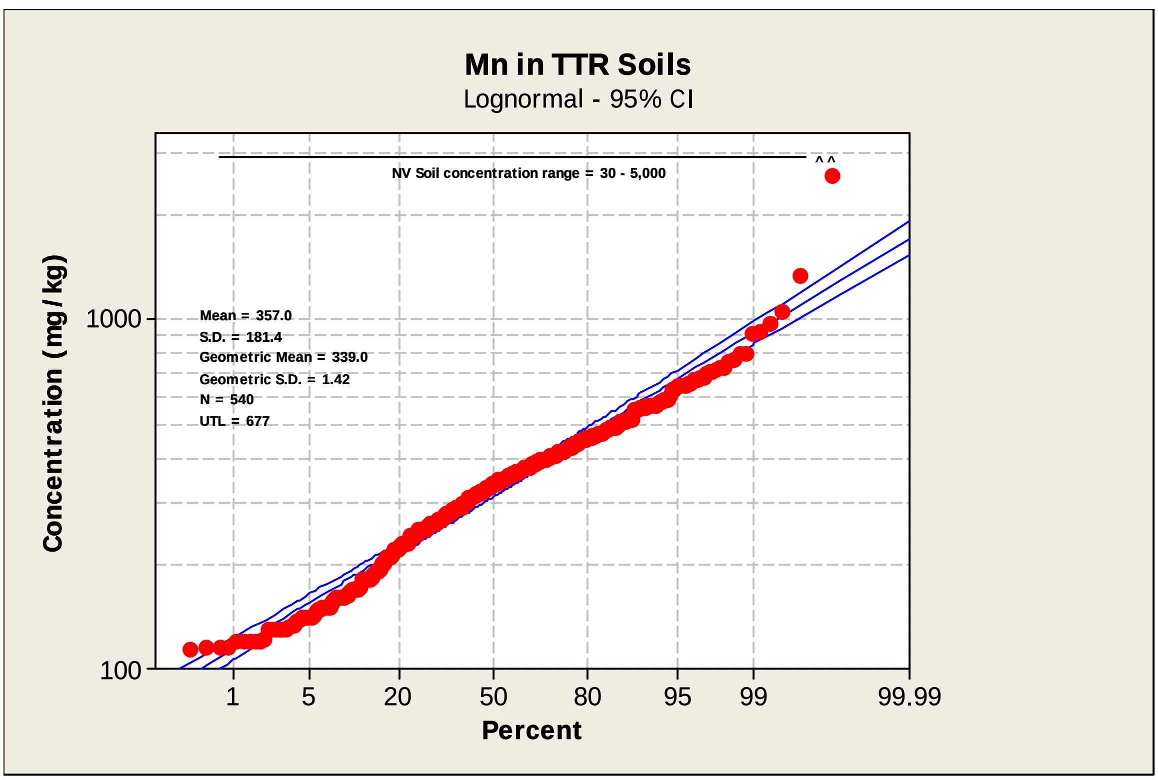


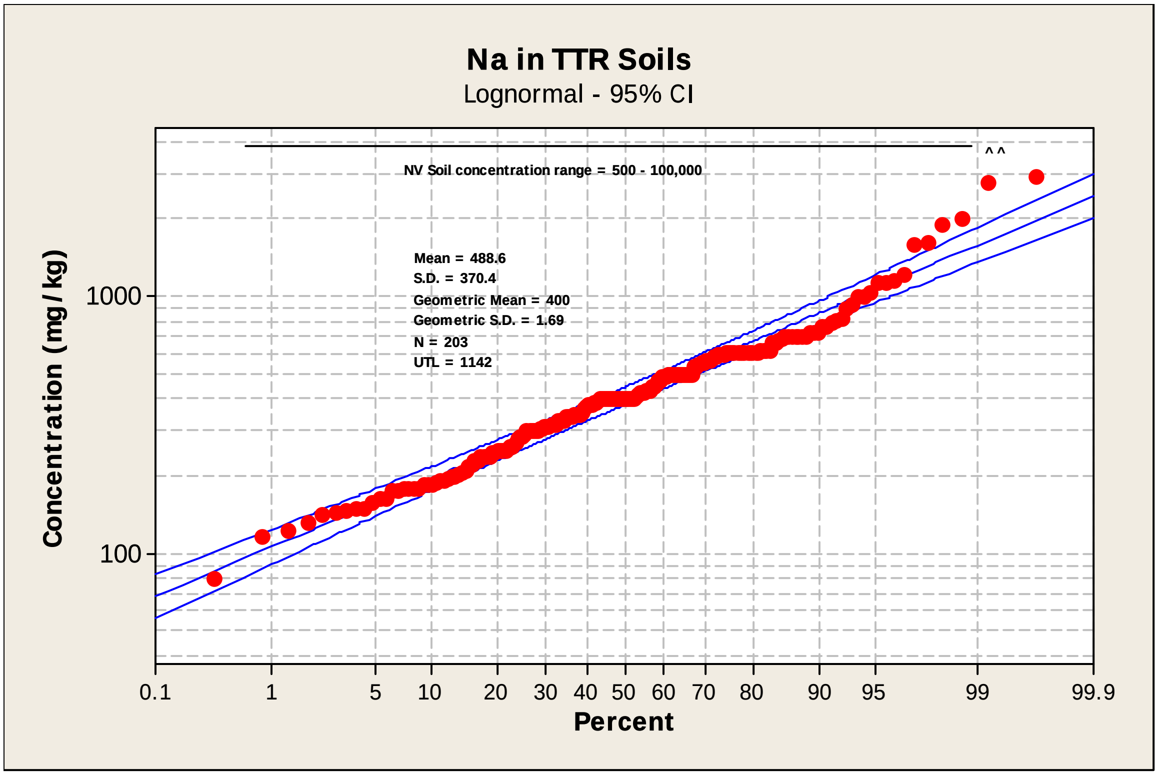
Fe in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 1000 - 100,000
Mean = 10000
S.D. = 4676
Geometric Mean = 8885
Geometric S.D. = 1.48
N = 540
UTL = 18,244
Concentration (mg/kg)
100000
10000
1000
0.01
1
5
20
50
80
95
99
99.99
Percent

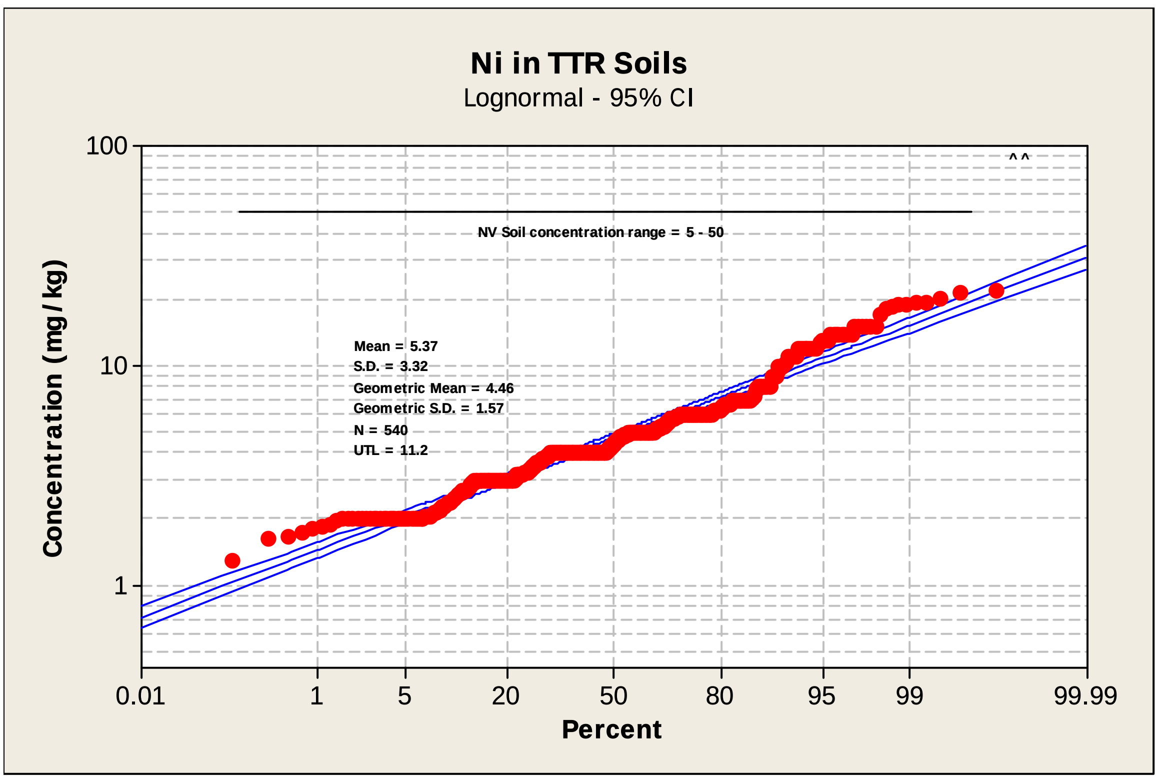


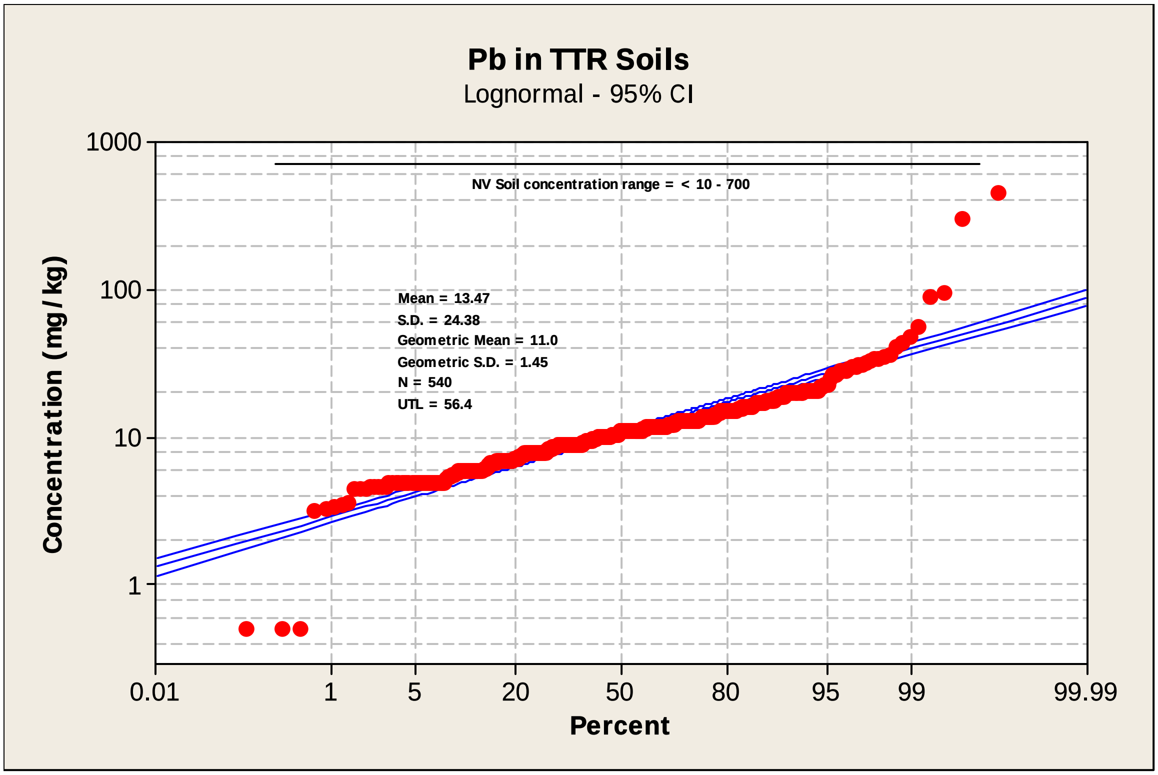
Hg in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 0.01 - 0.82
Mean = 0.04
S.D. = 0.04
Geometric Mean = 0.01
Geometric S.D. = 7.7
N = 268
UTL = 0.11
Concentration (mg/kg)
1.000
0.100
0.010
0.001
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
Percent

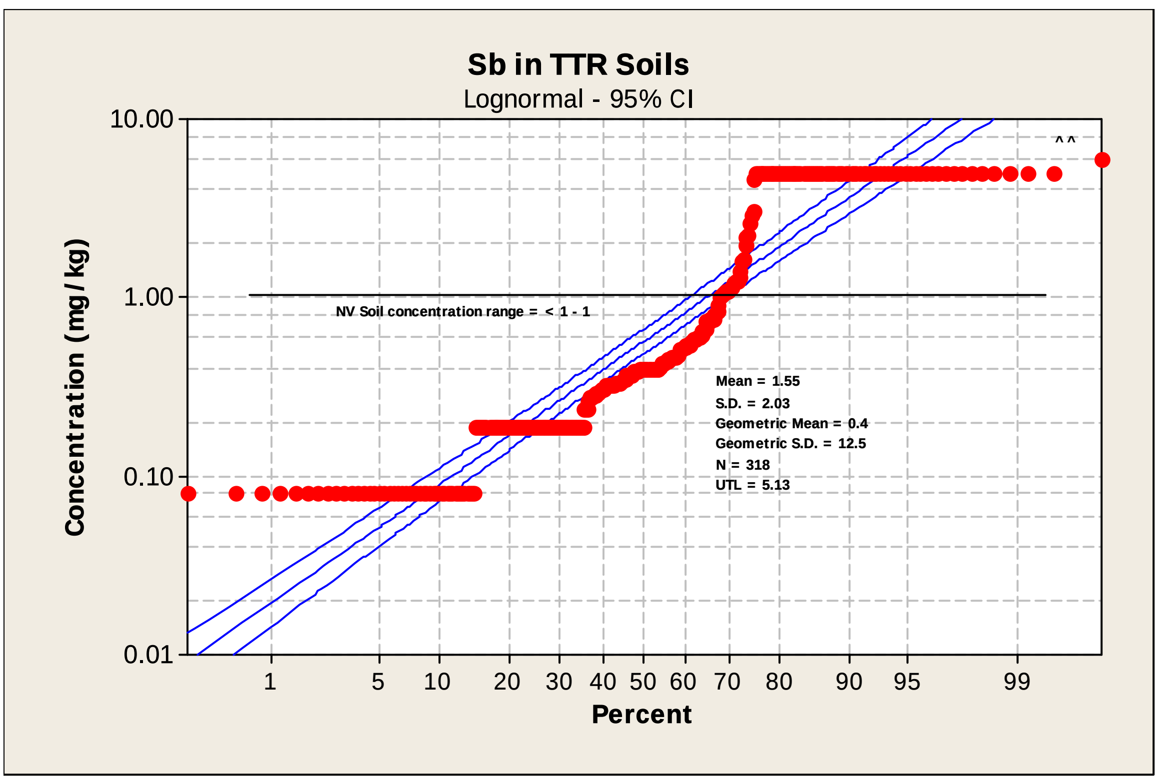

Mg in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 300 - 100,000
Mean = 3747
S.D. = 2579
Geometric Mean = 3100
Geometric S.D. = 1.55
N = 540
UTL = 8294
Concentration (mg/kg)
10000
1000
0.01
1
5
20
50
80
95
99
99.99
Percent

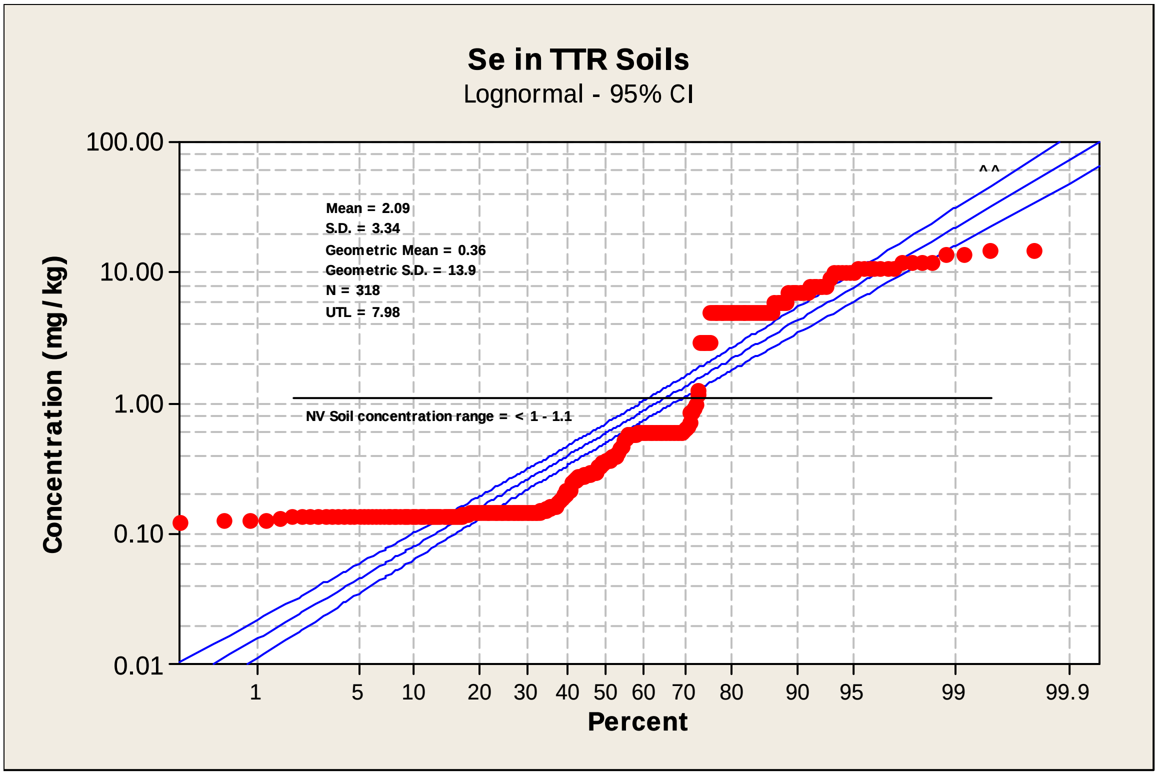

Mn in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 30 - 5,000
Mean = 357.0
S.D. = 181.4
Geometric Mean = 339.0
Geometric S.D. = 1.42
N = 540
UTL = 677
Concentration (mg/kg)
1000
100
1
5
20
50
80
95
99
99.99
Percent

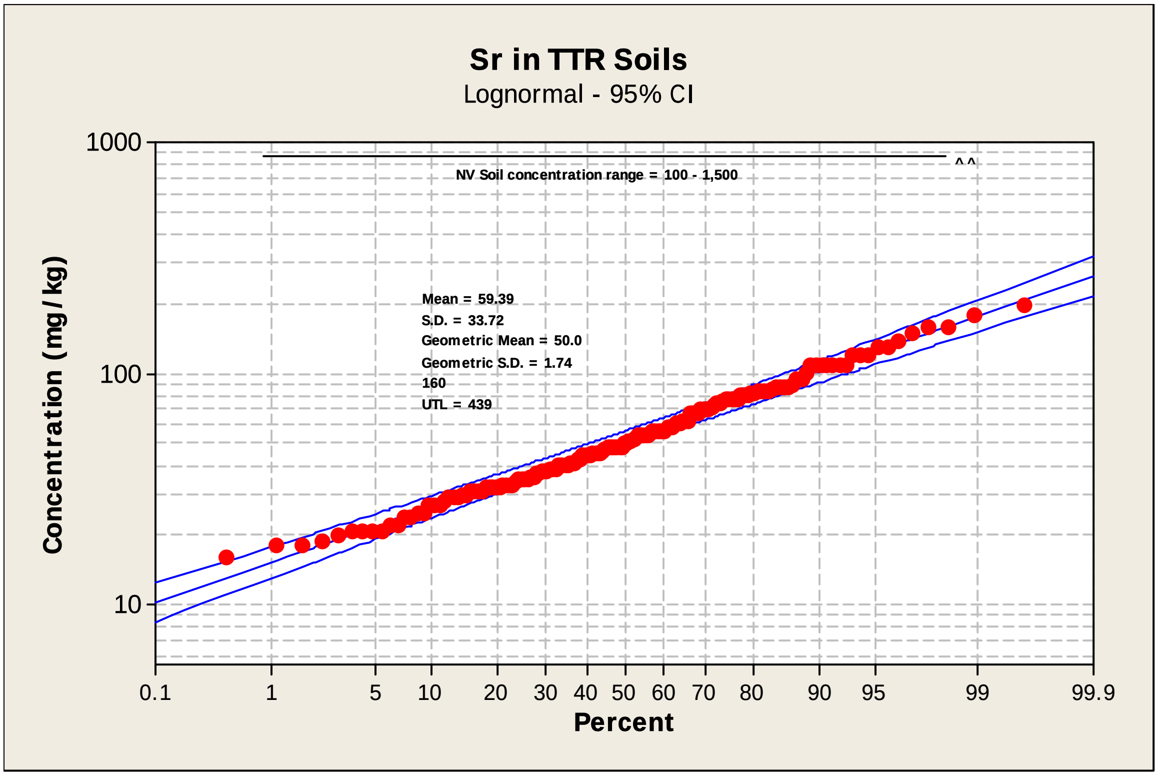

Na in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 500 - 100,000
^ ^
Mean = 488.6
S.D. = 370.4
Geometric Mean = 400
Geometric S.D. = 1.69
N = 203
UTL = 1142
Concentration (mg/kg)
1000
100
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
Percent

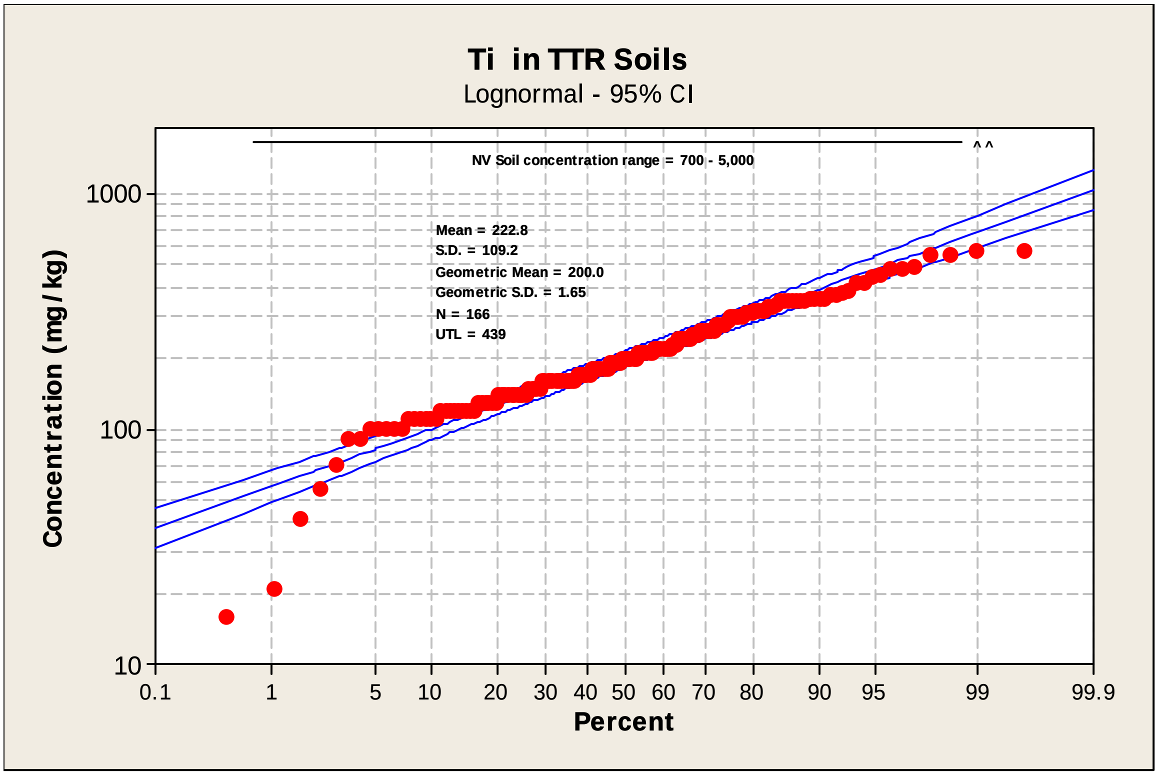

Ni in TTR Soils
Lognormal - 95% CI
^ ^
NV Soil concentration range = 5 - 50
Mean = 5.37
S.D. = 3.32
Geometric Mean = 4.46
Geometric S.D. = 1.57
N = 540
UTL = 11.2
Concentration (mg/kg)
100
10
1
0.01
1
5
20
50
80
95
99
99.99
Percent

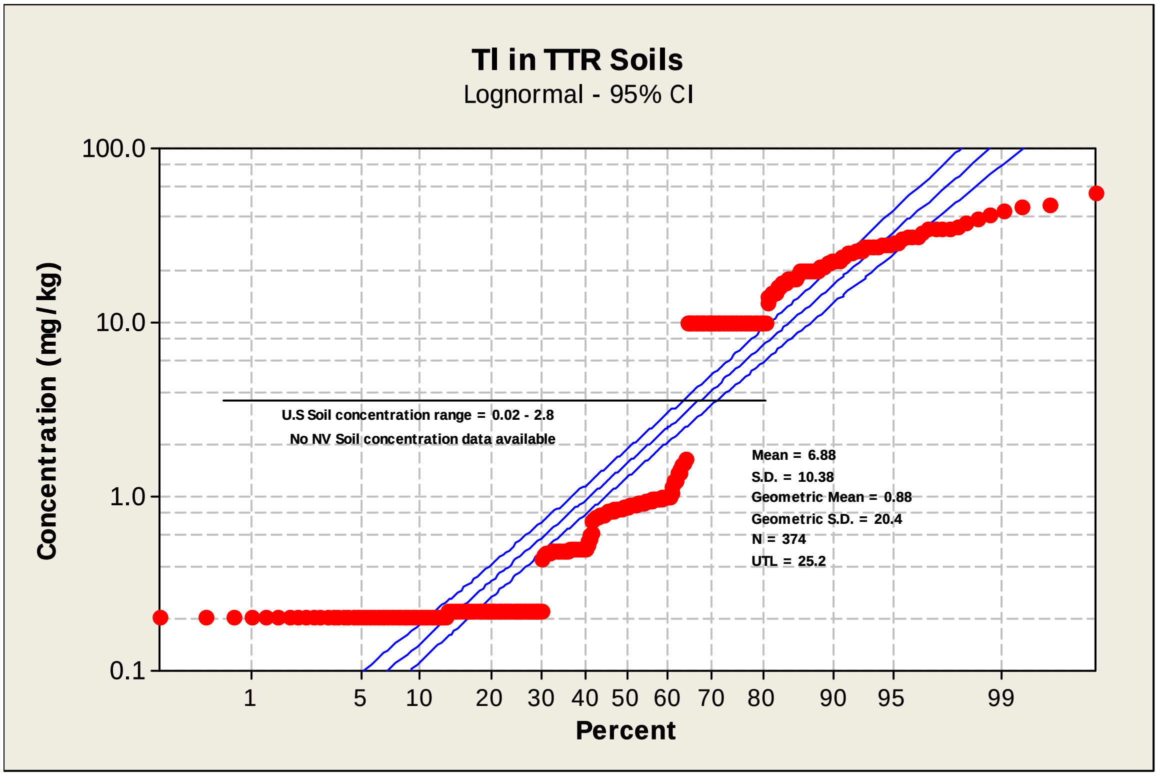

Pb in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = < 10 - 700
Mean = 13.47
S.D. = 24.38
Geometric Mean = 11.0
Geometric S.D. = 1.45
N = 540
UTL = 56.4
Concentration (mg/kg)
1000
100
10
1
0.01
1
5
20
50
80
95
99
99.99
Percent

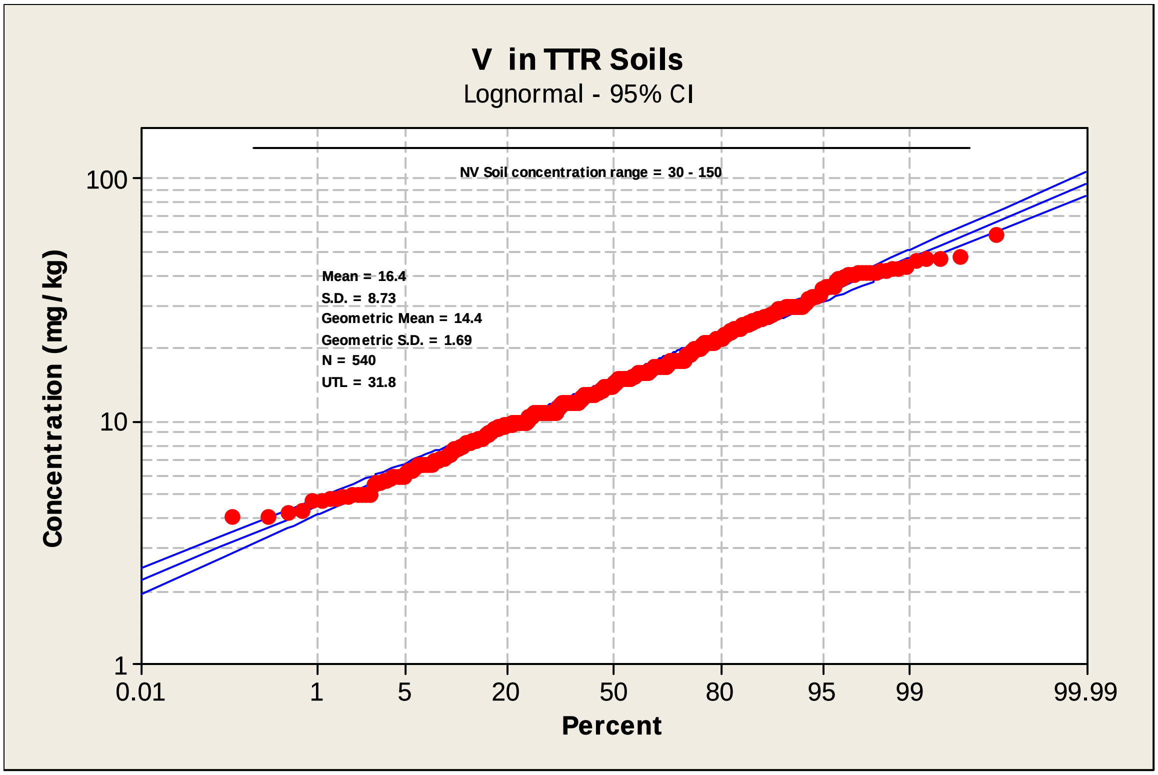

Sb in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = < 1 - 1
Mean = 1.55
S.D. = 2.03
Geometric Mean = 0.4
Geometric S.D. = 12.5
N = 318
UTL = 5.13
Concentration (mg/kg)
10.00
1.00
0.10
0.01
1
5
10
20
30
40
50
60
70
80
90
95
99
Percent

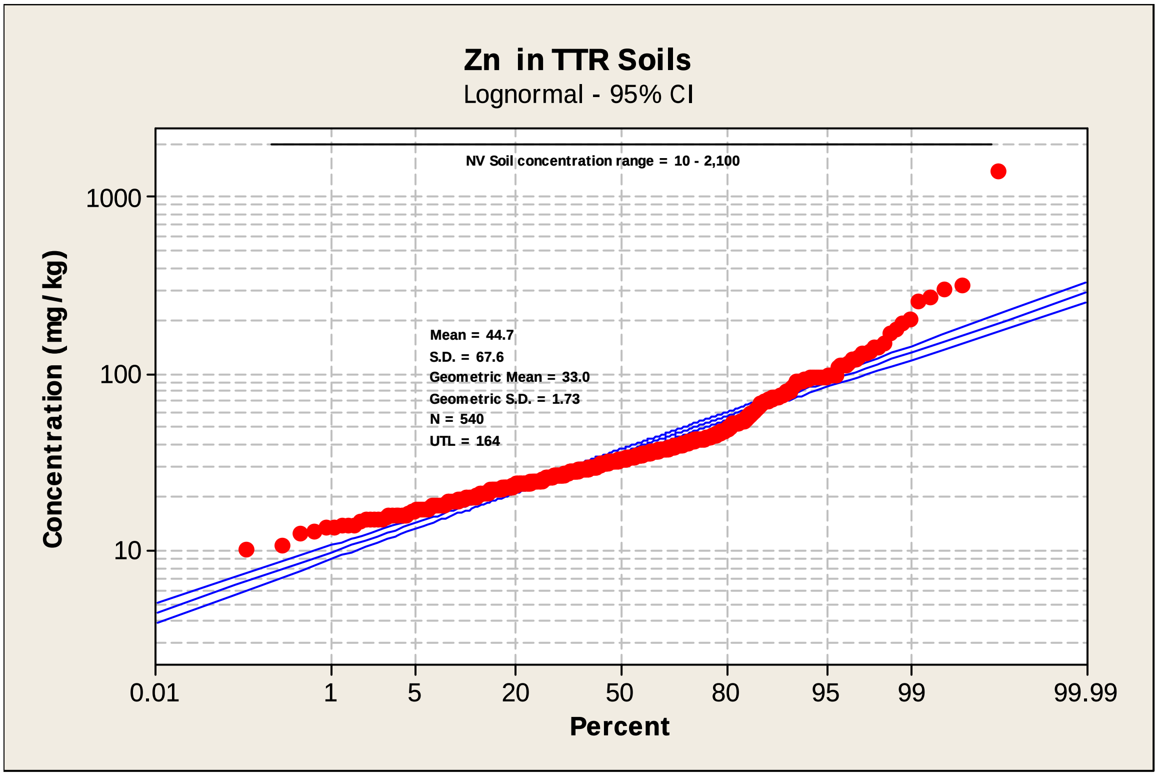

Se in TTR Soils
Lognormal - 95% CI
Mean = 2.09
S.D. = 3.34
Geometric Mean = 0.36
Geometric S.D. = 13.9
N = 318
UTL = 7.98
NV Soil concentration range = < 1 - 1.1
Concentration (mg/kg)
100.00
10.00
1.00
0.10
0.01
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
Percent


Sr in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 100 - 1,500
Mean = 59.39
S.D. = 33.72
Geometric Mean = 50.0
Geometric S.D. = 1.74
160
UTL = 439
Concentration (mg/kg)
1000
100
10
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9
Percent


Ti in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 700 - 5,000
Mean = 222.8
S.D. = 109.2
Geometric Mean = 200.0
Geometric S.D. = 1.65
N = 166
UTL = 439
Concentration (mg/kg)
Percent
1000
100
10
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99
99.9


Tl in TTR Soils
Lognormal - 95% CI
U.S Soil concentration range = 0.02 - 2.8
No NV Soil concentration data available
Mean = 6.88
S.D. = 10.38
Geometric Mean = 0.88
Geometric S.D. = 20.4
N = 374
UTL = 25.2
Concentration (mg/kg)
Percent
100.0
10.0
1.0
0.1
1
5
10
20
30
40
50
60
70
80
90
95
99


V in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 30 - 150
Mean = 16.4
S.D. = 8.73
Geometric Mean = 14.4
Geometric S.D. = 1.69
N = 540
UTL = 31.8
Concentration (mg/kg)
100
10
1
0.01
1
5
20
50
80
95
99
99.99
Percent


Zn in TTR Soils
Lognormal - 95% CI
NV Soil concentration range = 10 - 2,100
Mean = 44.7
S.D. = 67.6
Geometric Mean = 33.0
Geometric S.D. = 1.73
N = 540
UTL = 164
Concentration (mg/kg)
1000
100
10
0.01
1
5
20
50
80
95
99
99.99
Percent

Distribution

1	MS1042	Mark Miller	10331
1	MS1042	Regina Deola	10331
1	MS0890	Heidi Herrera	10312
1	MS0491	Hans Oldewage	12345
1	MS0184	Karen Agogino	SSO
1	MS0184	Susan Lacy	SSO
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