APPENDIX I

STATISTICAL AND GEOCHEMICAL EVALUATIONS OF METALS DATA

STATISTICAL
(TIERS 1 AND 2)

Statistical Comparison of Site and Background Data
Range K, Parcel 203(7)
Fort McClellan, Alabama

1.0 Introduction

This report provides the Tier 1 and Tier 2 site-to-background comparison results for Range K, Parcel 203(7) at Fort McClellan in Calhoun County, Alabama. Tier 1 and Tier 2 evaluations (Shaw E & I, 2003) have been performed on the surface soil, subsurface soil, and groundwater data sets. In the first step of the comparison, the maximum detected concentration (MDC) of each element is compared to two times the arithmetic mean of the background data (SAIC, 1998). Any metal that has an MDC greater than the background screening value is carried forward for Tier 2 evaluation, which includes the Slippage Test, the Wilcoxon Rank Sum Test (WRS), and Hot Measurement Test.

The methodology and results of the Tier 1 and Tier 2 comparisons are summarized in Tables 1 through 3, and described in more detail in the following sections. Site samples used in the site-to-background comparison include 13 surface soil samples (0 to 2 feet below ground surface [bgs]), 13 subsurface soil samples (2 to 12 feet bgs), and 18 groundwater samples that were collected at the site.

Background distributions and screening values have been established for target analyte list metals in surface soil, subsurface soil, and groundwater for Fort McClellan (SAIC, 1998).

2.0 Comparison Methodology

This section describes the statistical techniques that were employed in the Range K site-to-background comparisons.

2.1 Statistical Procedures

Contamination can be caused by a variety of processes that yield different spatial distributions of elevated contaminant concentrations. Slight but pervasive contamination can occur from non-point-source releases, and can result in slight increases in contaminant concentrations in a large percentage of samples. Localized, or "hot-spot," contamination can result in elevated concentrations in a small percentage of the total number of site samples. No single two-sample statistical comparison test is sensitive to both of these modes of contamination. For this reason, the use of several simultaneous tests is recommended for a valid and complete comparison of site

Table 1

Summary of Tier 1 and Tier 2 Site to Background Comparison for Surface Soil
Range K, Parcel 203(7)
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Tier 1 Evaluation[a]	Tier 2 Evaluation: Slippage Test[b]	Tier 2 Evaluation: Wilcoxon Rank Sum Test[b]	Tier 2 Evaluation: Hot Measurement Test[b,c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	13 / 13	Failed	Passed	Failed	NA	Yes
Antimony	1 / 13	Passed	NA	NA	NA	
Arsenic	13 / 13	Failed	Passed	Failed	NA	Yes
Barium	13 / 13	Failed	Passed	Passed	NA	
Beryllium	11 / 13	Failed	Passed	Failed	NA	Yes
Cadmium	1 / 13	Failed	NA[d]	NA[e]	Failed	Yes
Calcium	13 / 13	Failed	Passed	Failed	NA	Yes
Chromium	13 / 13	Failed	Passed	Failed	NA	Yes
Cobalt	11 / 13	Failed	Passed	Passed	NA	
Copper	13 / 13	Failed	Failed	Failed	NA	Yes
Iron	13 / 13	Failed	Passed	Failed	NA	Yes
Lead	13 / 13	Passed	NA	NA	NA	
Magnesium	13 / 13	Failed	Passed	Passed	NA	
Manganese	13 / 13	Passed	NA	NA	NA	
Mercury	5 / 13	Passed	NA	NA	NA	
Nickel	13 / 13	Failed	Failed	Failed	NA	Yes
Potassium	13 / 13	Passed	NA	NA	NA	
Selenium	6 / 13	Failed	Failed	NA[e]	Failed	Yes
Silver	0 / 13	NA	NA	NA	NA	
Sodium	9 / 13	Passed	NA	NA	NA	
Thallium	0 / 13	NA	NA	NA	NA	
Vanadium	13 / 13	Failed	Passed	Failed	NA	Yes
Zinc	13 / 13	Failed	Passed	Failed	NA	Yes

NA = not applicable
a Tier 1 evaluation per ***Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2***, Technical Memorandum, 24 June 2003 by Paul Goetchius.
b Part of Tier 2 evaluation per the above referenced memo.
c Performed only when the Slippage test and/or Wilcoxon Rank Sum (WRS) test cannot be performed.
d Slippage test is not performed on data sets for which the maximum background value is a nondetect.
e WRS test is not performed on data sets containing 50% or more nondetects.

Table 2

Summary of Tier 1 and Tier 2 Site to Background Comparison for Subsurface Soil
Range K, Parcel 203(7)
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Tier 1 Evaluation[a]	Tier 2 Evaluation: Slippage Test[b]	Tier 2 Evaluation: Wilcoxon Rank Sum Test[b]	Tier 2 Evaluation: Hot Measurement Test[b,c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	13 / 13	Failed	Passed	Failed	NA	Yes
Antimony	4 / 13	Passed	NA	NA	NA	
Arsenic	13 / 13	Failed	Passed	Failed	NA	Yes
Barium	13 / 13	Failed	Passed	Failed	NA	Yes
Beryllium	13 / 13	Failed	Failed	Failed	NA	Yes
Cadmium	5 / 13	Failed	Failed	NA[e]	Failed	Yes
Calcium	12 / 13	Failed	Failed	Failed	NA	Yes
Chromium	13 / 13	Failed	Passed	Failed	NA	Yes
Cobalt	13 / 13	Failed	Passed	Failed	NA	Yes
Copper	13 / 13	Failed	Passed	Failed	NA	Yes
Iron	13 / 13	Failed	Passed	Failed	NA	Yes
Lead	13 / 13	Passed	NA	NA	NA	
Magnesium	13 / 13	Failed	Passed	Failed	NA	Yes
Manganese	13 / 13	Passed	NA	NA	NA	
Mercury	9 / 13	Failed	Passed	NA[e]	Passed	
Nickel	13 / 13	Failed	Failed	Failed	NA	Yes
Potassium	13 / 13	Failed	Passed	Failed	NA	Yes
Selenium	6 / 13	Failed	NA[d]	NA[e]	Failed	Yes
Silver	0 / 13	NA	NA	NA	NA	
Sodium	10 / 13	Passed	NA	NA	NA	
Thallium	0 / 13	NA	NA	NA	NA	
Vanadium	13 / 13	Failed	Passed	Passed	NA	
Zinc	13 / 13	Failed	Failed	Failed	NA	Yes

NA = not applicable

a Tier 1 evaluation per ***Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2***, Technical Memorandum, 24 June 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or Wilcoxon Rank Sum (WRS) test cannot be performed.

d Slippage test is not performed on data sets for which the maximum background value is a nondetect.

e WRS test is not performed on data sets containing 50% or more nondetects.

Table 3

Summary of Tier 1 and Tier 2 Site to Background Comparison for Groundwater
Range K, Parcel 203(7)
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Tier 1 Evaluation[a]	Tier 2 Evaluation: Slippage Test[b]	Tier 2 Evaluation: Wilcoxon Rank Sum Test[b]	Tier 2 Evaluation: Hot Measurement Test[b,c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	6 / 18	Failed	Passed	NA[e]	Failed	Yes
Antimony	0 / 18	NA	NA	NA	NA	
Arsenic	8 / 18	Failed	Passed	NA[e]	Passed	
Barium	18 / 18	Failed	Passed	Failed	NA	Yes
Beryllium	0 / 18	NA	NA	NA	NA	
Cadmium	2 / 18	Failed	NA[d]	NA[e]	Failed	Yes
Calcium	18 / 18	Failed	Passed	Failed	NA	Yes
Chromium	2 / 18	Failed	NA[d]	NA[e]	Failed	Yes
Cobalt	5 / 18	Failed	Passed	NA[e]	Failed	Yes
Copper	1 / 18	Passed	NA	NA	NA	
Iron	16 / 18	Failed	Passed	Passed	NA	
Lead	2 / 18	Failed	NA[d]	NA[e]	Passed	
Magnesium	18 / 18	Failed	Passed	Passed	NA	
Manganese	18 / 18	Failed	Passed	Failed	NA	Yes
Mercury	2 / 18	Failed	NA[d]	NA[e]	Passed	
Nickel	5 / 18	Failed	NA[d]	NA[e]	Failed	Yes
Potassium	9 / 18	Passed	NA	NA	NA	
Selenium	0 / 18	NA	NA	NA	NA	
Silver	1 / 18	Passed	NA	NA	NA	
Sodium	18 / 18	Failed	Passed	Failed	NA	Yes
Thallium	0 / 18	NA	NA	NA	NA	
Vanadium	2 / 18	Failed	NA[d]	NA[e]	Failed	Yes
Zinc	5 / 18	Passed	NA	NA	NA	

NA = not applicable

a Tier 1 evaluation per ***Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2***, Technical Memorandum, 24 June 2003 by Paul Goetchius.

b Part of Tier 2 evaluation per the above referenced memo.

c Performed only when the Slippage test and/or Wilcoxon Rank Sum (WRS) test cannot be performed.

d Slippage test is not performed on data sets for which the maximum background value is a nondetect.

e WRS test is not performed on data sets containing 50% or more nondetects.

versus background distributions (U.S. Environmental Protection Agency [EPA], 1989, 1992, and 1994; U.S. Navy, 2002).

Analytes that fail the Tier 1 and Tier 2 comparisons are subject to a geochemical evaluation to determine if the elevated concentrations are due to natural processes or if they represent potential contamination.

2.1.1 Tier 1 - In this step of the background screening process, the maximum detected concentration (MDC) of the site data set is compared to the background screening value of two times the background mean (SAIC, 1998). Elements for which the site MDC does not exceed the background screening value are considered to be present at background concentrations, and are not considered site-related chemicals. Elements for which the site MDC exceeds the background screening value undergo further evaluation (Tier 2).

2.1.2 Tier 2 –

Slippage Test – The nonparametric Slippage test is designed to detect a difference between the upper tails of two distributions, and has been recommended for use in site-to-background comparisons to identify potential localized, or hot-spot, contamination (U.S. Navy, 2002). The test is performed by counting the number (*K*) of detected concentrations in the site data set that exceed the maximum background measurement, and then comparing this number to a critical value (K_c), which is a function of the number of background samples and the number of site samples. If $K > K_c$, then potential contamination is indicated and the analyte will be subjected to geochemical evaluation. If $K \leq K_c$, then localized contamination is not suspected.

Critical values tables for site and background data sets up to size n = 50 are provided in U.S. Navy (2002). Critical values for larger data sets are calculated using the test statistic provided in Rosenbaum (1954). In this report, the Slippage test is performed at the 95 percent confidence level. The test cannot be performed if the maximum background value is a nondetect, because the actual concentration in that sample is unknown.

Wilcoxon Rank Sum Test. The nonparametric WRS test is designed to detect a difference between the medians of two data sets, and has been recommended for use in site-to-background comparisons to identify slight but pervasive contamination (EPA, 2000; U.S. Navy, 2002). In this report, the WRS test is performed when the site and background data sets each contain less than 50 percent nondetects (i.e., measurements reported as not detected below the laboratory reporting limit). The WRS test will not be performed on data sets containing 50 percent or more

nondetects. The medians of such data sets are unknown, and hence the test results would lack sufficient power to yield reliable results.

The WRS test compares two data sets of size n and m ($n > m$), and tests the null hypothesis that the samples were drawn from populations with distributions having the same medians. To perform the test, the two sets of observations are pooled and arranged in order from smallest to largest. Each observation is assigned a rank; that is, the smallest is ranked 1, the next largest is ranked 2, and so on up to the largest observation, which is ranked ($n + m$). If ties occur between or within samples, each one is assigned the mid-rank. Next, the sum of the ranks of smaller data set m is calculated. Then the test statistic Z is determined,

$$Z = \frac{W - m(m + n + 1)/2}{\sqrt{mn(m + n + 1)/12}}$$

Where:

W = Sum of the ranks of the smaller data set
m = Number of data points in smaller group
n = Number of data points in larger group.

This test statistic Z is used to find the two-sided significance. For instance, if the test statistic yields a probability of a Type I error (p-level) less than 0.2, then there is a statistically significant difference between the medians at the 80 percent confidence level. A Type I error involves rejecting the null hypothesis when it is true. If the p-level is greater than 0.2, then there is no reasonable justification to reject the null hypothesis at the 80 percent confidence level. It can therefore be concluded that the medians of the two data sets are similar, and it can be assumed to be drawn from the same population.

If the p-level is less than 0.2, then the medians of the two distributions are significantly different at the 80 percent confidence level. This can occur if the site data are shifted higher or lower than the background data. If the site data are shifted higher relative to background, then contamination may be indicated, and the analyte in question will be carried on for geochemical evaluation; however, if the site data are shifted lower relative to background, then contamination is not indicated. If the p-level is greater than 0.2, then pervasive site contamination is not suspected.

Box Plots. A quick, robust graphical method recommended by the EPA to visualize and compare two or more groups of data is the box plot comparison (EPA, 1989 and 1992). These plots provide a summary view of the entire data set, including the overall location and degree of symmetry. The box encloses the central 50 percent of the data points so that the top of the box represents the 75th percentile and the bottom of the box represents the 25th percentile. The small box within the larger box represents the median of the data set. The upper whisker extends outward from the box to the maximum point and the lower whisker extends to the minimum point. Nondetect results are set equal to one-half of the reporting limit for plotting purposes.

For each analyte, box plots of site and background data are placed side by side to visually compare the distributions and qualitatively determine whether the data sets are similar or distinct. Accordingly, the box plots are a necessary adjunct to the WRS test. As described previously, the WRS test may indicate that the medians of the site and background data sets are significantly different. Examination of the box plots will confirm whether that difference is caused by site data that are shifted higher or lower relative to background.

Hot Measurement Test. The hot measurement test consists of comparing each site measurement with a concentration value that is representative of the upper limit of the background distribution (EPA, 1994). Ideally, a site sample with a concentration above the background screening value would have a low probability of being a member of the background distribution, and may be an indicator of contamination. It is important to select such a background screening value carefully so that the probability of falsely identifying site samples as contaminated or uncontaminated is minimized.

The 95th upper tolerance limit (95th UTL) is recommended as a screening value for normally or lognormally distributed analytes and the 95th percentile is recommended as a screening value for nonparametrically distributed analytes (EPA, 1989, 1992, and 1994). Site samples with concentrations above these values are not necessarily contaminated, but should be considered suspect. To perform the test, each analyte's site MDC is compared to the background 95th UTL or 95th percentile, in accordance with the type of background distribution. If the site MDC exceeds the background screening value, then that analyte will undergo a geochemical evaluation. If the MDC does not exceed the background threshold value, then hot-spot contamination is not indicated.

2.1.3 Geochemical Evaluation

If an analyte fails either of the statistical tests described above then a geochemical evaluation is performed to determine if the elevated concentrations are caused by natural processes. The methodology and results of the geochemical evaluation are provided separately.

3.0 Results of the Site-to-Background Comparisons

This section presents the results of the site-to-background comparisons for 23 TAL metals in the Range K surface soil, subsurface soil, and groundwater samples. Tables 1 through 3 summarize the Tier 1 and Tier 2 test results for each media as discussed in the following sections. The box plots discussed in the following sections are provided in Attachment 1.

3.1 Surface Soil

Twenty-three TAL metals were evaluated in the Ft. McClellan Range K surface soil data set. Two metals (silver and thallium) have no detected concentrations in surface soil, so no further discussion of these metals is included. Antimony, lead, manganese, mercury, potassium, and sodium have no detected concentrations above their respective background screening values, passing the Tier 1 evaluation. These 6 metals are not tested or discussed further. The remaining 15 metals are carried forward for Tier 2 evaluation.

Table 1 summarizes the surface soil statistical site to background comparison results. Box plots are provided in Attachment 1.

Aluminum

Tier 1 Evaluation

One site sample exceeds the background screening value of 16,306 mg/kg.

Tier 2 Evaluation

Slippage Test

The critical value, K_c, for aluminum is 2, and no site samples exceed the maximum background measurement (K=0). Because $K < K_c$, aluminum passes the Slippage test.

WRS Test

The p-level of 0.03 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values. The site maximum is lower than that of background (Figure 1-1).

Conclusion
Because aluminum in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Arsenic

Tier 1 Evaluation
Two site samples exceed the background screening value of 13.73 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for arsenic is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, arsenic passes the Slippage test.

WRS Test
The p-level of 0.0036 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values. The site maximum is lower than that of background (Figure 1-1).

Conclusion
Because arsenic in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Barium

Tier 1 Evaluation
One site sample exceeds the background screening value of 123.94 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for barium is 2, and one site sample exceeds the maximum background measurement. Because $K < K_c$, barium passes the Slippage test.

WRS Test
The p-level of 0.55 indicates strong agreement between the site and background distributions.

Box Plot
The site and background medians are similar. The site minimum, 25th percentile, and maximum are higher than the corresponding background values. The site 75th percentile is lower than that of background (Figure 1-2).

Conclusion
Barium in surface soil is considered to be within the range of background.

Beryllium

Tier 1 Evaluation

Three site samples exceed the background screening value of 0.8 mg/kg.

Tier 2 Evaluation

Slippage Test

K_c for beryllium is 2, and two site samples exceed the maximum background measurement. Because $K \leq K_c$, beryllium passes the Slippage test.

WRS Test

The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-2).

Conclusion

Because beryllium in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Cadmium

Tier 1 Evaluation

One site sample exceeds the background screening value of 0.29 mg/kg.

Tier 2 Evaluation

Slippage Test

The Slippage test is not used for cadmium, because the maximum background result for is a nondetect.

WRS Test

The WRS test is not performed because the site data set contains more than 50 percent nondetects.

Box Plot

The site minimum, 25th percentile, and median are higher than the corresponding background values (Figure 1-3). The site 75th percentile is slightly lower than that of background, and the site maximum is slightly higher than that of background. The shape and location of the site box plot reflect the high percentage of nondetects (92 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The site MDC of cadmium exceeds the 95th percentile of 1.2 mg/kg.

Conclusion
Because cadmium in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Calcium

Tier 1 Evaluation
One site sample exceeds the background screening value of 1,723 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for calcium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, calcium passes the Slippage test.

WRS Test
The p-level of 0.094 indicates a weak agreement between the site and background distributions.

Box Plots
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-3). The site maximum is lower than that of background.

Conclusion
Because calcium in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Chromium

Tier 1 Evaluation
One site sample exceeds the background screening value of 37.04 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for chromium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, chromium passes the Slippage test.

WRS Test
The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-4). The site maximum is lower than that of background.

Conclusion
Because chromium in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Cobalt

Tier 1 Evaluation

Two site samples exceed the background screening value of 15.15 mg/kg.

Tier 2 Evaluation

Slippage Test

K_c for cobalt is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, cobalt passes the Slippage test.

WRS Test

The p-level of 0.75 indicates strong agreement between the site and background distributions.

Box Plot

The site 25th percentile, 75th percentile, and maximum are lower than the corresponding background values (Figure 1-4). The site and background medians are similar, and the site minimum is higher than that of background.

Conclusion

Cobalt in surface soil passes statistical comparison to background and is considered to be within the range of background.

Copper

Tier 1 Evaluation

Seven site samples exceed the background screening value of 12.71 mg/kg.

Tier 2 Evaluation

Slippage Test

K_c for copper is 2, and 3 site samples exceed the maximum background measurement. Because $K > K_c$, copper fails the Slippage test.

WRS Test

The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-5).

Conclusion

Because copper in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Iron

Tier 1 Evaluation

Two site samples exceed the background screening value of 34,154 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for iron is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$ iron passes the Slippage test.

WRS Test
The p-level of 0.011 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-5). The site maximum is lower than that of background.

Conclusion
Because iron in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Magnesium

Tier 1 Evaluation
One site sample exceeds the background screening value of 1,033 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for magnesium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, magnesium passes the Slippage test.

WRS Test
The p-level of 0.45 indicates good agreement between the site and background distributions.

Box Plot
The site minimum and 25th percentile are slightly higher than the corresponding background value (Figure 1-6). The site median and 75th percentile are similar to that of background, and the site maximum is lower than the corresponding background value.

Conclusion
Magnesium in surface soil is considered to be within the range of background.

Nickel

Tier 1 Evaluation
Five site samples exceed the background screening value of 10.33 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for nickel is 2, and 3 site samples exceed maximum background measurement. Because $K > K_c$ nickel fails the Slippage test.

WRS Test
The p-level of 0.004 indicates a difference between the site and background distributions.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-6).

Conclusion
Because nickel in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Selenium

Tier 1 Evaluation
Six site samples exceed the background screening value of 0.48 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for selenium is 2, and 3 site samples exceed maximum background measurement. Because $K > K_c$, selenium fails the Slippage test.

WRS Test
The WRS test is not performed because the background and site data sets contain more than 50 percent nondetects.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-7). The shapes and locations of the background and site box plots are influenced by the high percentage of nondetects (99 percent and 54 percent, respectively), and the replacement values of one-half the reporting limit rather than detected concentrations.

Hot Measurement Test
The site MDC of selenium exceeds the background 95th percentile of 0.563 mg/kg.

Conclusion
Because selenium in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Vanadium

Tier 1 Evaluation
Two site samples exceed the background screening value of 58.84 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for vanadium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, vanadium passes the Slippage test.

WRS Test
The p-level of 0.006 indicates a significant difference between the site and background distributions.

Box Plots
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-7). The site maximum is lower than that of background.

Conclusion
Because vanadium in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Zinc

Tier 1 Evaluation
Six site samples exceed the background screening value of 40.64 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for zinc is 2, and one site sample exceeds the maximum background measurement. Because $K < K_c$, zinc passes the Slippage test.

WRS Test
The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-8).

Conclusion
Because zinc in surface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

3.2 Subsurface Soil

Twenty-three TAL metals were evaluated in the Range K subsurface soil. Two metals (silver and thallium) had no detected concentration in subsurface soil so no further discussion of these metals is included. Four metals (antimony, lead, manganese, and sodium) had no detected results that exceeded the background screening value, passing the Tier 1 evaluation. They will not be tested or discussed further.

The remaining 17 metals are carried forward for Tier 2 evaluation and the test results are discussed below in detail.

Table 2 summarizes the Tier 1 and Tier 2 evaluation of subsurface soil.

Aluminum

Tier 1 Evaluation
Three site samples exceed the background screening value of 13,591 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for aluminum is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, aluminum passes the Slippage test.

WRS Test
The p-level of < 0.001 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-8). The site maximum is lower than that of background.

Conclusion
Because aluminum in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Arsenic

Tier 1 Evaluation
Five site samples exceed the background screening value of 18.3 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for arsenic is 2, and one site sample exceeds the maximum background measurement. Because $K < K_c$, arsenic passes the Slippage test.

WRS Test
The p-level of 0.001 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-9).

Conclusion
Because arsenic in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Barium

Tier 1 Evaluation

One site sample exceeds the background screening value of 233.62 mg/kg.

Tier 2 Evaluation

Slippage Test

K_c for barium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, barium passes the Slippage test.

WRS Test

The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-9). The site maximum is lower than that of background.

Conclusion

Because barium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Beryllium

Tier 1 Evaluation

Twelve site samples exceed the background screening value of 0.86 mg/kg.

Tier 2 Evaluation

Slippage Test

K_c for beryllium is 2, and 3 site samples exceed the maximum background measurement. Because $K > K_c$, beryllium fails the Slippage test.

WRS Test

The p-level < 0.001 indicates a significant difference in the site and background distributions.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-10). The site maximum is slightly higher than that of background.

Conclusion

Because beryllium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Cadmium

Tier 1 Evaluation

Five site samples exceed the background screening value of 0.22 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for cadmium is 2, and 3 site samples exceed the maximum background measurement. Because $K > K_c$, cadmium fails the Slippage test.

WRS Test
The WRS test was not performed because the site data has more than 50 percent nondetects.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-10).

Hot Measurement Test
The site MDC exceeds the background 95th percentile of 0.62 mg/kg.

Conclusion
Because cadmium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Calcium

Tier 1 Evaluation
Nine site samples exceed the background screening value of 637.17 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for calcium is 2, and 3 site samples exceed the maximum background measurement. Because $K > K_c$, calcium fails the Slippage test.

WRS Test
The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-11).

Conclusion
Because calcium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Chromium

Tier 1 Evaluation
Two site samples exceed the background screening value of 38.25 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for chromium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, chromium passes the Slippage test.

WRS Test
The p-level of 0.075 indicates weak agreement between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-11). The site maximum is less than that of background.

Conclusion
Because chromium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Cobalt

Tier 1 Evaluation
One site sample exceeds the background screening value of 17.54 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for cobalt is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, cobalt passes the Slippage test.

WRS Test
The p-level of 0.007 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-12). The site maximum is less than that of background.

Conclusion
Because cobalt in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Copper

Tier 1 Evaluation
Eleven site samples exceed the background screening value of 19.43 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for copper is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, copper passes the Slippage test.

WRS Test
The p-level of < 0.001 indicates significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-12). The site maximum is slightly lower than that of background.

Conclusion
Because copper in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Iron

Tier 1 Evaluation
Two site samples exceed the background screening value of 44,817 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for iron is 2, and one site sample exceeds the maximum background measurement. Because $K < K_c$, iron passes the Slippage test.

WRS Test
The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum, interquartile range, and maximum are higher than the respective background values (Figure 1-13).

Conclusion
Because iron in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Magnesium

Tier 1 Evaluation
Two site samples exceed the background screening value of 766.24 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for magnesium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, magnesium passes the Slippage test.

WRS Test
The p-level of 0.0029 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-13). The site maximum is lower than that of background.

Conclusion
Because magnesium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Mercury

Tier 1 Evaluation
Three site samples exceed the background screening value of 0.07 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for mercury is 2, and no site samples exceed the maximum background measurement. Since $K < K_c$, mercury passes the Slippage test.

WRS Test
The WRS test was not performed because the background data set contains more than 50 percent nondetects.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-14). The site maximum is lower than that of background. The shape and location of the background box plot are influenced by the percentage of nondetects (53 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
The site MDC of mercury is less than the background 95th percentile of 0.094 mg/kg.

Conclusion
Mercury in subsurface soil passed the Tier 2 evaluation and is considered to be within the range of background.

Nickel

Tier 1 Evaluation
Twelve site samples exceed the background screening value of 12.89 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for nickel is 2, and 5 site samples exceed the maximum background measurement. Since $K > K_c$, nickel fails the Slippage test.

WRS Test
The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-14).

Conclusion
Because nickel in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Potassium

Tier 1 Evaluation
Two site samples exceed the background screening value of 710.74 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for potassium is 2, and no site samples exceed the maximum background measurement. Since $K < K_c$, potassium passes the Slippage test.

WRS Test
The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-15). The site maximum is less than that of background.

Conclusion
Because potassium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Selenium

Tier 1 Evaluation
Six site samples exceed the background screening value of 0.47 mg/kg.

Tier 2 Evaluation
Slippage Test
The Slippage test is not performed because the maximum detected background result for selenium is a nondetect.

WRS Test
The WRS test is not evaluated because the background and site data sets contain more than 50 percent nondetects.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-15). The shapes and locations of the background and site box plots are influenced by the percentage of nondetects (98 percent and 54 percent, respectively), and the replacement values of one-half the reporting limit rather than detected concentrations.

Hot Measurement Test
The site MDC of selenium exceeds the background 95th percentile of 0.574 mg/kg.

Conclusion
Because selenium in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Vanadium

Tier 1 Evaluation
One site sample exceeds the background screening value of 64.89 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for vanadium is 2, and no site samples exceed the maximum background measurement. Because $K < K_c$, vanadium passes the Slippage test.

WRS Test
The p-level of 0.258 indicates a good agreement between the site and background distributions.

Box Plot
The site minimum, 25th percentile, median, and 75th percentile are slightly elevated compared to the corresponding background values (Figure 1-16). The site maximum is less than that of background.

Conclusion
Vanadium passed the Tier 2 evaluation and is considered to be within the range of background.

Zinc

Tier 1 Evaluation
Twelve site samples exceed the background screening value of 34.86 mg/kg.

Tier 2 Evaluation
Slippage Test
K_c for zinc is 2, and 11 site samples exceed the maximum background measurement. Because $K > K_c$, zinc fails the Slippage test.

WRS Test
The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-16).

Conclusion
Because zinc in subsurface soil failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

3.3 Groundwater

This section presents the results of the statistical site-to-background comparison of 23 TAL metals from unfiltered groundwater samples. Four metals (antimony, beryllium, selenium, and thallium) had no detected results in the groundwater site samples and are not considered any further.

Four metals (copper, potassium, silver, and zinc) had no detected concentrations that exceeded their respective background screening values. These metals are considered to be within the range of background based on the Tier 1 evaluation. They will not be tested or discussed further.

The remaining 15 metals are carried forward for Tier 2 evaluation. The results of this evaluation are discussed in detail below.

Table 3 summarizes the Tier 1 and Tier 2 results for groundwater.

Aluminum

Tier 1 Evaluation
Two site samples exceed the background screening value of 2.335 mg/L.

Tier 2 Evaluation
Slippage Test
K_c for aluminum is 3, and one site sample exceeds the maximum background measurement. Because $K < K_c$, aluminum passes the Slippage test.

WRS Test
The WRS test was not performed because the site data set contains more than 50 percent nondetects.

Box Plot
The site median and 75th percentile are less than the corresponding background values (Figure 1-17). The site minimum, 25th percentile, and maximum are higher than that of background. The shape and location of the site box plot are influenced by the percentage of nondetects (67 percent), and the replacement values of one-half the reporting limit rather than detected concentrations.

Hot Measurement Test
The site MDC is greater than the background 95th percentile of 5.95 mg/L.

Conclusion
Because aluminum in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Arsenic

Tier 1 Evaluation
One site sample exceeds the background screening value of 0.01776 mg/L.

Tier 2 Evaluation
Slippage Test
K_c for arsenic is 3, and no site samples exceed the maximum background measurement. Because $K < K_c$, arsenic passes the Slippage test.

WRS Test
The WRS test was not performed because the background and site data sets contain more than 50 percent nondetects.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-17). The site maximum is lower than that of background. The shapes and locations of the background and site box plots are influenced by the high percentage of nondetects (84 percent and 56 percent, respectively), and the replacement values of one-half the reporting limit rather than detected concentrations.

Hot Measurement Test
The site MDC is less than the background 95th percentile of 0.117 mg/L.

Conclusion
Arsenic in groundwater passed the Tier 2 evaluation and is considered to be within the range of background.

Barium

Tier 1 Evaluation
Seven site samples exceed the background screening value of 0.127 mg/L.

Tier 2 Evaluation
Slippage Test
K_c for barium is 3 and no site samples exceed the maximum background measurement. Because $K < K_c$, barium passes the Slippage test.

WRS Test
The p-level of 0.0116 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-18). The site maximum is lower than that of background.

Conclusion
Because barium in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Cadmium

Tier 1 Evaluation
One site sample exceeds the background screening value of 0.00251 mg/L.

Tier 2 Evaluation
Slippage Test
The Slippage test is not performed because the maximum background result for cadmium is a nondetect.

WRS Test
The WRS test was not performed because the background and site data sets contain more than 50 percent nondetects.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-18). The shapes and locations of the background and site box plots are influenced by the high percentage of nondetects (64 percent and 89 percent, respectively), and the replacement values of one-half the reporting limit rather than detected concentrations.

Hot Measurement Test
The site MDC exceeds the background 95th percentile of 0.00678 mg/L.

Conclusion
Because cadmium in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Calcium

Tier 1 Evaluation
Fifteen site samples exceed the background screening value of 56.493 mg/L.

Tier 2 Evaluation
Slippage Test
K_c for calcium is 3, and no site samples exceed the maximum background measurement. Because $K < K_c$, calcium passes the Slippage test.

WRS Test
The p-level < 0.001 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-19). The site maximum is less than that of background.

Conclusion
Because calcium in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Chromium

Tier 1 Evaluation
No background screening value is available for chromium, and there are 2 detected results in the site samples.

Tier 2 Evaluation
Slippage Test
The Slippage test is not performed because the maximum background result for chromium is a nondetect.

WRS Test
The WRS test was not performed because the background and site data sets contain more than 50 percent nondetects.

Box Plot
The site interquartile range and maximum are higher than the corresponding background values (Figure 1-19). The site minimum is slightly lower than that of background. The shapes and locations of the background and site box plots are influenced by the high percentage of nondetects (100 percent and 89 percent, respectively), and the replacement values of one-half the reporting limit rather than detected concentrations.

Hot Measurement Test
The site MDC exceeds the background 95th percentile of 0.0168 mg/L.

Conclusion
Because chromium in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Cobalt

Tier 1 Evaluation
One site sample exceeds the background screening value of 0.02336 mg/L.

Tier 2 Evaluation

Slippage Test

K_c for cobalt is 3, and one site sample exceeds the maximum background measurement. Because $K < K_c$, cobalt passes the Slippage test.

WRS Test

The WRS test was not performed because the background and site data sets contain more than 50 percent nondetects.

Box Plot

The site minimum, median, and 75th percentile are lower than the corresponding background values (Figure 1-20). The site and background 25th percentiles appear to be the same, and the site maximum is higher than that of background. The shapes and locations of the background and site box plots are influenced by the high percentage of nondetects (94 percent and 72 percent, respectively), and the replacement values of one-half the reporting limit rather than detected concentrations.

Hot Measurement Test

The site MDC exceeds the background 95th percentile of 0.0202 mg/L.

Conclusion

Because cobalt in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Iron

Tier 1 Evaluation

Three site samples exceed the background screening value of 7.04 mg/L.

Slippage Test

K_c for iron is 3, and one site sample exceeds the maximum background measurement. Because $K < K_c$, iron passes the Slippage test.

WRS Test

The p-level of 0.9 indicates an excellent agreement between the site and background distributions.

Box Plot

The site median and 75th percentile are lower than the corresponding background values (Figure 1-20). The site minimum and 25th percentile are higher than that of background, and the site maximum is just slightly greater than that of background.

Conclusion

Iron in groundwater is considered to be within the range of background.

Lead

Tier 1 Evaluation

One site sample exceeds the background screening value of 0.007998 mg/L.

Tier 2 Evaluation

Slippage Test

The Slippage test is not performed because the maximum background result for lead is a nondetect.

WRS Test

The WRS test was not performed because the background and site data sets contain more than 50 percent nondetects.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-21). The site maximum is lower than that of background. The shapes and locations of the background and site box plots are influenced by the high percentage of nondetects (60 percent and 89 percent, respectively), and the replacement values of one-half the reporting limit rather than detected concentrations.

Hot Measurement Test

The site MDC is less than the background 95th percentile of 0.0434 mg/L.

Conclusion

Lead in groundwater passed the Tier 2 evaluation and is considered to be within the range of background.

Magnesium

Tier 1 Evaluation

One sample exceeds the background screening value of 21.282 mg/L.

Tier 2 Evaluation

Slippage Test

K_c for magnesium is 3, and no site sample exceeds the maximum background measurement. Because $K < K_c$, magnesium passes the Slippage test.

WRS Test

The p-level of 0.53 indicates a strong agreement between the site and background distributions.

Box Plot

The site median, 75th percentile, and maximum are lower than the corresponding background values (Figure 1-21). The site minimum and 25th percentile are higher compared to background.

Conclusion

Magnesium in groundwater passed the Tier 2 evaluation and is considered to be within the range of background.

Manganese

Tier 1 Evaluation

Three site samples exceed the background screening value of 0.5805 mg/L.

Tier 2 Evaluation

Slippage Test

K_c for manganese is 3, and no site samples exceed the maximum background measurement. Because $K < K_c$, manganese passes the Slippage test.

WRS Test

The p-level of 0.0566 indicates a weak agreement between the site and background distributions.

Box Plot

The site minimum, 25th percentile, and median are higher than the corresponding background values (Figure 1-22). The site and background 75th percentiles are the same, and the site maximum is lower than that of background.

Conclusion

Because manganese in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Mercury

Tier 1 Evaluation

No background screening value is available for mercury. Two site samples have detected concentrations.

Tier 2 Evaluation

Slippage Test

The Slippage test is not performed because the maximum background result for mercury is a nondetect.

WRS Test

The WRS test was not performed because the background and site data sets contain more than 50 percent nondetects.

Box Plot

The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-22). The shapes and locations of the background and site box plots are influenced by the high percentage of nondetects (100 percent and 89 percent, respectively), and the replacement values of one-half the reporting limit rather than detected concentrations.

Hot Measurement Test

The site MDC is less than the background 95th percentile of 0.000243 mg/L.

Conclusion
Mercury in groundwater passed the Tier 2 evaluation and is considered to be within the range of background.

Nickel

Tier 1 Evaluation
No background screening value is available for nickel. Five site samples have detected concentrations.

Tier 2 Evaluation
Slippage Test
The Slippage test is not performed because the maximum background result for nickel is a nondetect.

WRS Test
The WRS test was not performed because the background and site data sets contain more than 50 percent nondetects.

Box Plot
The site minimum and 75th percentile are lower than the corresponding background values (Figure 1-23). The site 25th percentile, median, and maximum are higher than that of background. The shapes and locations of the background and site box plots are influenced by the high percentage of nondetects (100 percent and 72 percent, respectively), and the replacement values of one-half the reporting limit rather than detected concentrations.

Hot Measurement Test
The site MDC exceeds the background 95th percentile of 0.0343 mg/L.

Conclusion
Because nickel in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Sodium

Tier 1 Evaluation
Four site samples exceed the background screening value of 14.846 mg/L.

Tier 2 Evaluation
Slippage Test
K_c for sodium is 3, and no site samples exceed the maximum background measurement. Because $K < K_c$, sodium passes the Slippage test.

WRS Test
The p-level of 0.007 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-23). The site maximum is lower compared to that of background.

Conclusion
Because sodium in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

Vanadium

Tier 1 Evaluation
One site sample exceeds the background screening value of 0.016975 mg/L.

Tier 2 Evaluation
Slippage Test
The Slippage test is not performed because the maximum background result for vanadium is a nondetect.

WRS Test
The WRS test was not performed because the background and site data sets contain more than 50 percent nondetects.

Box Plot
The site minimum and 75th percentile are lower than the corresponding background values (Figure 1-24). The site median, 25th percentile, and maximum are higher compared to those of background. The shapes and locations of the background and site box plots are influenced by the high percentage of nondetects (96 percent and 89 percent, respectively), and the replacement values of one-half the reporting limit rather than detected concentrations.

Hot Measurement Test
The site MDC exceeds the background 95th percentile of 0.0276 mg/L.

Conclusion
Because vanadium in groundwater failed statistical comparison to background, it will be carried forward for Tier 3 geochemical evaluation.

4.0 Summary and Conclusions

The statistical methodology used to compare samples taken from Range K, Parcel 203(7), and background data sets for 23 elements in surface soil, subsurface soil, and groundwater includes a comparison of the site MDC to the background screening value, Tier 1 evaluation. Analytes that failed this comparison were subjected to the Slippage test and WRS test. Box-and-whisker plots were prepared to visually compare the two data sets and properly interpret the WRS test results. For elements with data sets that did not allow for either the Slippage test or WRS test to be performed, the Hot Measurement test was used. Analytes that failed these statistical tests, Tier 2

evaluation, are carried forward for Tier 3 geochemical evaluation to determine if natural processes can explain the elevated concentrations.

Tables 1 through 3 summarize the statistical comparison test results and show the metals carried forward for geochemical evaluation.

5.0 References

Rosenbaum, S., 1954, "Tables for a Nonparametric Test of Location," ***Annals of Mathematical Statistics***, Vol. 24, pp. 146-150.

Science Application International Corporation (SAIC), 1998, ***Final Background Metals Survey Report, Fort McClellan, Anniston, Alabama***, prepared for U.S. Army Corps of Engineers, Mobile, Alabama, July.

Shaw Environmental and Infrastructure (Shaw E&I), 2003, ***Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 2,*** Technical Memorandum, 24 June 2003 by Paul Goetchius.

U.S. Environmental Protection Agency (EPA), 1989, ***Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance***, Office of Solid Waste, Waste Management Division, EPA/530/SW-89/026, July.

U.S. Environmental Protection Agency (EPA), 1992, ***Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance***, Environmental Statistics and Information Division, Office of Policy, Planning, and Evaluation, EPA/530/R-93/003, July.

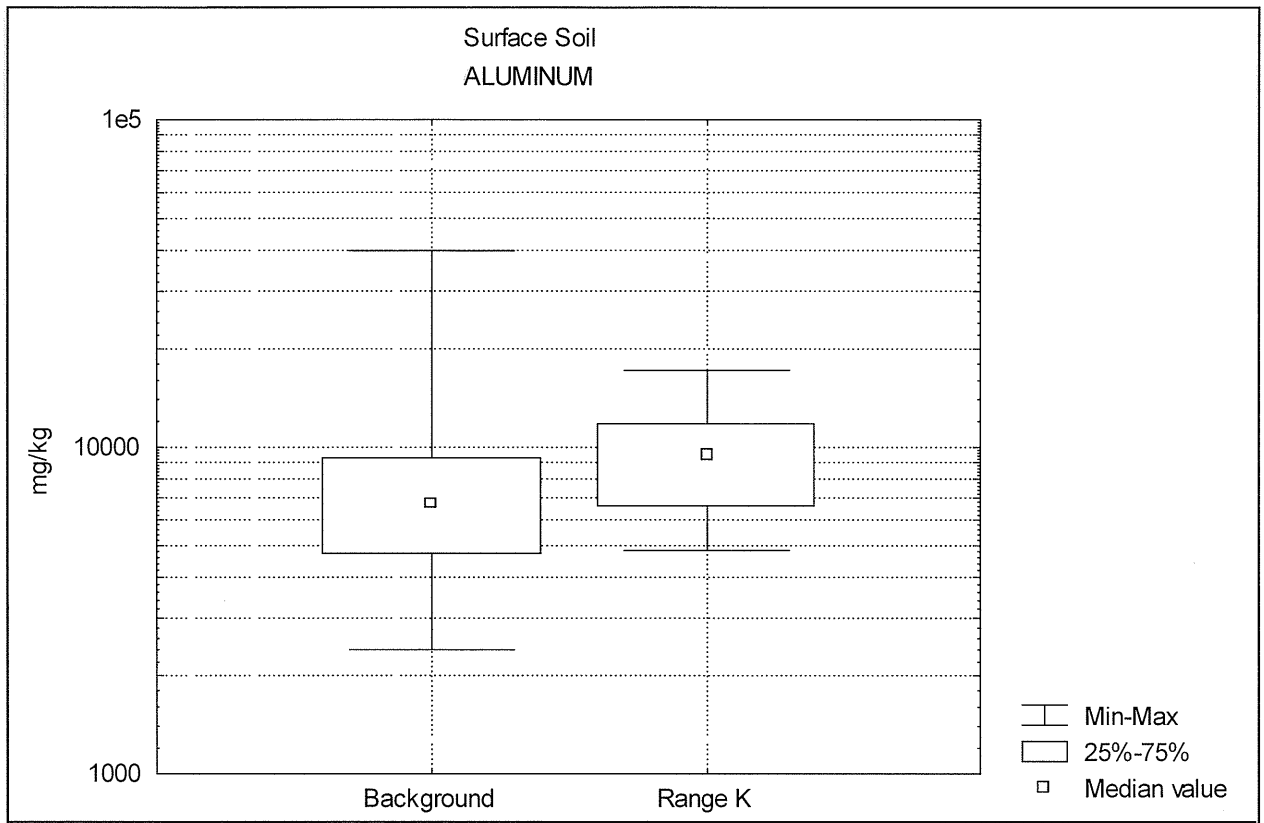
U.S. Environmental Protection Agency (EPA), 1994, ***Statistical Methods For Evaluating The Attainment Of Cleanup Standards***, Environmental Statistics and Information Division, Office of Policy, Planning, and Evaluation, EPA/230/R-94/004, June.

U.S. Environmental Protection Agency (EPA), 2000, ***Guidance for Data Quality Assessment: Practical Methods for Data Analysis, EPA QA/G-9, QA00 Update***, Office of Environmental Information, EPA/600/R-96/084, July.

U.S. Navy, 2002, ***Guidance for Environmental Background Analysis, Volume 1: Soil***, NFESC User's Guide UG-2049-ENV, Naval Facilities Engineering Command, Washington, D.C., April.

ATTACHMENT 1

Figure 1-1


Surface Soil
ALUMINUM
1e5
10000
1000
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

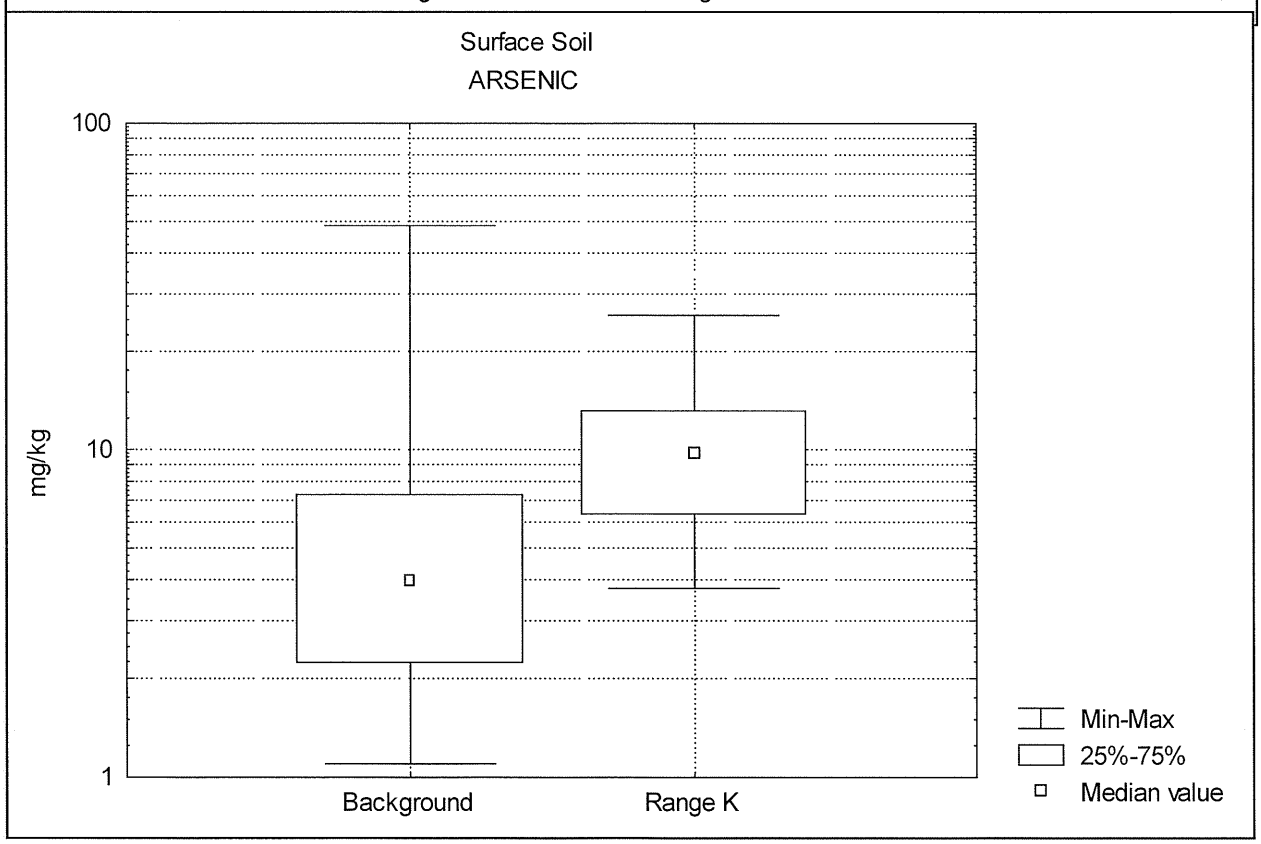
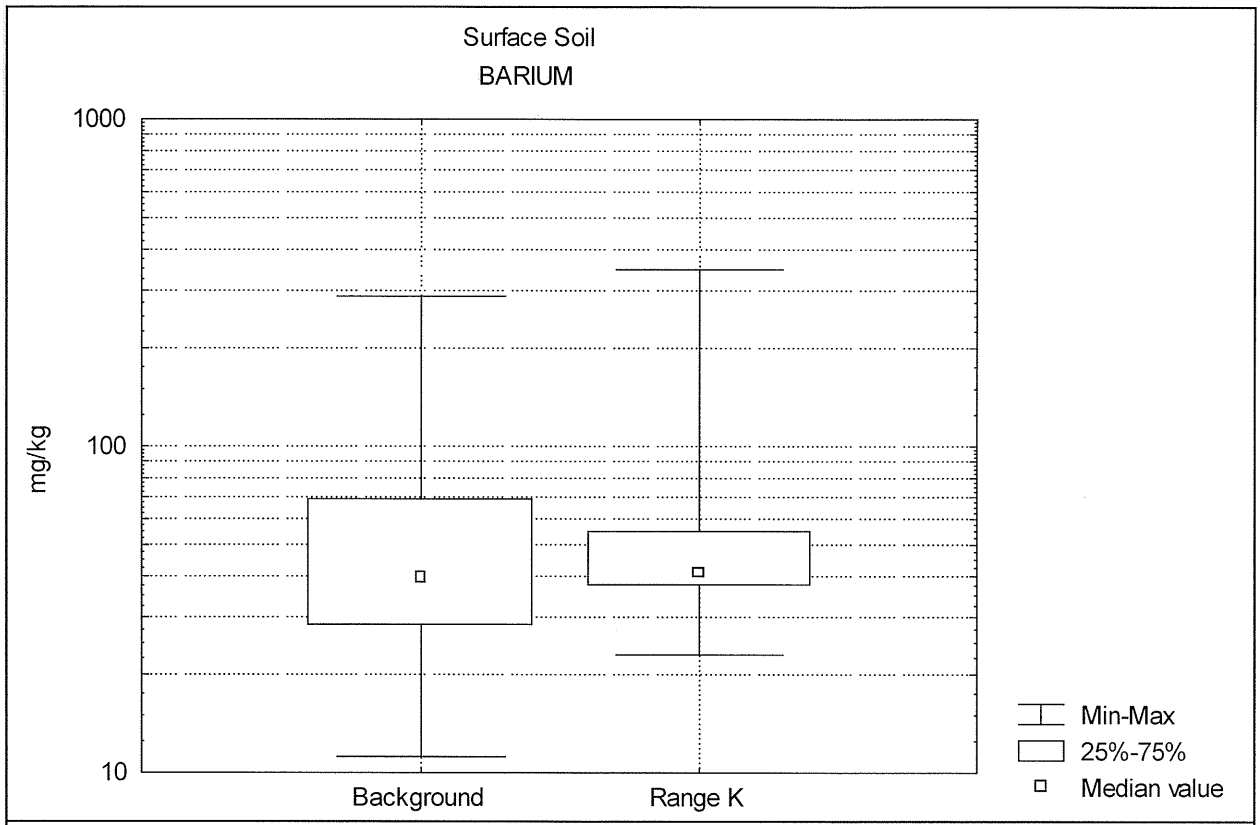

Surface Soil
ARSENIC
100
10
1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-2


Surface Soil
BARIUM
1000
100
10
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

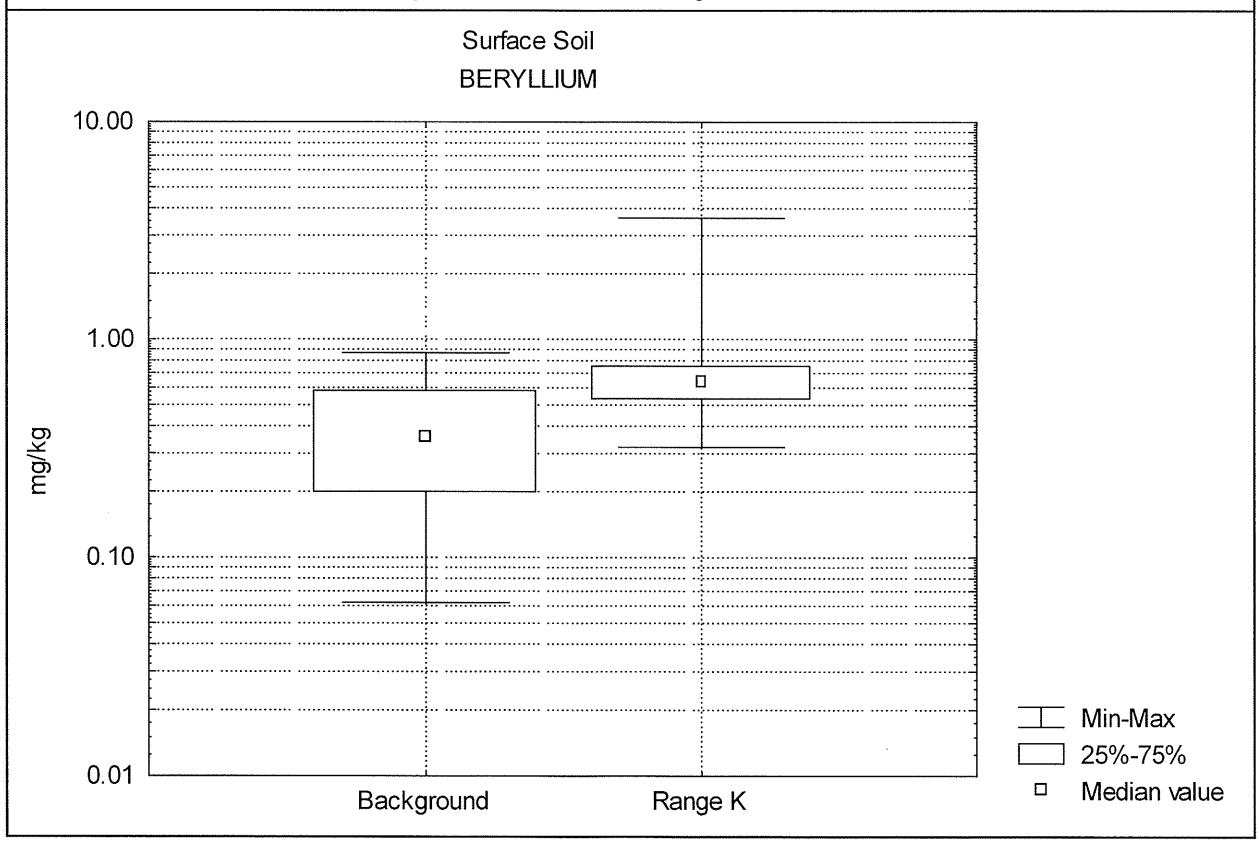
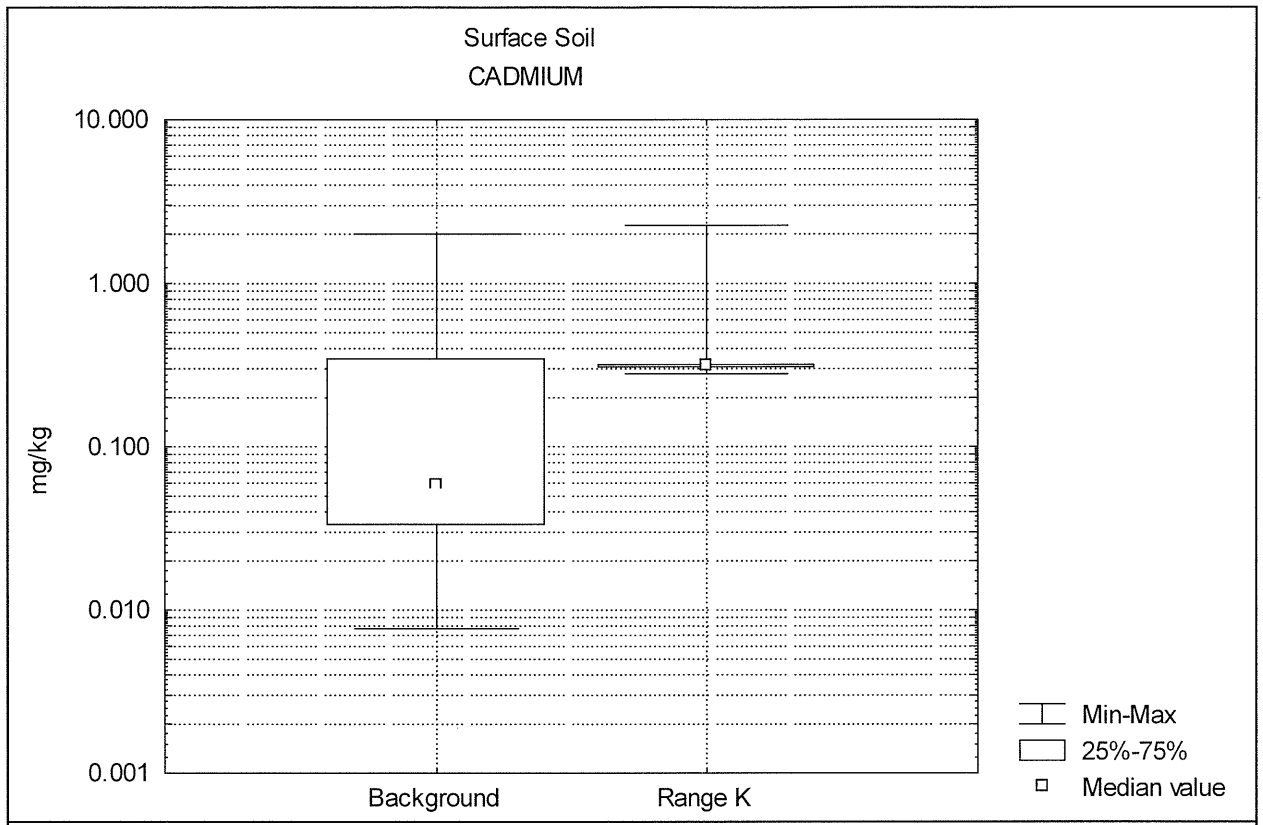

Surface Soil
BERYLLIUM
10.00
1.00
0.10
0.01
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-3


Surface Soil
CADMIUM
10.000
1.000
0.100
0.010
0.001
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

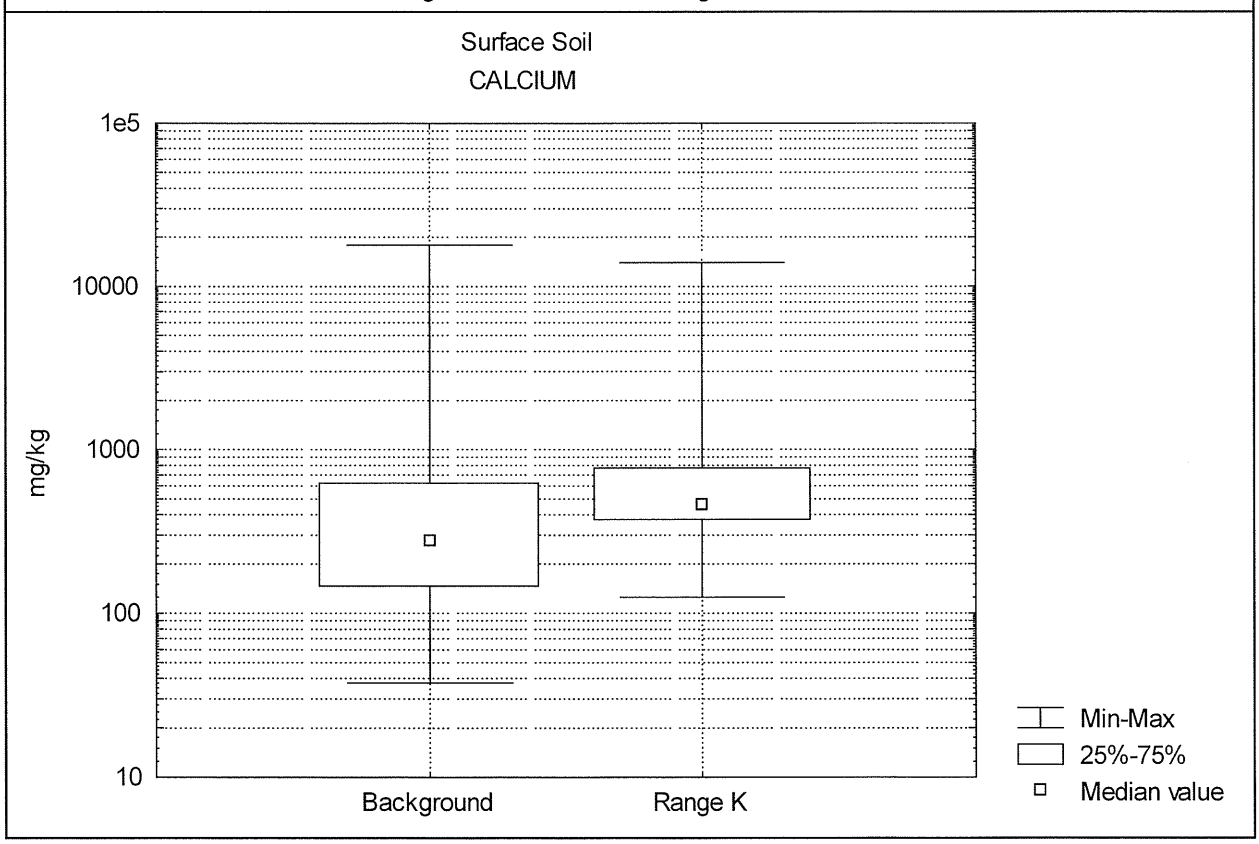

Surface Soil
CALCIUM
1e5
10000
1000
100
10
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-4

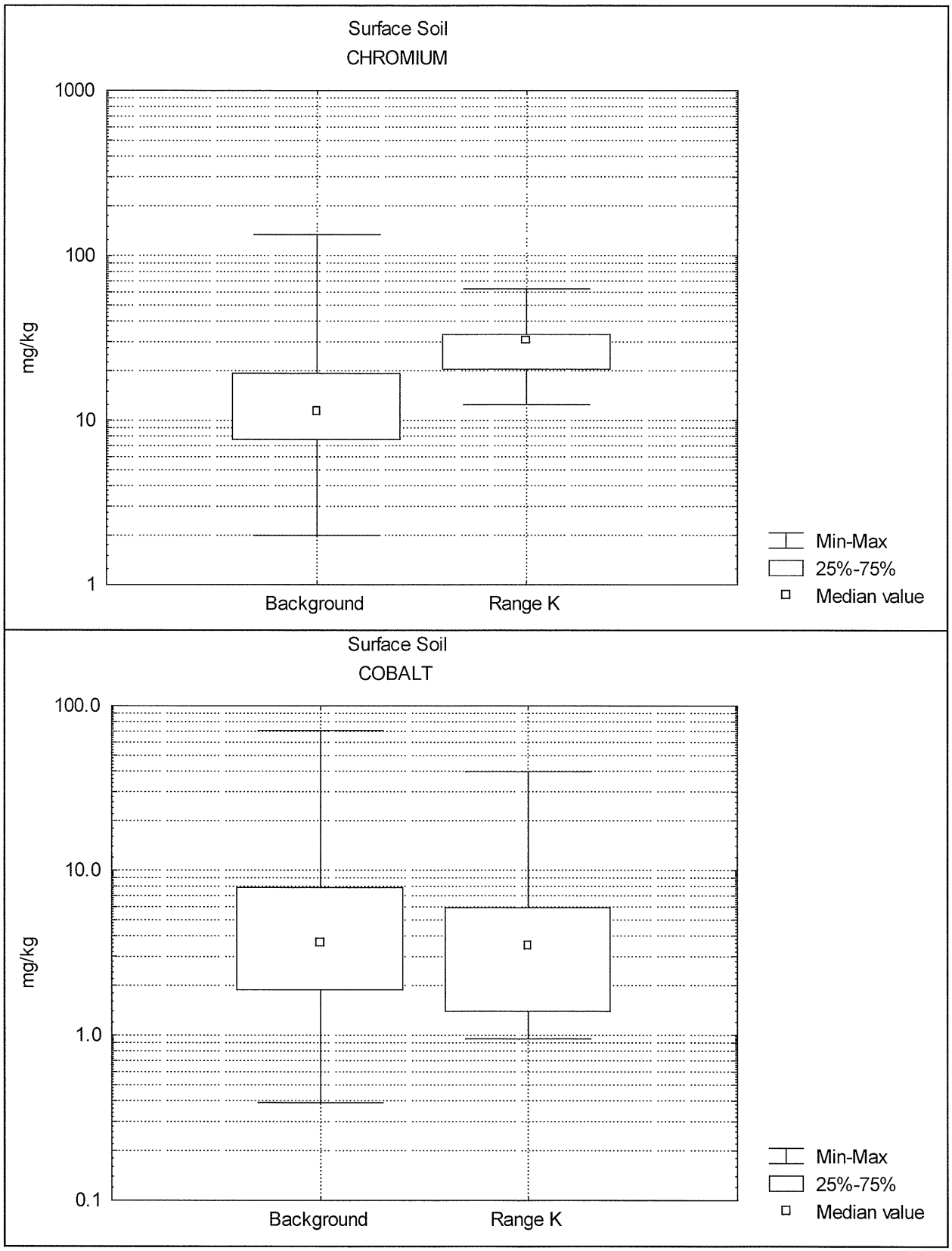

Surface Soil
CHROMIUM
1000
100
10
1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value
Surface Soil
COBALT
100.0
10.0
1.0
0.1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-5

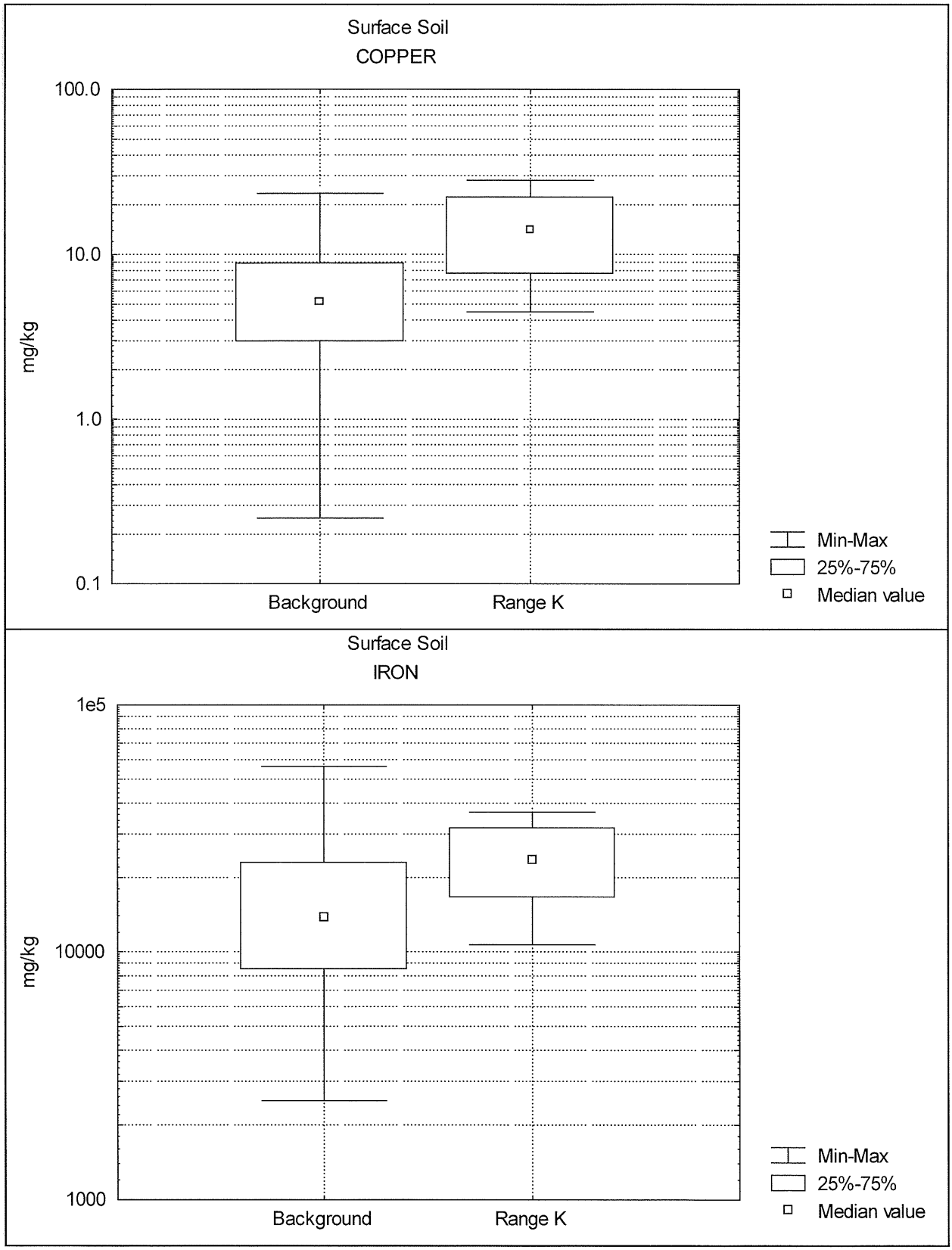

Surface Soil
COPPER
100.0
10.0
1.0
0.1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value
Surface Soil
IRON
1e5
10000
1000
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-6

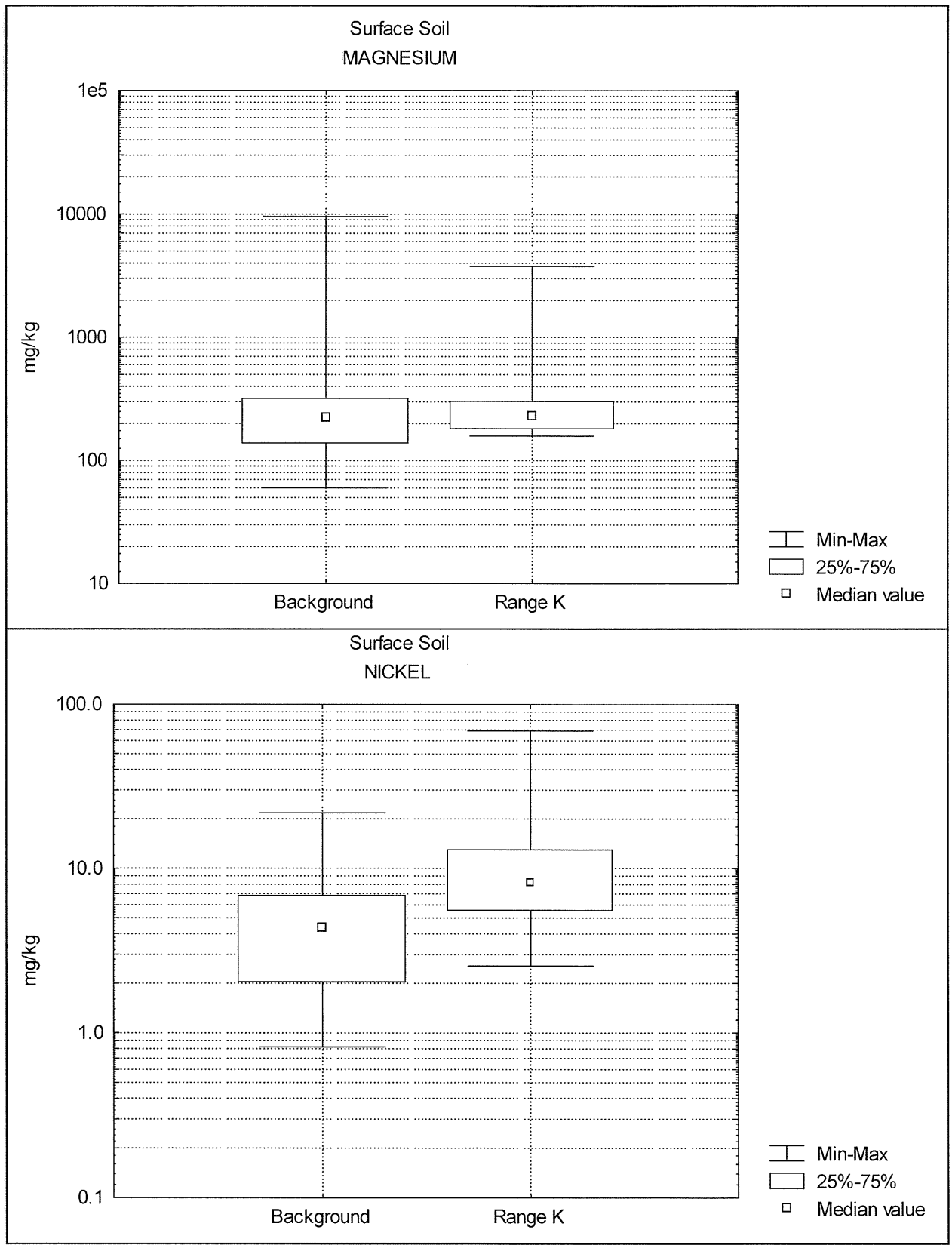

Surface Soil
MAGNESIUM
1e5
10000
1000
100
10
mg/kg
Background
Range K
Min-Max
25%-75%
Median value
Surface Soil
NICKEL
100.0
10.0
1.0
0.1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-7

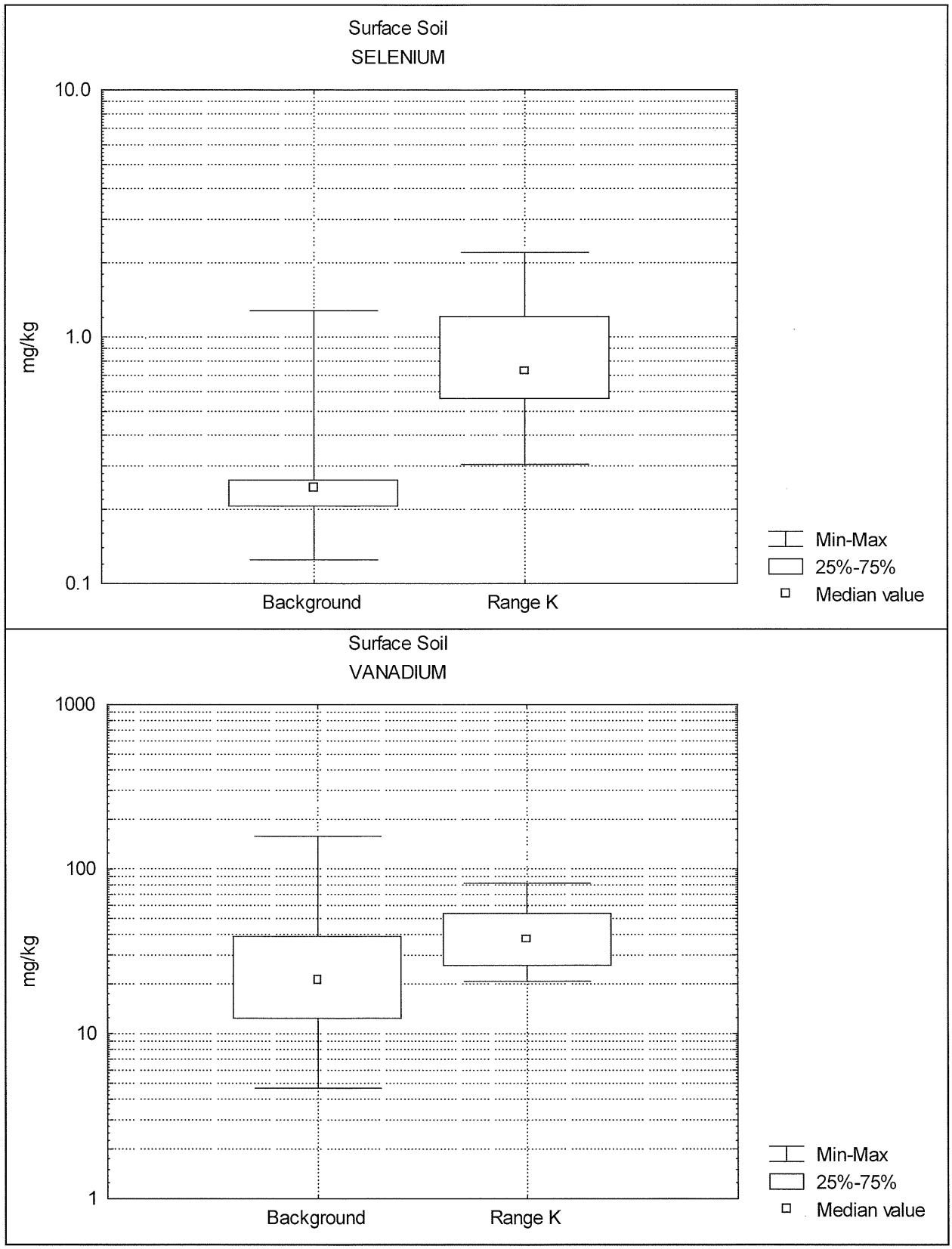

Surface Soil
SELENIUM
10.0
1.0
0.1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value
Surface Soil
VANADIUM
1000
100
10
1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-8

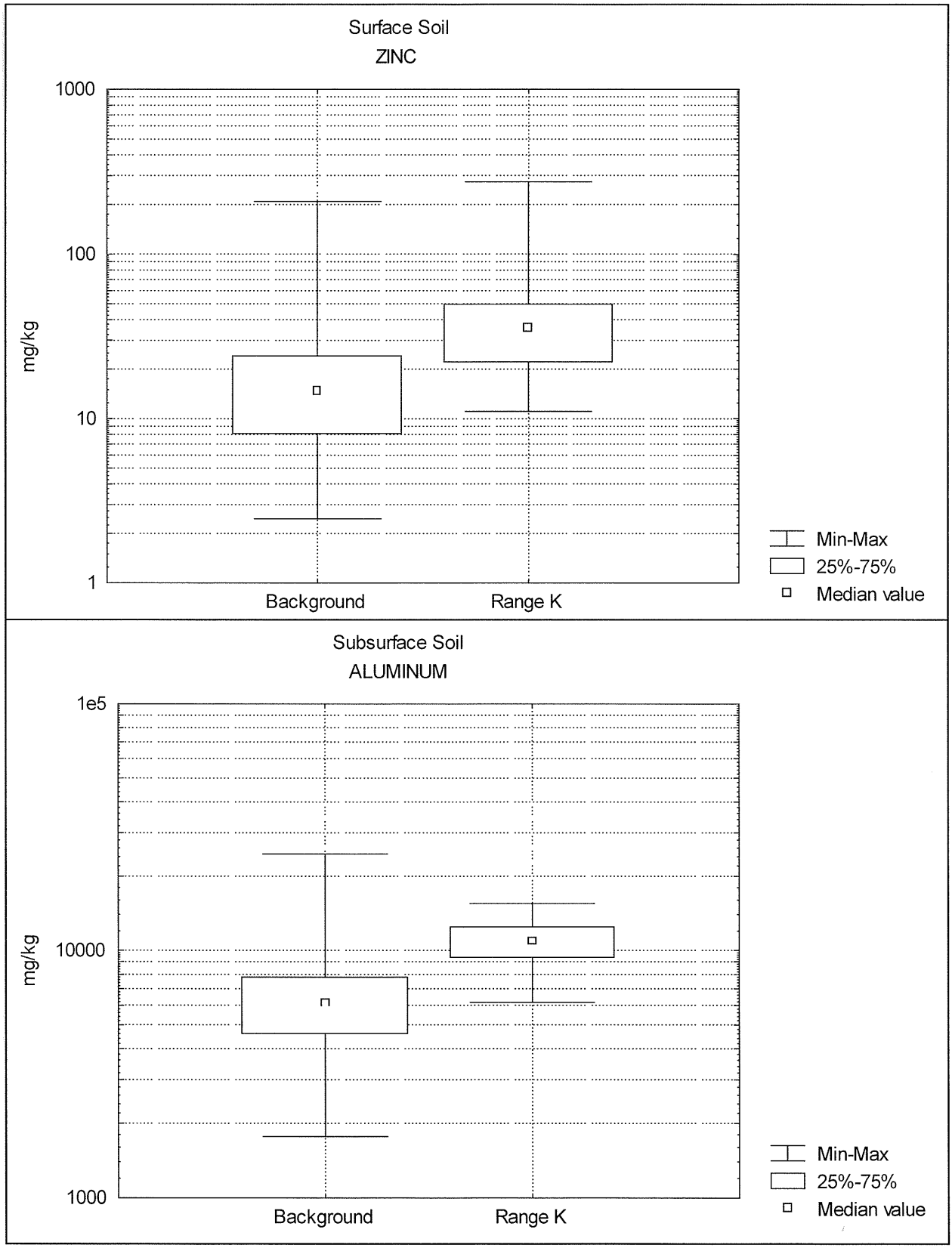
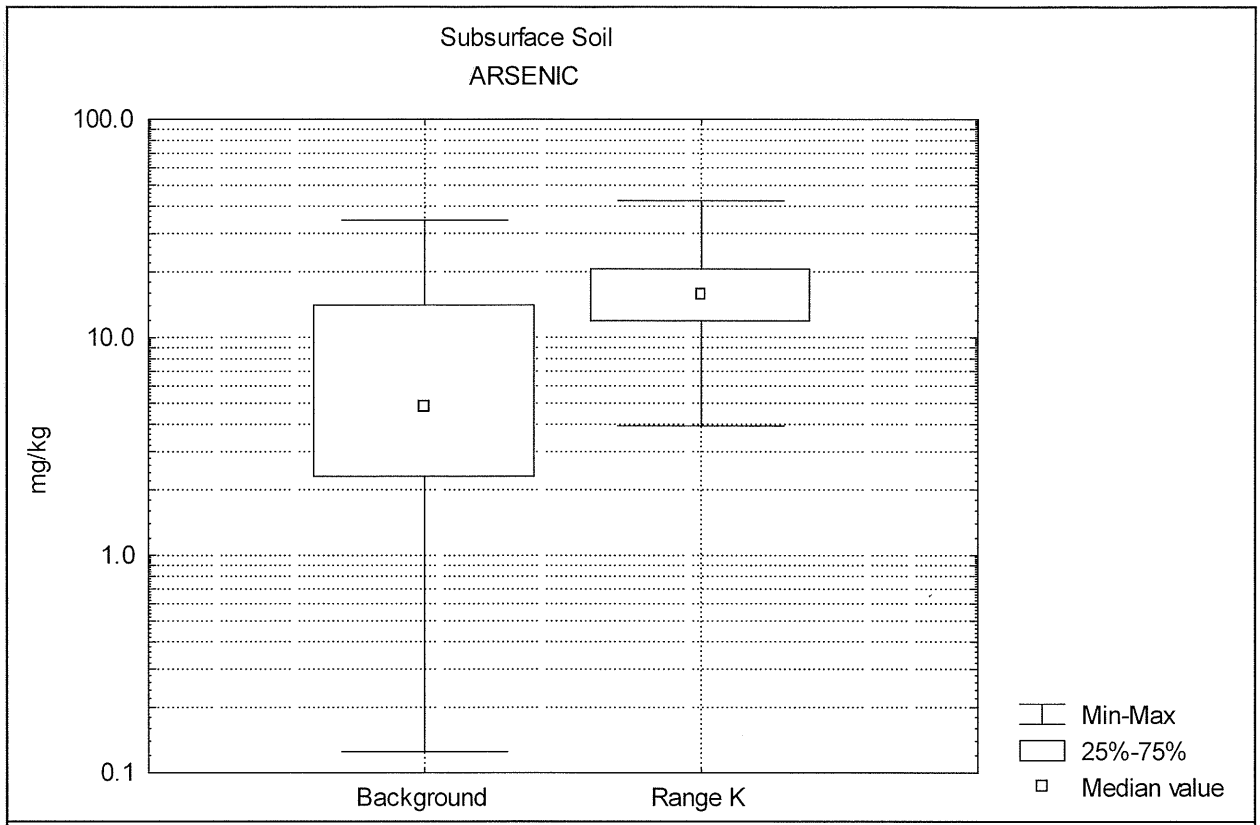

Surface Soil
ZINC
1000
100
10
1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value
Subsurface Soil
ALUMINUM
1e5
10000
1000
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-9


Subsurface Soil
ARSENIC
100.0
10.0
1.0
0.1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

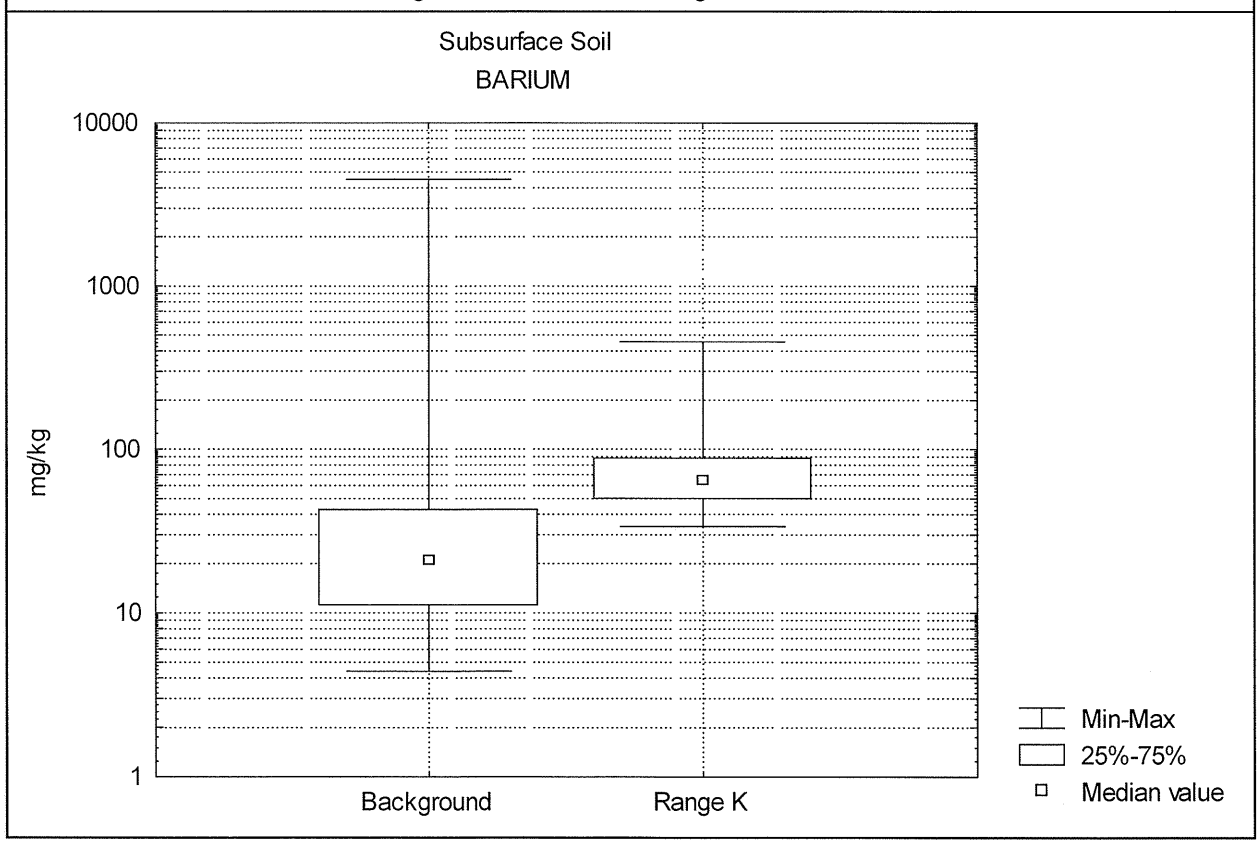
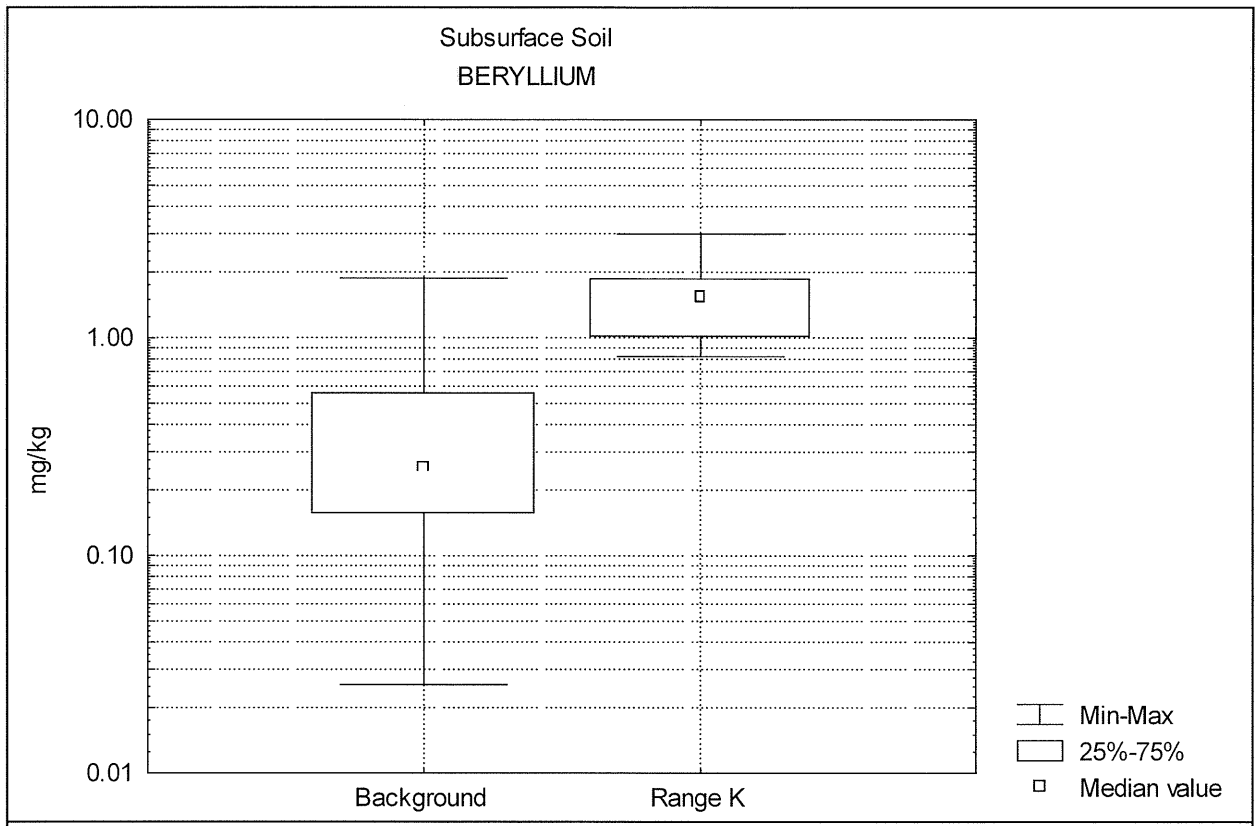

Subsurface Soil
BARIUM
10000
1000
100
10
1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-10


Subsurface Soil
BERYLLIUM
10.00
1.00
0.10
0.01
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

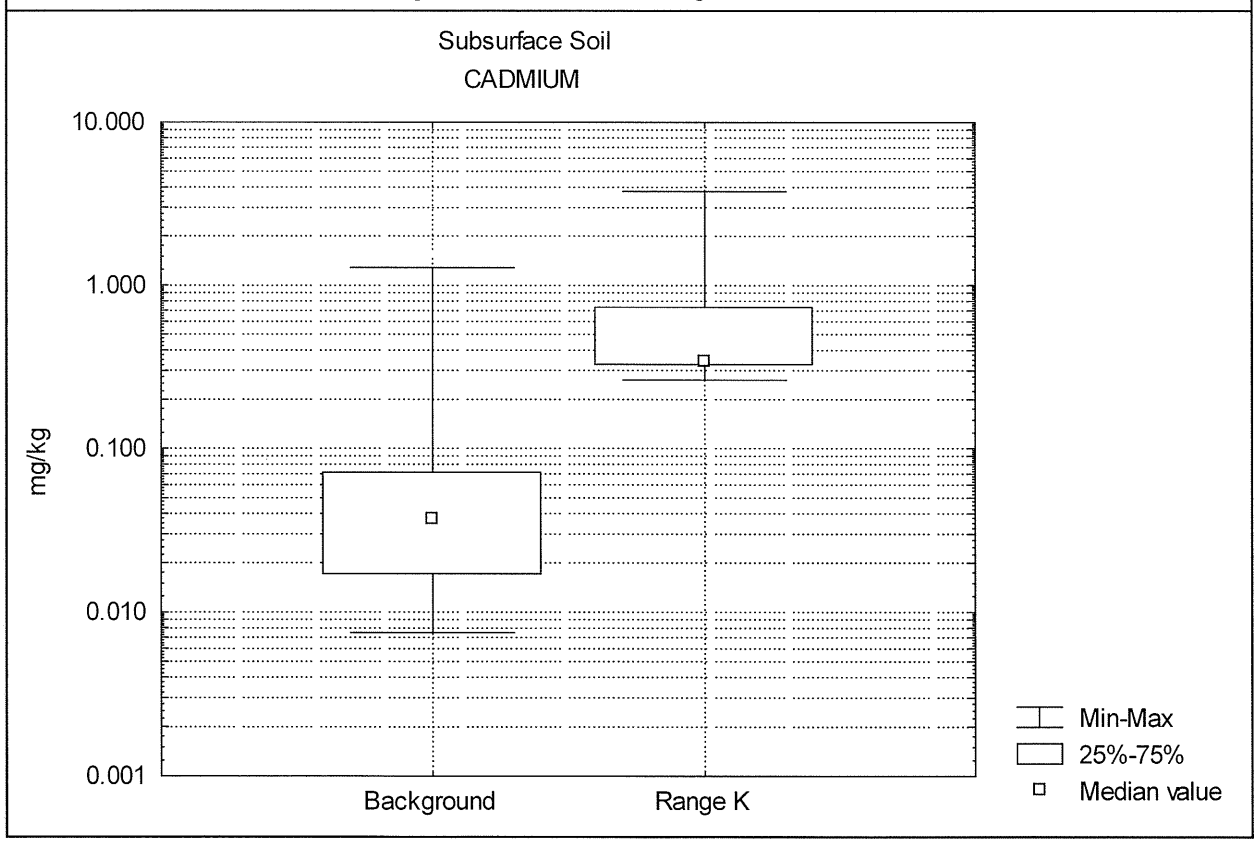

Subsurface Soil
CADMIUM
10.000
1.000
0.100
0.010
0.001
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-11

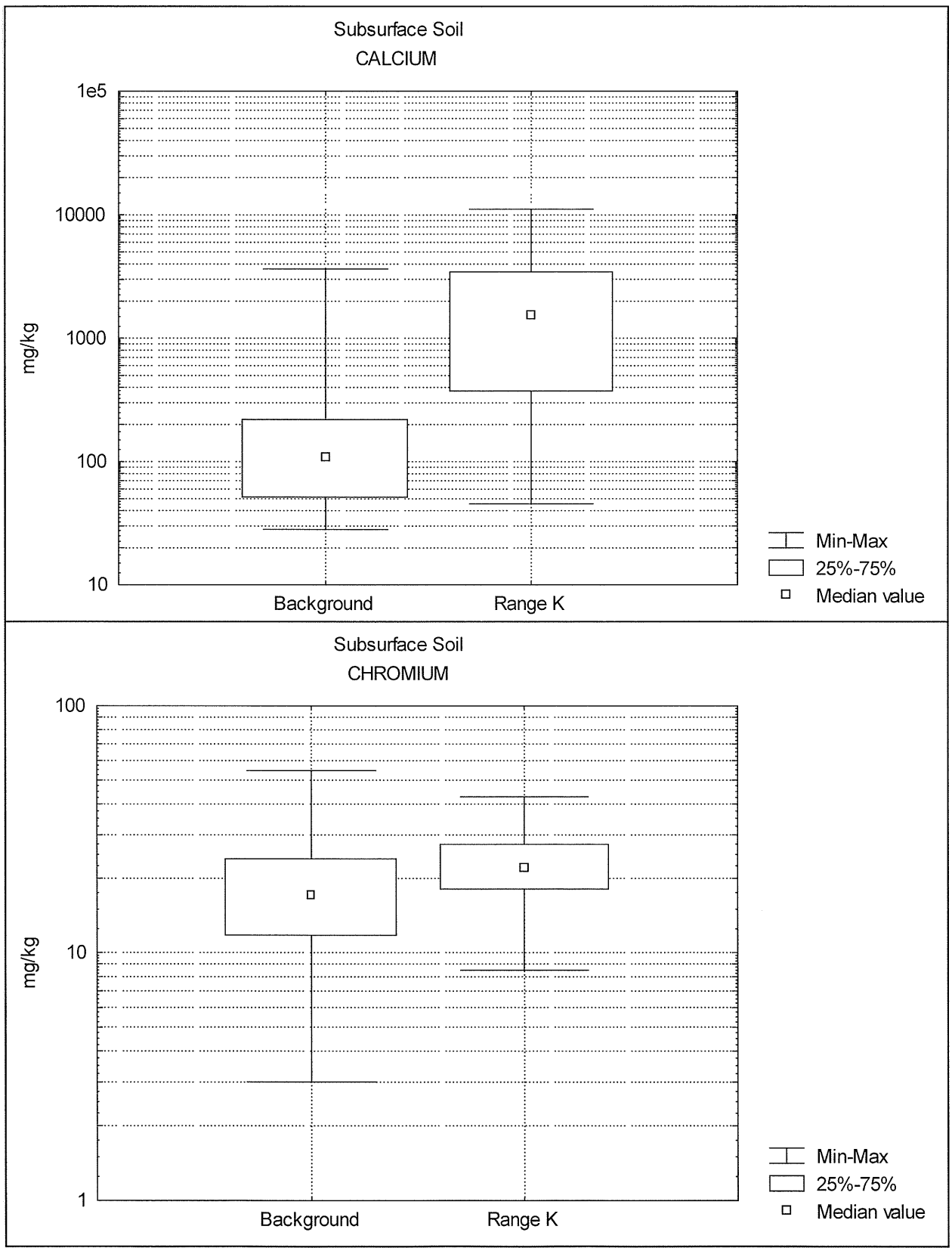
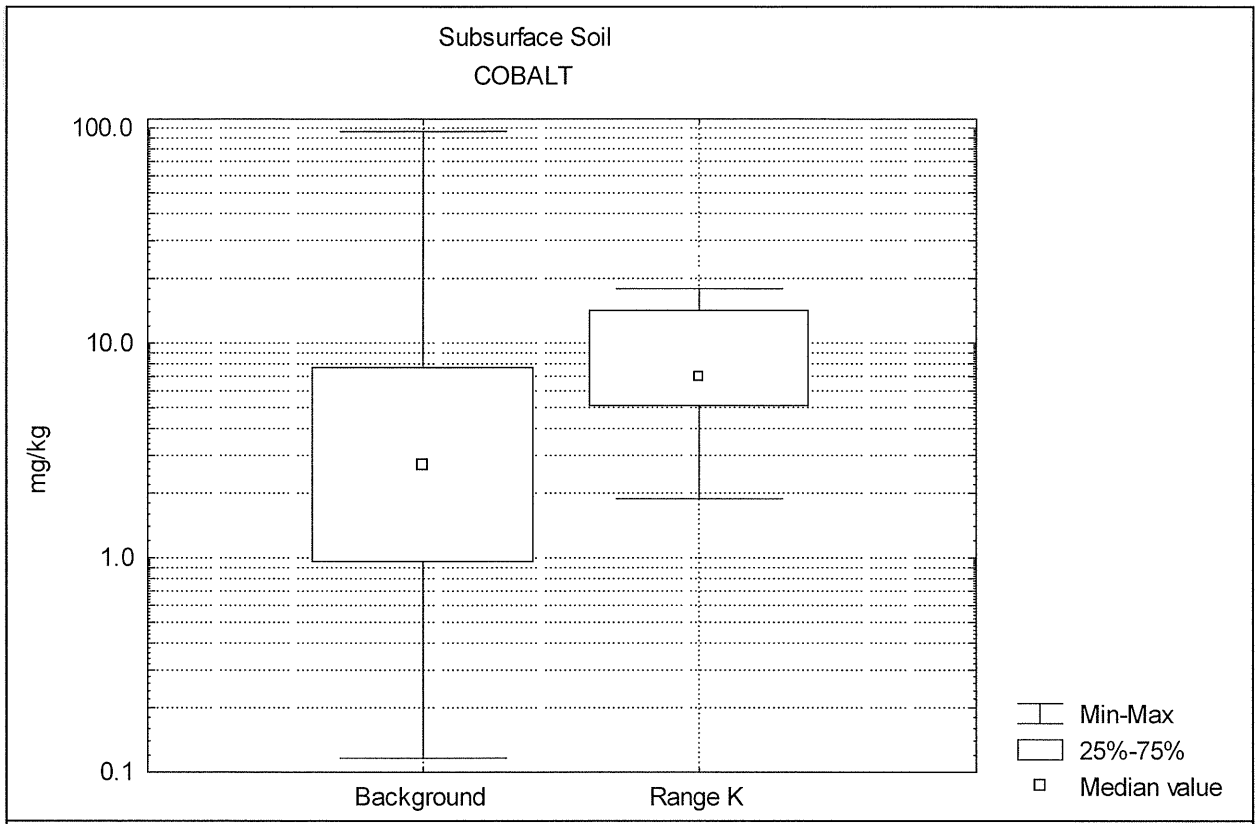

Subsurface Soil
CALCIUM
1e5
10000
1000
100
10
mg/kg
Background
Range K
Min-Max
25%-75%
Median value
Subsurface Soil
CHROMIUM
100
10
1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-12


Subsurface Soil
COBALT
100.0
10.0
1.0
0.1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

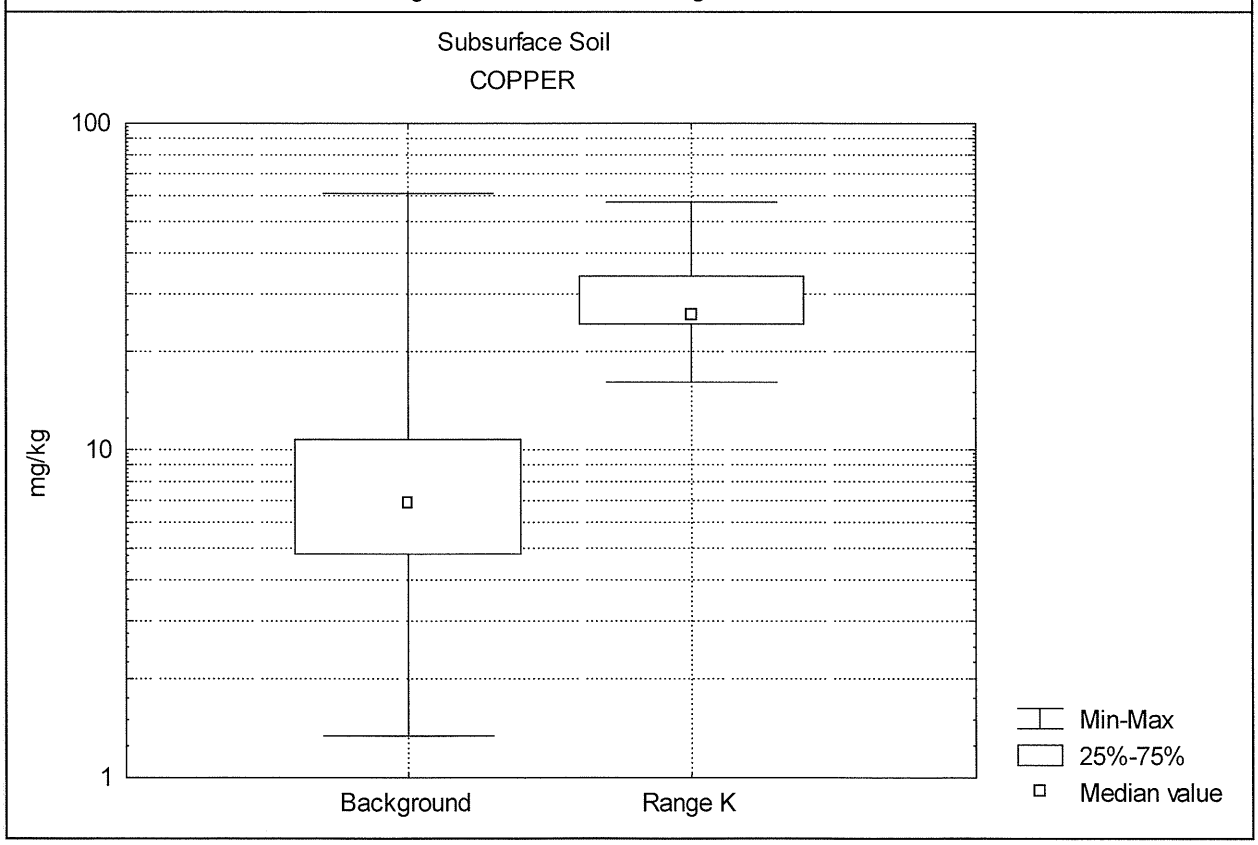

Subsurface Soil
COPPER
100
10
1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-13

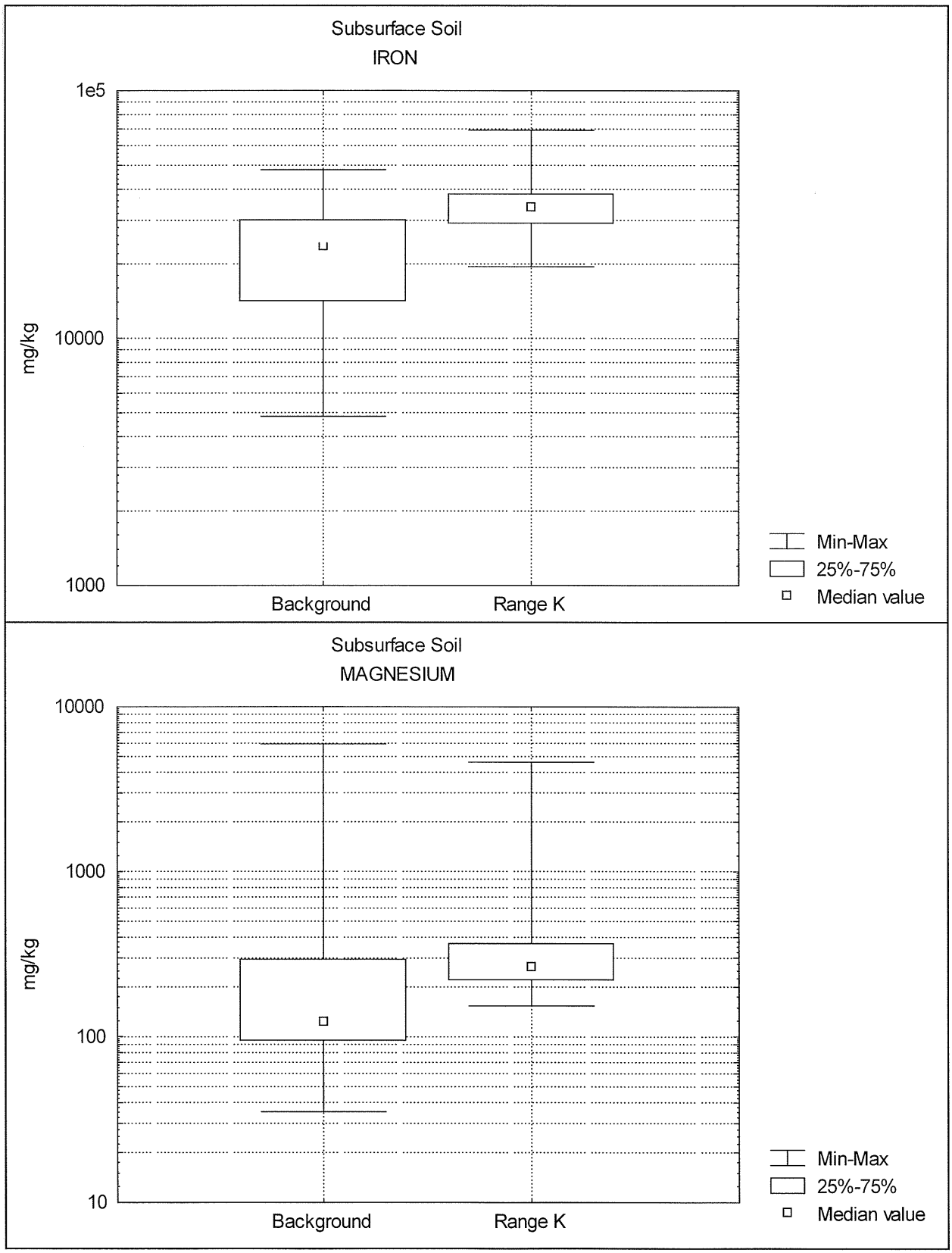

Subsurface Soil
IRON
1e5
10000
1000
mg/kg
Background
Range K
Min-Max
25%-75%
Median value
Subsurface Soil
MAGNESIUM
10000
1000
100
10
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-14

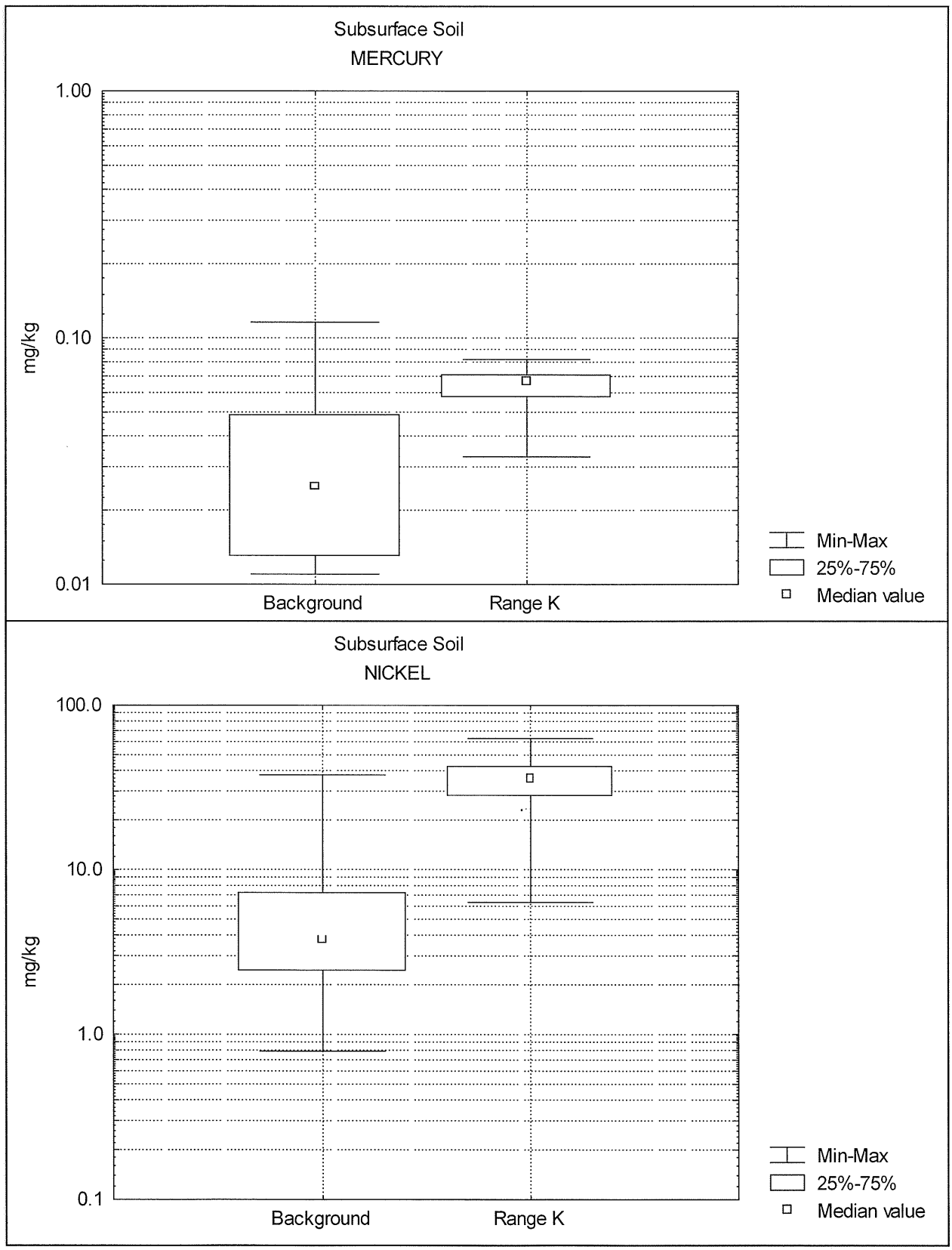

Subsurface Soil
MERCURY
1.00
0.10
0.01
mg/kg
Background
Range K
Min-Max
25%-75%
Median value
Subsurface Soil
NICKEL
100.0
10.0
1.0
0.1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-15

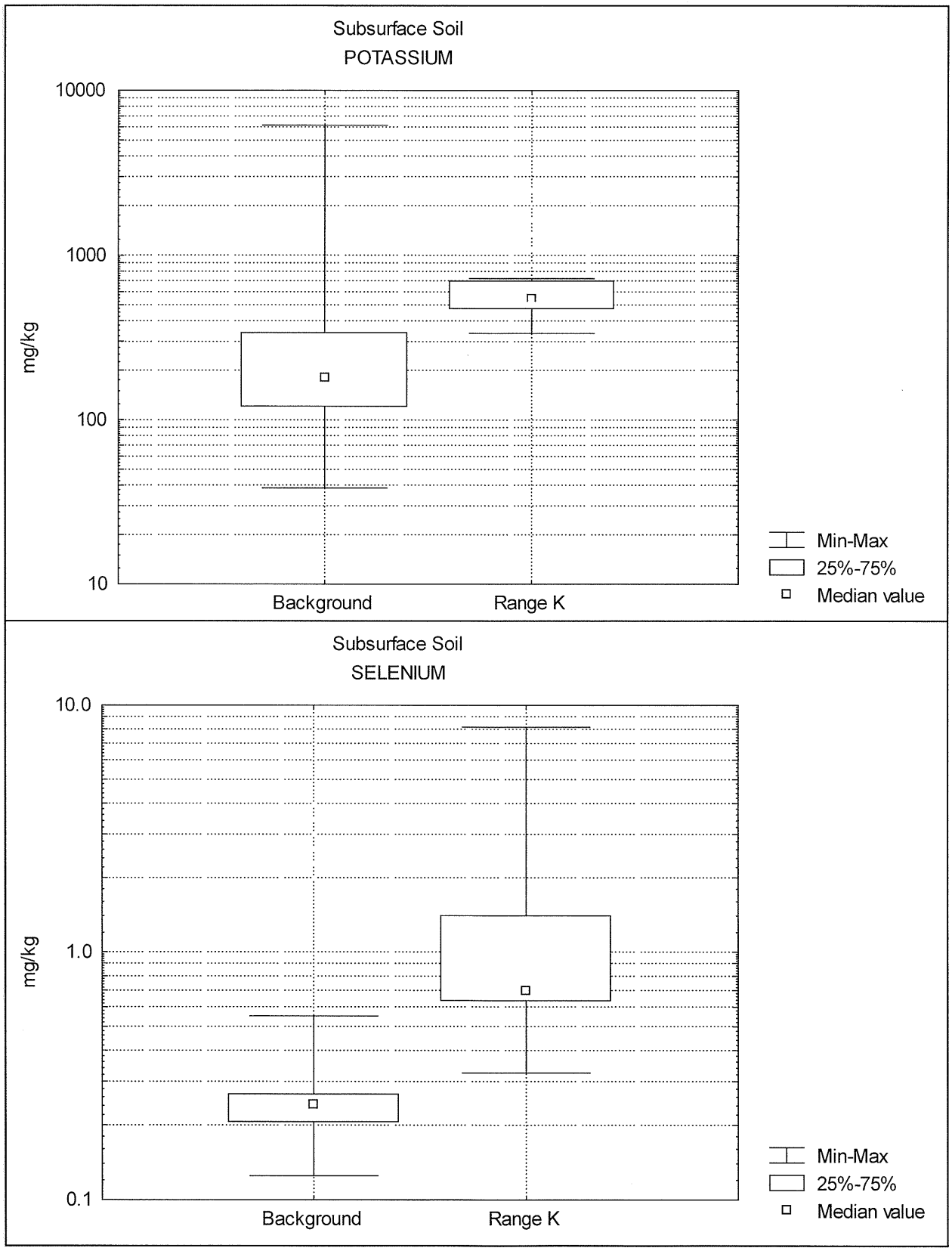

Subsurface Soil
POTASSIUM
10000
1000
100
10
mg/kg
Background
Range K
Min-Max
25%-75%
Median value
Subsurface Soil
SELENIUM
10.0
1.0
0.1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-16

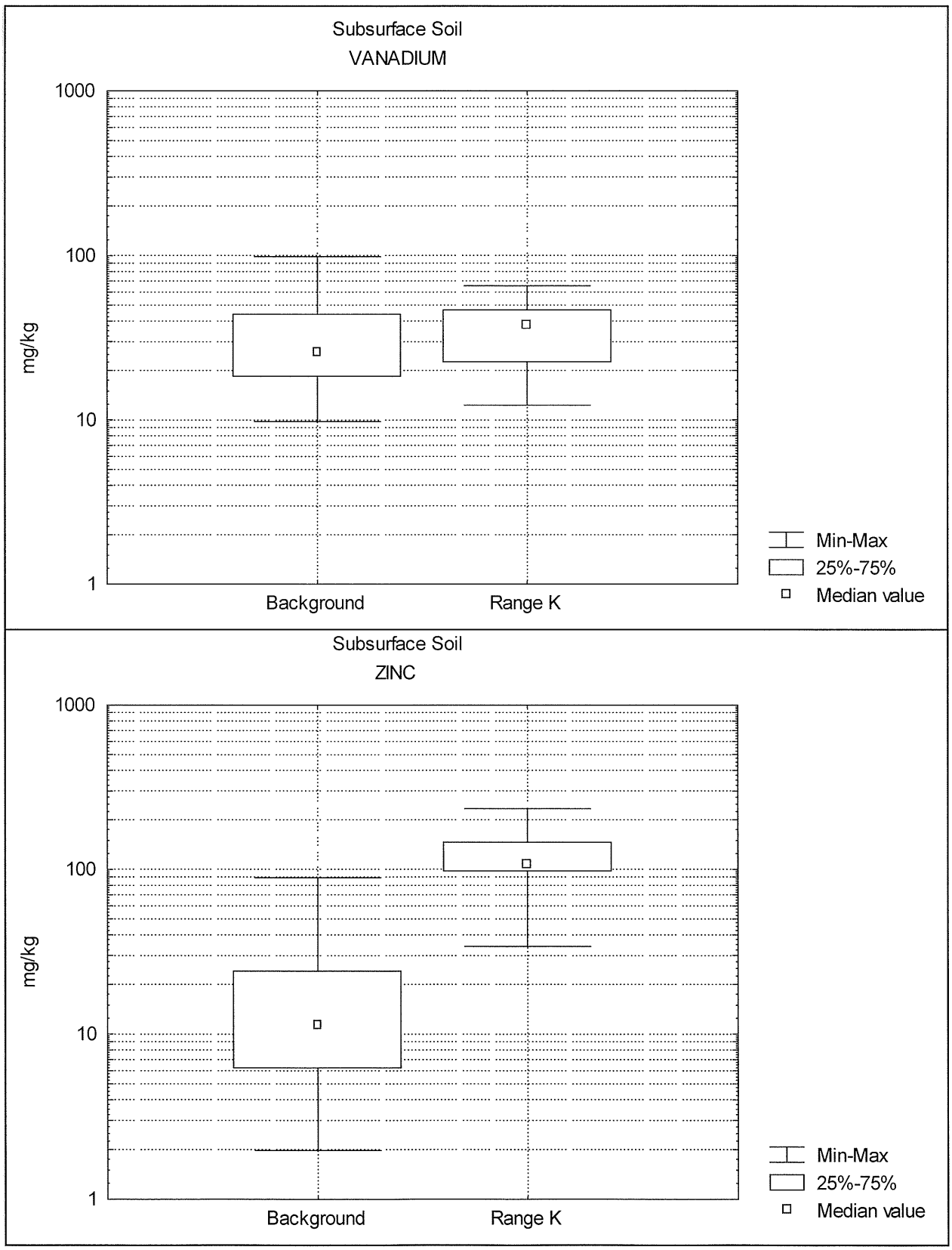
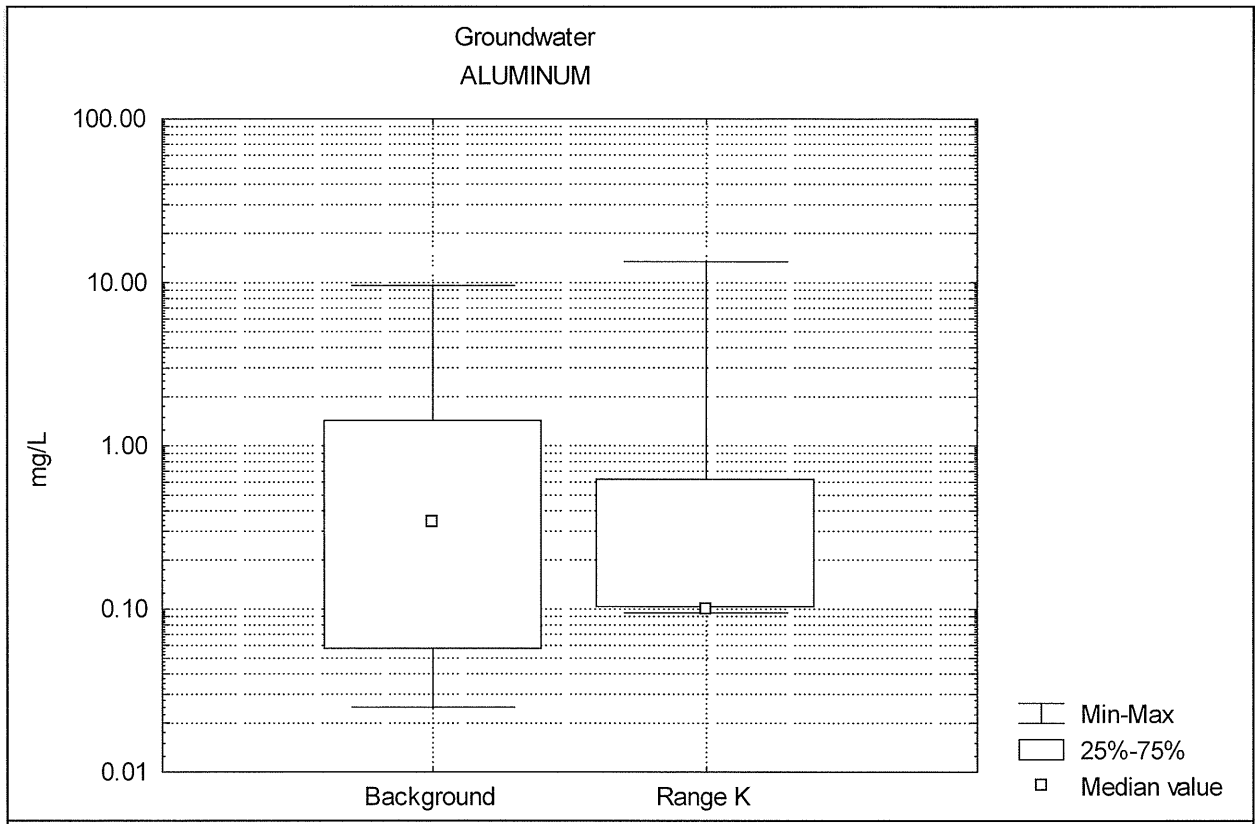

Subsurface Soil
VANADIUM
1000
100
10
1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value
Subsurface Soil
ZINC
1000
100
10
1
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-17


Groundwater
ALUMINUM
100.00
10.00
1.00
0.10
0.01
mg/L
Background
Range K
Min-Max
25%-75%
Median value

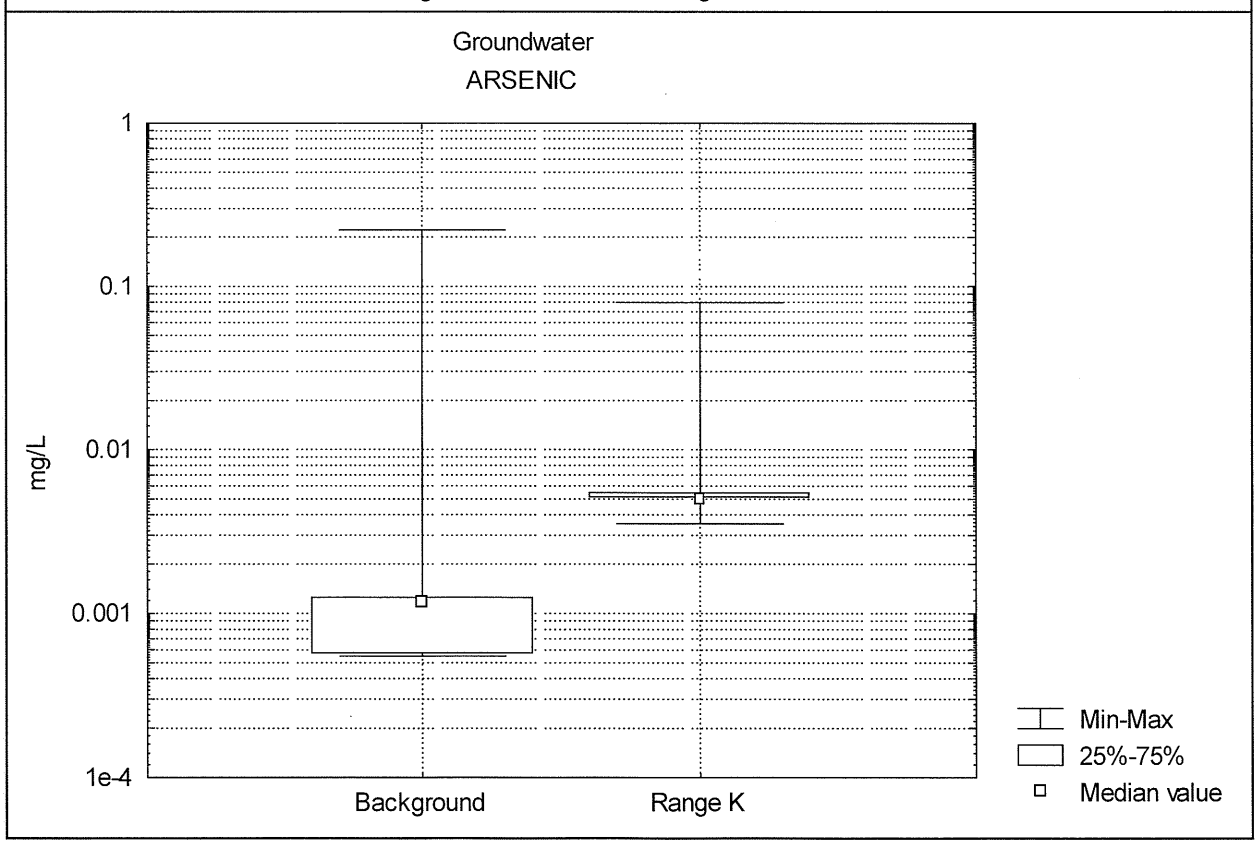

Groundwater
ARSENIC
1
0.1
0.01
0.001
1e-4
mg/L
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-18

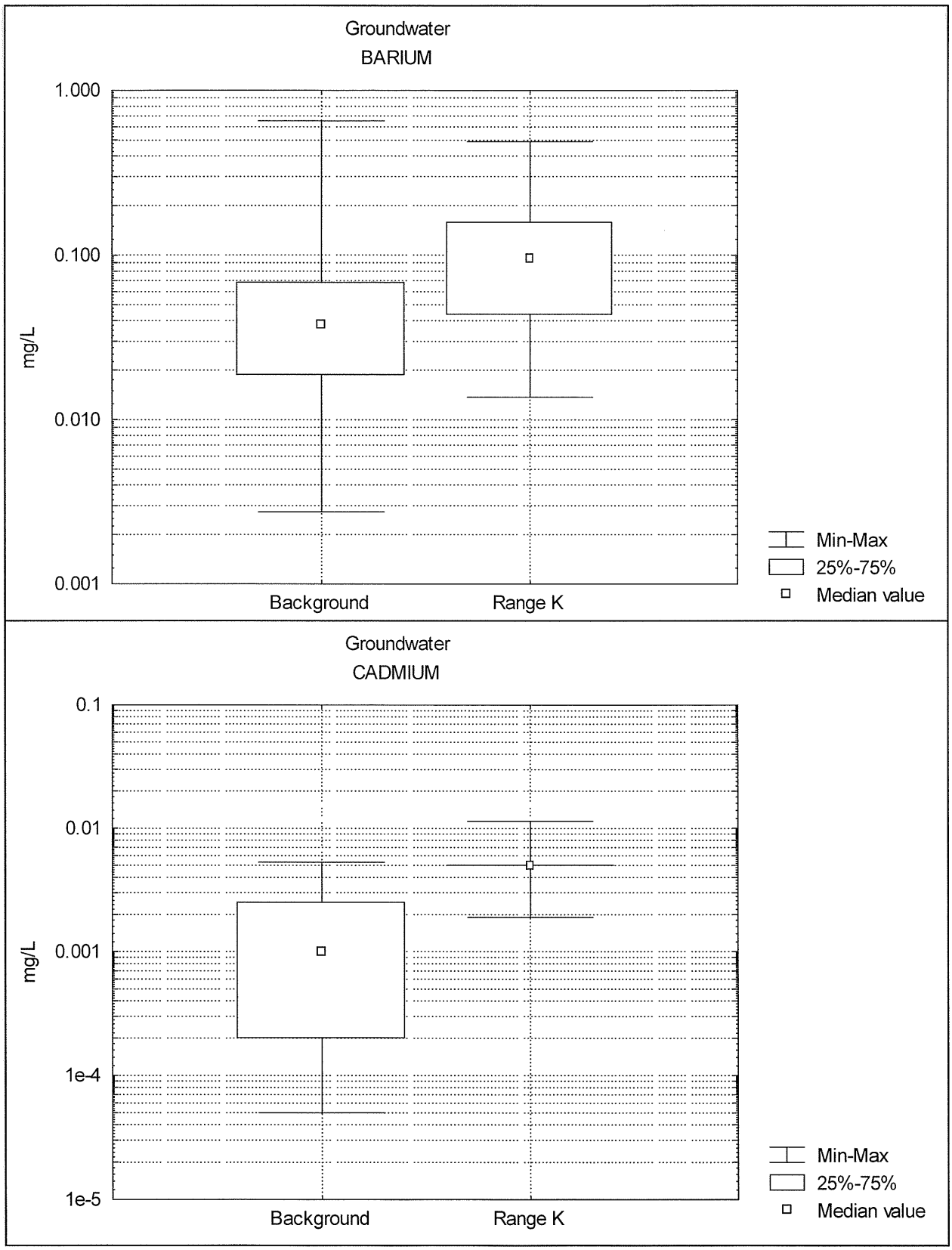

Groundwater
BARIUM
1.000
0.100
0.010
0.001
mg/L
Background
Range K
Min-Max
25%-75%
Median value
Groundwater
CADMIUM
0.1
0.01
0.001
1e-4
1e-5
mg/L
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-19

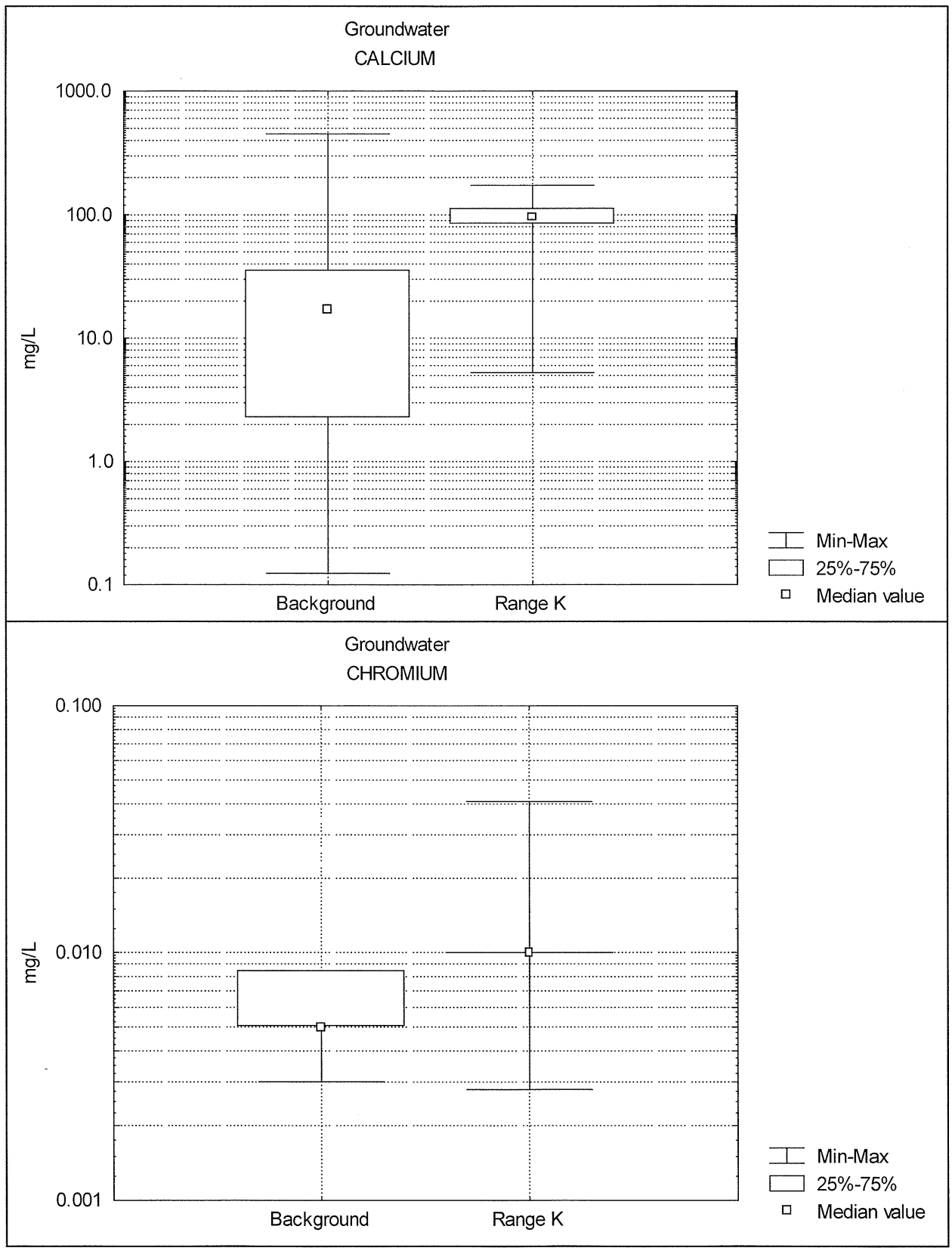
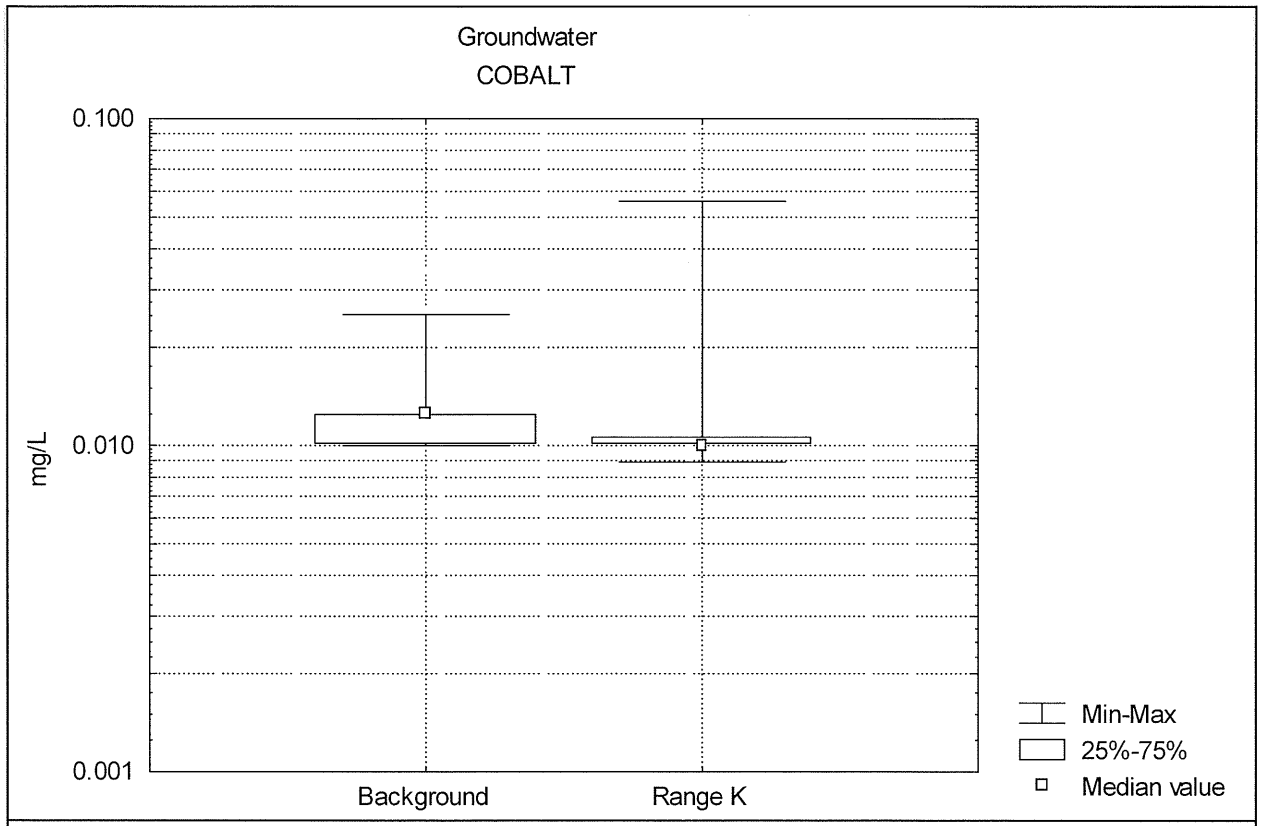

Groundwater
CALCIUM
1000.0
100.0
10.0
1.0
0.1
mg/L
Background
Range K
Min-Max
25%-75%
Median value
Groundwater
CHROMIUM
0.100
0.010
0.001
mg/L
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-20


Groundwater
COBALT
0.100
0.010
0.001
mg/L
Background
Range K
Min-Max
25%-75%
Median value

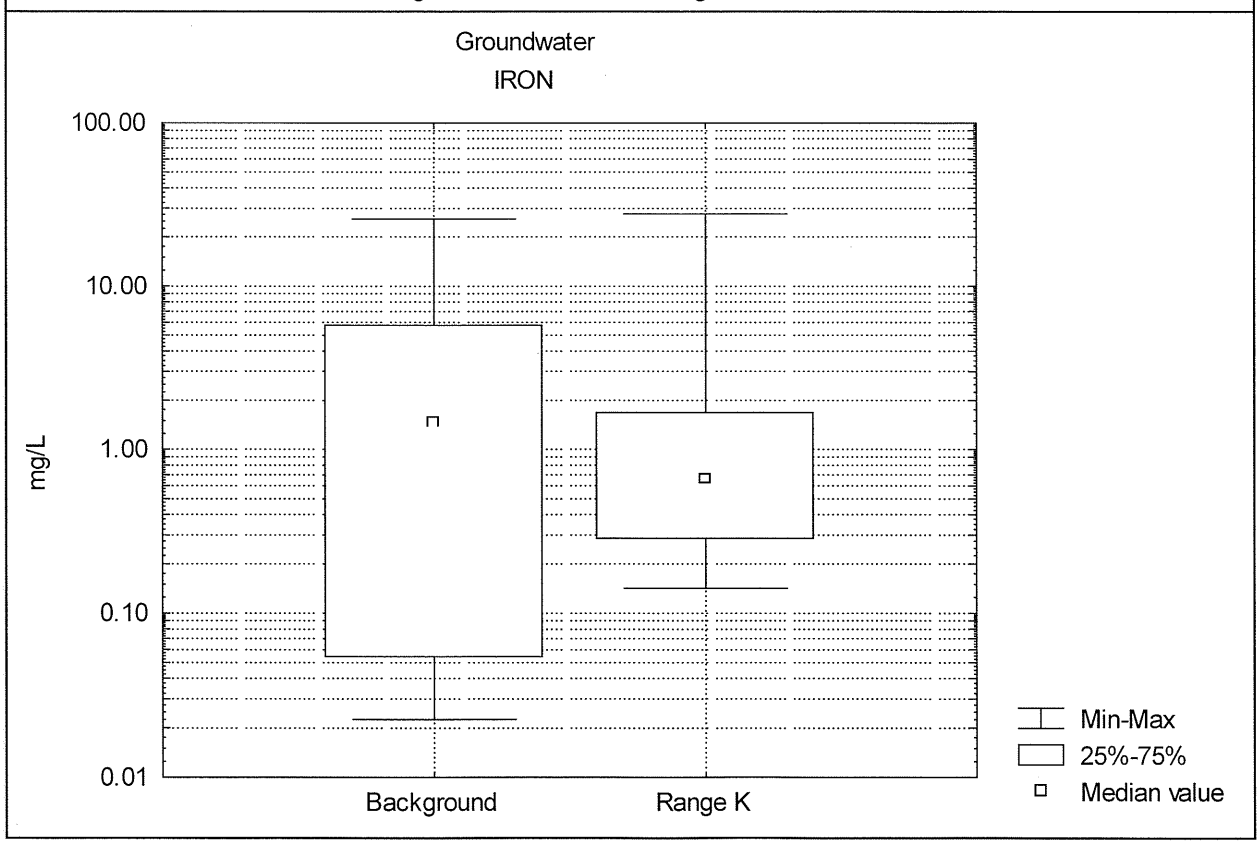
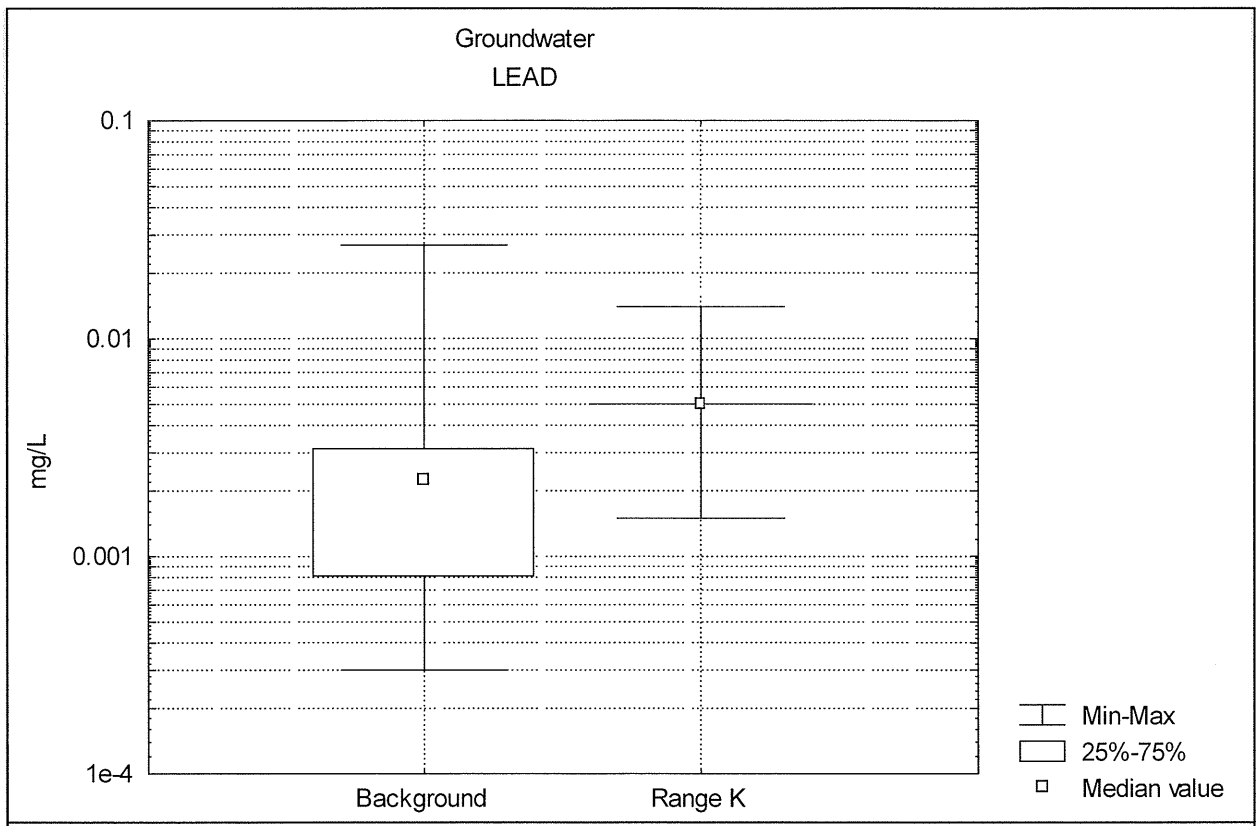

Groundwater
IRON
100.00
10.00
1.00
0.10
0.01
mg/L
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-21


Groundwater
LEAD
0.1
0.01
0.001
1e-4
mg/L
Background
Range K
Min-Max
25%-75%
Median value

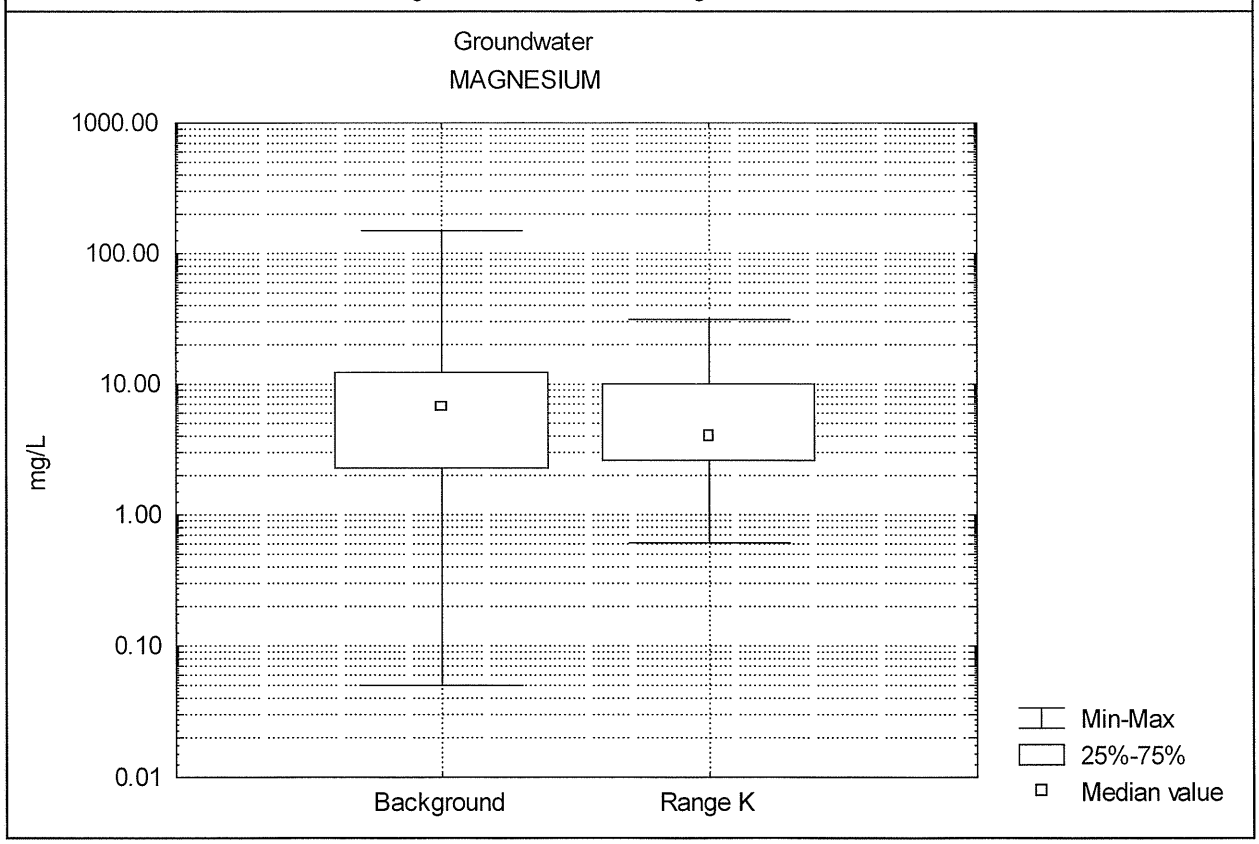

Groundwater
MAGNESIUM
1000.00
100.00
10.00
1.00
0.10
0.01
mg/L
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-22

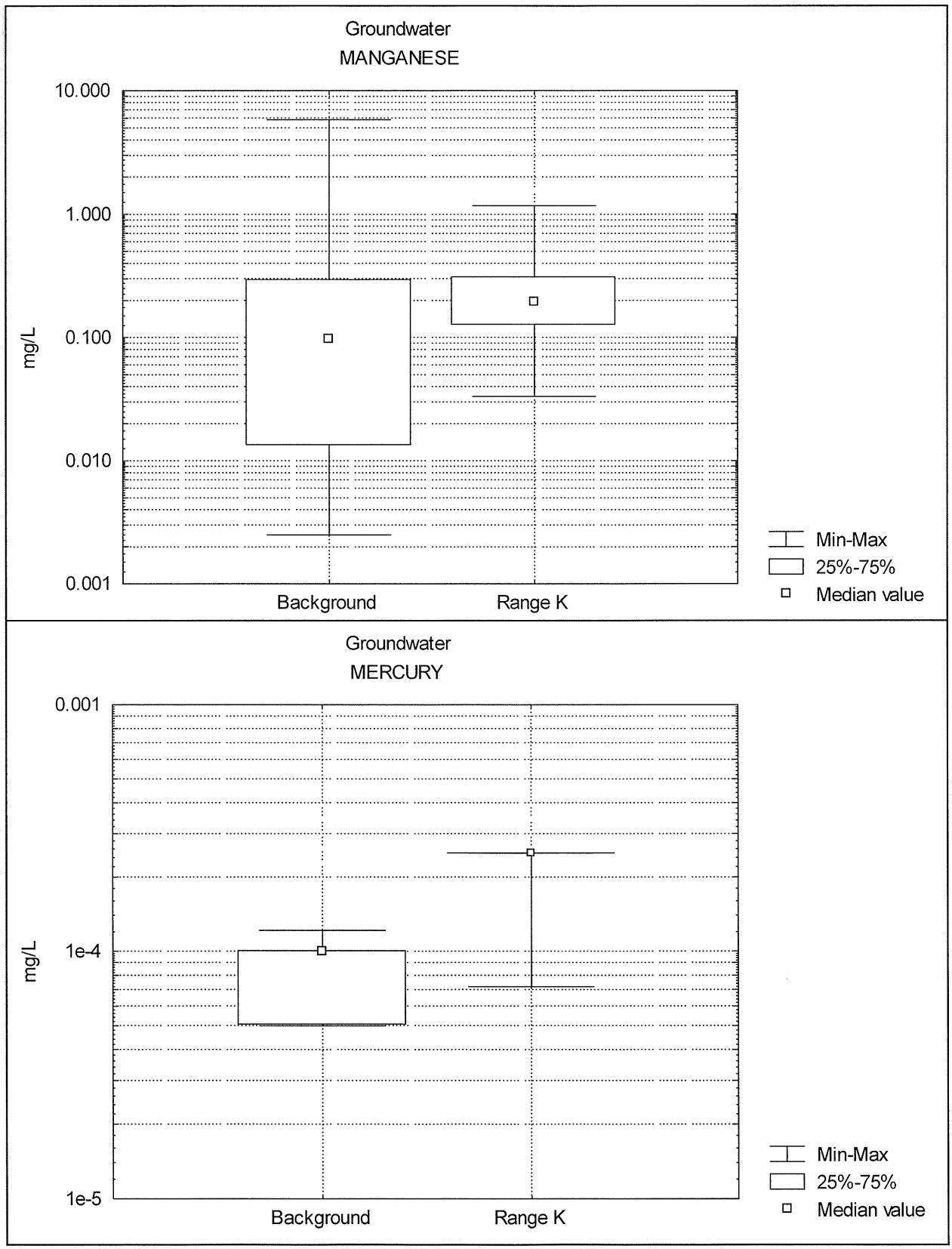
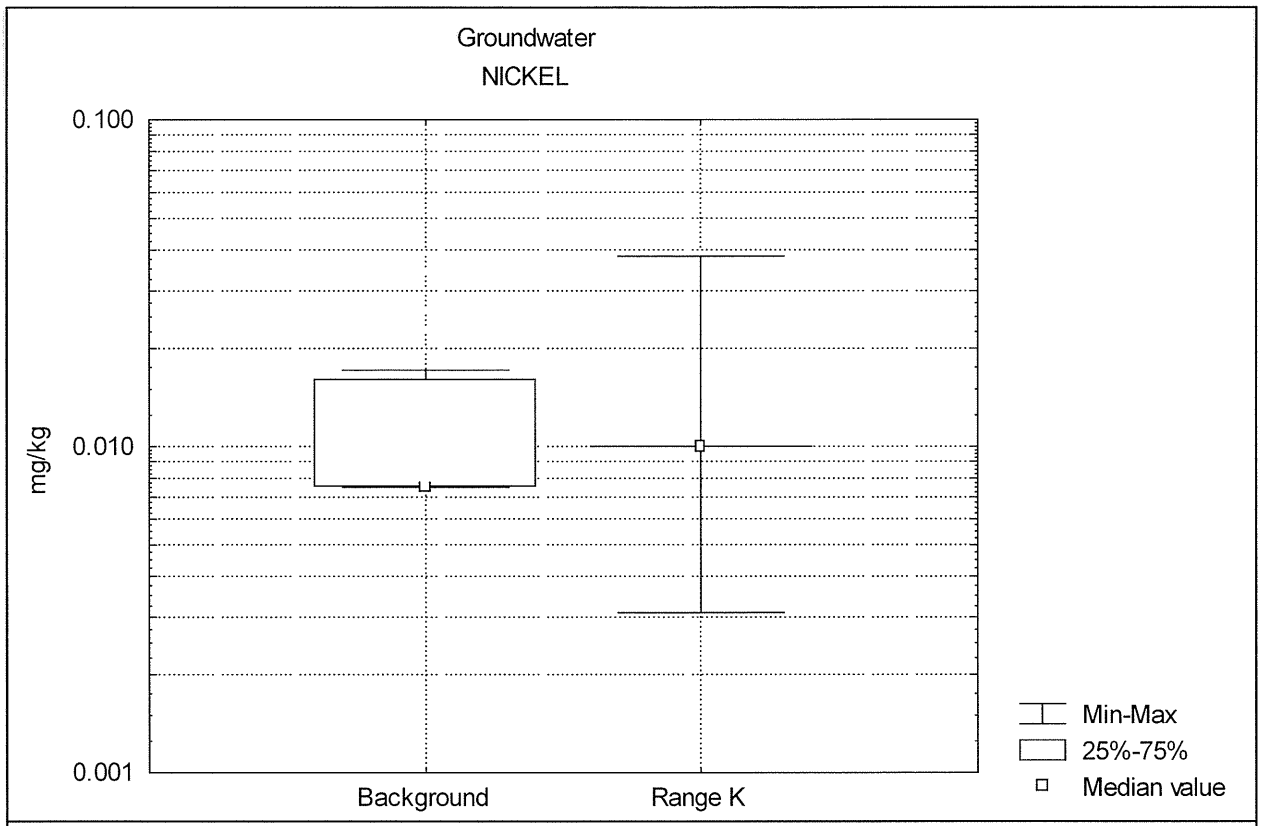

Groundwater
MANGANESE
10.000
1.000
0.100
0.010
0.001
mg/L
Background
Range K
Min-Max
25%-75%
Median value
Groundwater
MERCURY
0.001
1e-4
1e-5
mg/L
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-23


Groundwater
NICKEL
0.100
0.010
0.001
mg/kg
Background
Range K
Min-Max
25%-75%
Median value

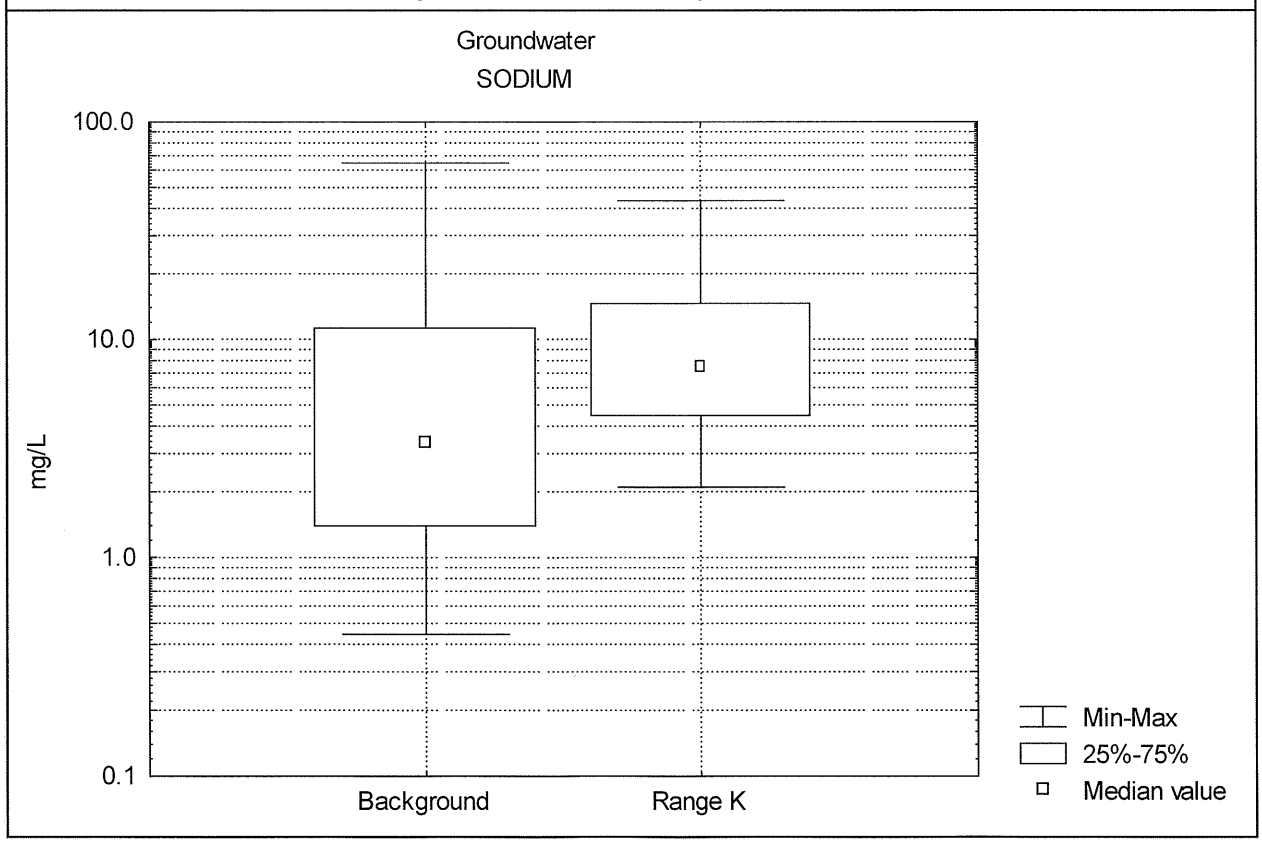
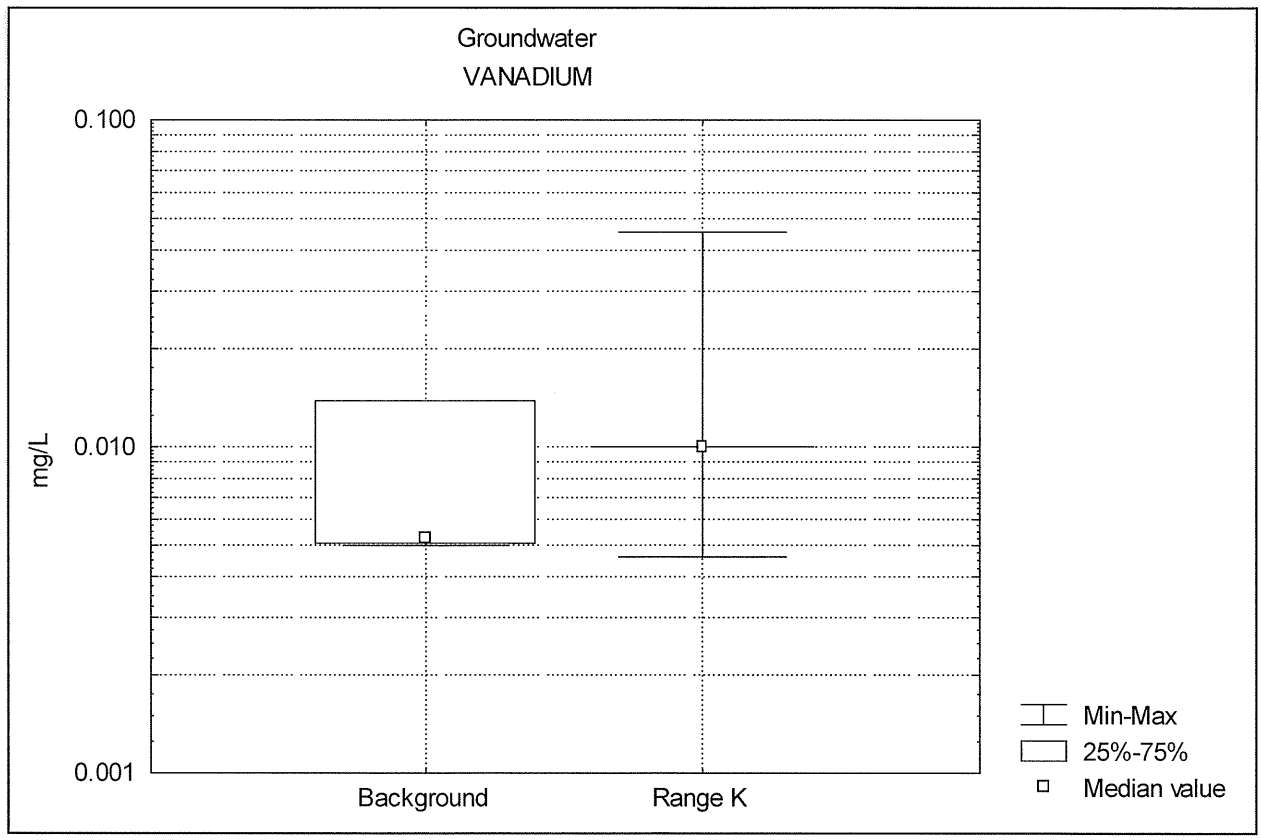

Groundwater
SODIUM
100.0
10.0
1.0
0.1
mg/L
Background
Range K
Min-Max
25%-75%
Median value

Figure 1-24


Groundwater
VANADIUM
0.100
0.010
0.001
mg/L
Background
Range K
Min-Max
25%-75%
Median value

GEOCHEMICAL
(TIER 3)

Geochemical Evaluation of Metals in Soil and Groundwater
Range K, Parcel 203(7)
Fort McClellan, Alabama

1.0 Introduction

This report provides the results of a geochemical evaluation of inorganic constituents in soil and groundwater samples from Range K, Parcel 203(7), at Fort McClellan in Calhoun County, Alabama. Sixteen elements in soil and ten elements in groundwater failed statistical comparison to background. A geochemical evaluation was performed to determine if the elevated concentrations are naturally occurring or if they contain a component of contamination.

Site samples included in the evaluation consist of 13 surface soil samples (obtained from depths of 0 to 1 foot below ground surface [bgs] and 0 to 2 feet bgs) and 13 subsurface soil samples (various depths ranging from 2 to 12 feet bgs) collected from February 2000 through August 2001; and 18 unfiltered groundwater samples collected from June 2000 through October 2001. All of the site samples were analyzed for the full suite of 23 target analyte list (TAL) metals. Installation-wide background data for TAL metals in soil and groundwater are provided in the background study report (Science Applications International Corporation, 1998) and are used in the following evaluation.

2.0 Geochemical Evaluation Methodology

Naturally occurring trace element concentrations in environmental media commonly exceed regulatory screening criteria. Trace element distributions in uncontaminated soil tend to have very large ranges (two to three orders of magnitude are not uncommon), and are highly right-skewed, resembling lognormal distributions. These trace elements are naturally associated with specific soil-forming minerals, and the preferential enrichment of a sample with these minerals will result in elevated trace element concentrations. It is thus important to be able to identify these naturally high concentrations and distinguish them from potential contamination.

If an analyte fails statistical comparison to background as described in the "Statistical Comparison of Site and Background Data for Range K, Parcel 203(7)," then a geochemical evaluation is performed to determine if the elevated concentrations are caused by natural processes. The importance of geochemical evaluations in distinguishing between site and background data sets has been recognized in the industry (U.S. Environmental Protection Agency, 1995; Barclift, *et al.*, 2000; U.S. Navy, 2002; Myers and Thorbjornsen, 2004). When

properly evaluated, geochemistry can provide mechanistic explanations for apparently high, yet naturally occurring, constituents. Anomalous samples that may represent contamination can also be readily distinguished from uncontaminated samples. This section describes the geochemical evaluation techniques that were employed in the site-to-background comparisons for Range K. Additional supporting information on these techniques are provided in the installation-wide work plan (IT Corporation, 2002) and Shaw Environmental's technical memorandum dated May 1, 2003.

It should be noted that the geochemical evaluations rely in part on professional judgment and qualitative assessment is a necessary part of the process. Samples that plot off the linear trend on a correlation plot are certainly suspect, but because all uncertainty cannot be eliminated from the evaluation, such plots cannot be construed as definitive proof of contamination. However, anomalous samples should be flagged as suspect and their results used as a basis for further investigation, risk assessment, or remediation, as appropriate. The combination of statistical evaluations (Tiers 1 and 2) and geochemical evaluation (Tier 3) as presented in this appendix is effective in reducing the occurrences of decision errors relative to consideration of statistics or geochemistry alone.

2.1 Soil and Sediment

The geochemical evaluation is based on the natural associations of trace elements with specific minerals in the soil or sediment matrix. As an example, arsenic in most uncontaminated oxic soils is almost exclusively associated with iron oxide minerals (Bowell, 1994; Schiff and Weisberg, 1997). (The term "iron oxide" is used here to include oxides, hydroxides, oxyhydroxides, and hydrous oxides of iron.) This association of arsenic with iron oxides is a result of the adsorptive behavior of this particular trace metal in an oxic soil environment. Arsenic is present in oxic soil pore fluid as negatively charged oxyanions ($HAsO_4^{-2}$, $H_2AsO_4^{-}$) (Brookins, 1988). These anions have strong affinities to adsorb on the surfaces of iron oxides, which maintain a strong positive surface charge (Electric Power Research Institute [EPRI], 1986). If a soil sample has a high percentage of iron oxides, then it is expected to have a proportionally higher concentration of arsenic.

The absolute concentrations of arsenic and iron can vary by several orders of magnitude at a site, but the arsenic/iron ratios in the samples are usually quite constant as long as no contamination is present (Daskalakis and O'Connor, 1995). If a sample has some naturally occurring arsenic plus additional arsenic from an herbicide or some other source, then it will have an anomalously high

ratio relative to the other uncontaminated samples. These ratios thus serve as a powerful technique for identifying contaminated samples.

The evaluation includes the generation of plots in which detected arsenic concentrations in a set of samples are plotted on the y-axis, and the corresponding detected iron concentrations are plotted on the x-axis. The slope of a best-fit line through the samples is equal to the average arsenic/iron background ratio. If the samples with the highest arsenic concentrations plot on the same linear trend as the other samples, then it is most probable that the elevated concentrations are natural, and are caused by the preferential enrichment of iron oxides in those samples. If the site samples with elevated arsenic concentrations plot above the trend displayed by the uncontaminated samples, then there is evidence that those samples have an excess contribution of arsenic, and contamination may be indicated.

Each trace element is associated with one or more minerals in the soil matrix. Vanadium and selenium, along with arsenic, form anionic species in solution and are associated with iron oxides, which maintain a positive surface charge. Divalent metals such as barium, cadmium, lead, and zinc tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. These trace elements would be evaluated against aluminum, which is a major component of clay minerals. Manganese oxide minerals have high adsorption capacities, and have an affinity to adsorb divalent cations such as barium, cobalt, and lead (Post, 1999; Kabata-Pendias, 2001). These trace elements would be evaluated against manganese.

It is important to note that some trace elements have very strong affinities for a particular type of mineral, whereas other elements will partition themselves between several minerals. For instance, vanadium has a particularly strong affinity for iron oxides, so correlation coefficients for vanadium versus iron in uncontaminated samples are usually very high, and this is expressed on a correlation plot as a highly linear trend. In contrast, chromium will form several co-existing aqueous species [$Cr(OH)_2^+$, $Cr(OH)_3^0$, $Cr(OH)_4^-$], which will adsorb on several different types of minerals including iron oxides and clays. This behavior will yield lower correlation coefficients for chromium versus iron or chromium versus aluminum relative to the coefficients observed for vanadium versus iron, and more scatter may be observed on the correlation plots. Some elements are more selective than others with respect to adsorption on specific mineral surfaces, and this selectivity is dependent on site conditions.

2.2 Groundwater and Surface Water

Elevated concentrations of inorganic constituents in groundwater and surface water samples may be due to naturally high dissolved concentrations, the presence of suspended particulates in the samples, reductive dissolution, or contamination resulting from site activities. This section discusses the major geochemical processes considered during the evaluation of groundwater and surface water analytical data.

Effects of Suspended Particulates. The presence of trace elements adsorbed on suspended particulates can greatly increase trace element concentrations as reported by an analytical laboratory. These adsorbed trace elements are not in true solution and can be removed by settling or filtration. The same concepts involved in the evaluation of soil and sediment data also apply to groundwater and surface water data: samples containing trace elements adsorbed on suspended clay particulates should show a positive correlation with aluminum concentrations, and samples containing trace elements adsorbed on suspended iron oxides should show a positive correlation with iron concentrations. These correlations are evaluated by generating x-y plots of the concentrations of an elevated trace metal versus aluminum or iron (depending on the trace element).

The most common suspended particulates in groundwater samples are clay minerals; hydrous aluminum oxides ($Al_2O_3 \bullet nH_2O$) and hydroxides [$Al(OH)_3$]; and iron oxide (Fe_2O_3), hydrous iron oxide, iron hydroxide [$Fe(OH)_3$], and iron oxyhydroxide ($FeO \bullet OH$) minerals, collectively referred to as "iron oxides." All clay minerals contain aluminum and have low solubilities over a neutral pH range of 6 to 8. Measured concentrations of aluminum in excess of ~1 milligram per liter (mg/L) indicate the presence of suspended clay minerals (Hem, 1985; Stumm and Morgan, 1996), with higher aluminum concentrations being a qualitative indicator of the mass of suspended clay minerals. Iron also has a very low solubility under neutral pH and moderate to oxidizing redox conditions, so that measured iron concentrations in excess of ~1 mg/L under these conditions indicate the presence of suspended iron oxides (Hem, 1985).

The presence of suspended clay or iron oxides in groundwater samples has particular importance in the interpretation of trace element concentrations. Most clay particles maintain a negative surface charge under neutral pH conditions, and have a strong tendency to adsorb positively charged (cationic) aqueous species. Iron oxides display the opposite behavior; they maintain a positive surface charge under neutral pH conditions, and have a strong tendency to adsorb negatively charged (anionic) aqueous species.

Barium, lead, and zinc are usually present in groundwater as divalent cations and thus tend to concentrate on clay surfaces (EPRI, 1984; Brookins, 1988). Arsenic, selenium, and vanadium are usually present under oxidizing conditions as oxyanions, and thus tend to concentrate on iron oxide surfaces (Pourbaix, 1974; Hem, 1985; Brookins, 1988; Bowell, 1994).

Chromium can be present in groundwater as a mixture of aqueous species with different charges such as $Cr(OH)_2^+$, $Cr(OH)_3^o$, and $Cr(OH)_4^-$, depending on pH (EPRI, 1984). The positive, neutral, and negative charges on these species result in the distribution of chromium on several different types of sorptive surfaces, including clay and iron oxide minerals.

As an example, the concentrations of zinc (y-axis) would be plotted against aluminum (x-axis). If all of the samples display a common linear trend, then it is most likely that the zinc concentrations are due to the presence of suspended clay minerals in the samples. The slope of a best-fit line through the points is equal to the average zinc/aluminum ratio. If some samples plot above the linear trend established by the other samples, then those samples have an anomalously high zinc/aluminum ratio, and most likely contain excess zinc that cannot be explained by these natural processes.

If the concentrations of trace elements in unfiltered samples are correlated with aluminum or iron, then they are most likely adsorbed to the surfaces of suspended particulates. If these correlations are linear, then the elevated concentrations are most likely natural.

Alternative techniques for assessing the effects of suspended particulates on trace element concentrations are the evaluation of correlations of trace element concentrations versus turbidity, and comparison of analyses of filtered versus unfiltered splits of samples. Turbidity measurements are qualitative, and do not distinguish between suspended clay minerals, iron oxides, and natural organic material, so this approach lacks the resolution provided by trace element versus aluminum or trace element versus iron correlations. Comparisons of filtered versus unfiltered splits of samples are highly informative and permit the identification of elements that are present as suspended particulates versus those that are in true solution. Filtered splits were obtained for 14 of the Range K groundwater samples, but were not obtained for the June 2000 samples from wells RNG-203-MW01, -02, -03, and -04 (sample numbers RG3001, -4, -5, and -6).

Effects of Reductive Dissolution. Iron and manganese oxides concentrate several trace elements such as arsenic, selenium, and vanadium on mineral surfaces, as discussed above. In

soils and sedimentary aquifers, these elements are almost exclusively associated with iron and manganese oxide minerals and grain coatings, as long as the redox conditions are moderate to oxidizing.

The release of organic contaminants such as fuels or chlorinated solvents can establish local reducing environments caused by anaerobic microbial degradation of the organic compounds. The establishment of local reducing conditions can drive the dissolution of iron and manganese oxides, which become soluble as the redox potential drops below a threshold value. Dissolution of these oxide minerals can mobilize the trace elements that were adsorbed on the oxide surfaces, which is a process termed "reductive dissolution." Several investigations have documented the mobilization of arsenic, selenium, and other trace elements under locally reducing redox conditions (Sullivan and Aller, 1996; Nickson, *et al.*, 2000; Belzile, *et al.*, 2000).

Evidence for reductive dissolution would be a correlation between elevated trace elements (arsenic, selenium, and vanadium in particular) versus lower redox conditions. Low redox conditions can be identified by local depressions in oxidation-reduction potential (ORP) or dissolved oxygen (DO) measurements, or the presence of reducing gases such as hydrogen, methane, ethane, or ethene. Anaerobic microbes can also reduce sulfate to sulfide and nitrate to ammonia, resulting in local depressions in sulfate and nitrate concentrations, and local detections of sulfide and ammonia. In areas impacted by chlorinated solvents, additional evidence for the establishment of anaerobic reducing conditions is the presence of *cis*-1,2-dichloroethene and/or vinyl chloride, which are reductive dechlorination products resulting from the microbial degradation of trichloroethene (TCE) or tetrachloroethene under anaerobic conditions.

3.0 Results of the Geochemical Evaluation of Multiple Elements in Soil

This section presents the results of the geochemical evaluation of aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, magnesium, nickel, potassium, selenium, vanadium, and zinc in soil samples from Range K. Correlation plots are provided in Attachment 1.

Aluminum

Aluminum is the second most abundant element analyzed in the site soil samples, with a mean concentration of 10,532 milligrams per kilogram (mg/kg) (1 weight percent). Aluminum is a primary component of common soil-forming minerals such as clays, feldspars, and micas. Aluminum also substitutes for ferric iron in iron oxide minerals, and can adsorb on iron oxide surfaces (Cornell and Schwertmann, 2003). Iron is the most abundant element analyzed in the

site soil samples (mean concentration of 30,000 mg/kg; 3 weight percent). The site soil boring logs note that red-orange, yellow-orange, or brown clay is the predominant soil type in many of the sampled intervals. The iron in the site samples is mostly present as iron oxides, which are also common soil-forming minerals and which occur as discrete mineral grains or as coatings on silicate minerals (Cornell and Schwertmann, 2003). The color of the site soils is imparted by the iron oxides, which are highly pigmented. Clays and iron oxides tend to exist as very fine particles, so both aluminum and iron are enriched in samples with finer grain sizes.

A plot of aluminum versus iron concentrations provides a qualitative indicator of the relative abundance of clay and iron oxide minerals in site soil (Figure 1). Site surface soil samples are represented by open triangles, site subsurface soil samples by filled triangles, and background soil samples by filled circles. For both soil intervals, the site samples contain similar aluminum concentrations as the background samples and lie on the general background trend (Figure 1). The similarity in Al/Fe ratios between the site and background samples indicates a natural source for the aluminum in the site samples. It is important to note that clays and iron oxides adsorb specific trace elements (as discussed in Section 2.1), so the samples that plot on the upper end of the trend in Figure 1 are expected to contain proportionally higher concentrations of trace elements.

Conclusion
Aluminum detected in the site soil samples is naturally occurring.

Arsenic
As discussed in Section 2.1, arsenic in oxic soils has a strong affinity to adsorb on iron oxides. A positive correlation between arsenic and iron is expected for uncontaminated samples under those conditions. A plot of arsenic versus iron reveals a common linear trend with a positive slope for the site and background samples (Figure 2). The site samples with high arsenic concentrations also contain proportionally higher iron, and lie on the linear trend. These observations indicate that arsenic in the site samples is associated with iron oxides at a relatively constant ratio, and is natural.

Conclusion
Arsenic detected in the site soil samples is naturally occurring.

Barium
Manganese oxides have an affinity to adsorb divalent cations such as barium and cobalt (Kabata-Pendias, 2001). If a soil sample contains a high proportion of manganese oxides, then it is expected to contain high concentrations of manganese and associated trace elements. The site and background samples form a collinear trend in a plot of barium versus manganese (Figure 3). The two site samples with the highest barium concentrations (348 and 456 mg/kg) lie slightly above the linear trend, but their Ba/Mn ratios (0.96 and 0.80) are similar to the Ba/Mn ratios of several background samples (the maximum of which is 4.42). These samples likely reflect the natural variability in Ba/Mn ratios in Ft. McClellan soils. All of these observations indicate that barium in the site samples is associated with manganese oxides at ratios consistent with those of the background samples, and is natural.

Conclusion
Barium detected in the site soil samples is naturally occurring.

Beryllium

Beryllium concentrations in soil are commonly controlled through adsorption on iron oxides (Vesely, *et al.*, 2002), so a positive correlation between beryllium and iron concentrations is expected for uncontaminated samples. The background samples and most of the site samples form a generally linear trend with a positive slope in a plot of beryllium versus iron (Figure 4). Most of the site samples with high beryllium concentrations have proportionally higher iron content and lie on the linear trend. Beryllium in these samples is associated with iron oxides at a relatively constant ratio, and is natural. Surface soil sample RG0028 and subsurface soil sample RG0021, however, contain elevated beryllium (2.92 and 3.62 mg/kg, respectively) but only moderate iron (as well as only moderate aluminum and manganese), and lie above the linear background trend. These samples contain an excess amount of beryllium beyond that which can be explained by the reference element content, and may contain a component of contamination. Surface soil sample RG0028 was collected from sample location RNG-203-GP02, and subsurface soil sample RG0021 was collected from sample location RNG-203-MW12 at a depth of 10 to 12 feet bgs.

Conclusion
The beryllium concentrations in surface soil sample RG0028 and subsurface soil sample RG0021 are anomalously high relative to the reference elements, and may contain a component of contamination (Table 1). Beryllium detected in the other site soil samples is naturally occurring.

Cadmium

Manganese oxides have an affinity to adsorb divalent cations such as cadmium (Kabata-Pendias, 2001), so a positive correlation between cadmium and manganese concentrations is expected for uncontaminated samples. A plot of cadmium versus manganese is provided in Figure 5. The background samples and two of the site samples form a common, generally linear trend with a positive slope. The relatively constant Cd/Mn ratios of these samples indicates a natural source for their cadmium concentrations. However, surface soil sample RG0028 and subsurface soil samples RG0021, -23, and -25 contain elevated cadmium (1.88 mg/kg and higher) but only moderate manganese (as well as only moderate aluminum and iron), and lie above the linear background trend. These samples contain an excess amount of cadmium beyond that which can be explained by the reference element content, and may contain a component of contamination. Table 1 provides the location and depth intervals for the samples with anomalous element concentrations.

Conclusion
The cadmium concentrations in surface soil sample RG0028 and subsurface soil samples RG0021, -23, -25 are anomalously high relative to the reference elements, and may contain a component of contamination (Table 1). Cadmium detected in the other site soil samples is naturally occurring.

Table 1

Samples Containing Anomalous Element Concentrations
Range K, Parcel 203(7)
Fort McClellan, Calhoun County, Alabama

Medium	Sample Location	Sample No.	Depth Interval [a]	Anomalous Element(s)
Surface Soil	RNG-203-GP02	RG0028	0 - 1	Beryllium, Cadmium, Nickel, Zinc
Subsurface Soil	RNG-203-GP02	RG0029	8 - 10	Selenium
Subsurface Soil	RNG-203-MW12	RG0021	10 - 12	Beryllium, Cadmium, Nickel, Zinc
Subsurface Soil	RNG-203-MW14	RG0023	10 - 12	Cadmium
Subsurface Soil	RNG-203-MW15	RG0025	10 - 12	Cadmium

[a] Feet below ground surface.

Calcium

Calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. As a result, their concentrations typically covary in soil samples. A plot of magnesium versus calcium is provided in Figure 6. The background samples exhibit a generally linear trend with a positive slope, and the site samples lie on this trend. The site samples with the highest calcium concentrations also have high proportionally higher magnesium, and lie on the background trend. This indicates a natural source for calcium in the site samples.

Conclusion

Calcium detected in the site soil samples is naturally occurring.

Chromium

Chromium has an affinity to adsorb on iron oxides (Cornell and Schwertmann, 1996). If a soil sample contains a high proportion of iron oxides, then it is expected to contain high concentrations of manganese and associated trace elements such as chromium. A plot of chromium versus iron reveals a collinear trend for the site and background samples (Figure 7). The site samples with high chromium concentrations contain proportionally higher iron and lie on the background trend. This indicates that chromium in these samples is associated with iron oxides at a relatively constant ratio, and is natural.

Conclusion

Chromium detected in the site soil samples is naturally occurring.

Cobalt

Manganese oxides have an affinity to adsorb divalent cations such as barium and cobalt (Kabata-Pendias, 2001). If a soil sample contains a high proportion of manganese oxides, then it is expected to contain high concentrations of manganese and associated trace elements. A plot of cobalt versus manganese reveals a common linear trend with a positive slope for the site and background samples (Figure 8). Sample RG0028 contains the highest cobalt concentration of the site data set (39.6 mg/kg) but only moderately high manganese (Co/Mn ratio of 0.21), and lies slightly above the linear trend. However, there is also one background sample with a similarly high Co/Mn ratio (0.18). These samples likely reflect the natural variability in Co/Mn ratios in Ft. McClellan soils. Furthermore, the cobalt concentration of sample RG0028 is well below the background maximum of 96.2 mg/kg, so any contamination, if present, would not be significant. All of these observations indicate that cobalt in the site samples is associated with manganese oxides at ratios consistent with those of the background samples, and is natural.

Conclusion

Cobalt detected in the site soil samples is naturally occurring.

Copper

Copper in soil has an affinity to adsorb on the surfaces of minerals such as clays and iron oxides (Kabata-Pendias, 2001), so positive correlations for copper versus aluminum and copper versus iron are expected for uncontaminated samples. The site and background samples form a common linear trend with a positive slope in a plot of copper versus iron (Figure 9). Subsurface soil sample RG0008 contains the highest copper of the site samples (57.3 mg/kg), but it also

contains proportionally higher iron and lies on the trend established by the other samples. Subsurface soil sample RG0029 contains elevated copper (48.3 mg/kg) but only moderately high iron (Cu/Fe ratio of 0.0018), and lies slightly above the linear trend. However, there is also one background sample with an even higher Cu/Fe ratio (0.0034). These two samples likely reflect the natural variability in Cu/Fe ratios in Ft. McClellan soils. Furthermore, the copper concentration of sample RG0029 is below the background maximum of 60.9 mg/kg, so any contamination, if present, would not be significant. All of these observations indicate that copper in the site samples is associated with iron oxides at ratios consistent with those of the background samples, and is natural.

Conclusion
Copper detected in the site soil samples is naturally occurring.

Iron

Iron is the most abundant element analyzed in the site soil samples, with a mean concentration of 30,000 mg/kg (3 weight percent). The site soil boring logs note that red-orange, yellow-orange, or brown clay is the predominant soil type in many of the sampled intervals. The iron in the samples is dominantly present as iron oxides, which are highly pigmented and impart the color to the site soils. Iron oxides are common soil-forming minerals, and occur as discrete mineral grains or as coatings on silicate minerals (Cornell and Schwertmann, 2003). Aluminum is the second most abundant element analyzed in the site sediment samples (mean concentration of 10,532 mg/kg; 1 weight percent), and is a primary component of minerals such as clays, feldspars, and micas. Aluminum also substitutes for ferric iron in iron oxide minerals, and can adsorb on iron oxide surfaces (Cornell and Schwertmann, 2003). Clays and iron oxides tend to exist as very fine particles, so both aluminum and iron are enriched in samples with finer grain sizes.

As discussed in the Aluminum evaluation, a plot of aluminum versus iron concentrations can be used as a qualitative indicator of the relative abundance of clay and iron oxide minerals in site soil (Figure 1). The site and background samples form a common, generally linear trend with a positive slope. Site subsurface soil sample RG0008 has a higher iron concentration (69,300 mg/kg) than the background samples, but its Al/Fe ratio is similar to those of the background samples. These observations indicate that the iron and aluminum in the site samples have a natural source. It is important to note that clays and iron oxides adsorb specific trace elements (as discussed in Section 2.1), so samples that plot on the upper end of the trend in Figure 1 are expected to contain proportionally higher concentrations of trace elements.

Conclusion
Iron detected in the site soil samples is naturally occurring.

Magnesium

Magnesium and calcium have similar chemical properties, and magnesium often substitutes for calcium in minerals. As a result, their concentrations typically covary in soil samples. A plot of calcium versus magnesium is provided in Figure 6. The background samples exhibit a generally linear trend with a positive slope, and the site samples lie on this trend. The site samples with the highest magnesium concentrations also have proportionally higher calcium, and lie on the

trend established by the other samples. These observations indicate that magnesium in the site samples has a natural source.

Conclusion
Magnesium detected in the site soil samples is naturally occurring.

Nickel

Nickel is commonly associated with iron oxides in soils (Kabata-Pendias, 2001) so a positive correlation between nickel and iron concentrations is expected for uncontaminated samples. The background samples and most of the site samples form a generally linear trend with a positive slope in a plot of nickel versus iron (Figure 10). Most of the site samples with high nickel concentrations have proportionally higher iron content and lie on the linear trend. Nickel in these samples is associated with iron oxides at a relatively constant ratio, and is natural. Surface soil sample RG0028 and subsurface soil sample RG0021, however, contain elevated nickel (69 and 53.3 mg/kg, respectively) but only moderate iron (as well as only moderate aluminum and manganese), and lie above the linear background trend. These samples contain an excess amount of nickel beyond that which can be explained by the reference element content, and may contain a component of contamination. Surface soil sample RG0028 was collected from sample location RNG-203-GP02, and subsurface soil sample RG0021 was collected from sample location RNG-203-MW12 at a depth of 10 to 12 feet bgs.

Conclusion
The nickel concentrations in surface soil sample RG0028 and subsurface soil sample RG0021 are anomalously high relative to the reference elements, and may contain a component of contamination (Table 1). Nickel detected in the other site soil samples is naturally occurring.

Potassium

Potassium is a major element that is a common constituent of minerals such as clays, which also contain aluminum. The site and background samples form a common linear trend in a plot of potassium versus aluminum (Figure 11). The site samples exhibit K/Al ratios that are similar to those of the background samples, indicating a natural source for potassium in the site samples.

Conclusion
Potassium detected in the site soil samples is naturally occurring.

Selenium

As explained in Section 2.1, selenium has a strong affinity to adsorb on iron oxides in oxic soils, so a positive correlation between selenium and iron is expected for uncontaminated samples under those conditions. Comparison to background is hindered because of the high percentage of nondetects in the background data set. A plot of selenium versus iron is provided in Figure 12. Most of the site samples and the two background samples with detectable selenium form a generally linear trend with a shallow positive slope. Selenium in these samples is associated with iron oxides at a relatively constant ratio, and is natural. Subsurface soil sample RG0029 contains the highest selenium concentration of both data sets (8.14 J mg/kg) but only low iron (as well as only low manganese and moderate aluminum), and lies above the trend established by the

other samples. There may be a component of contamination in this sample, which was collected from location RNG-203-GP02 at a depth of 8 to 10 feet bgs (Table 1).

Conclusion
The selenium concentration in subsurface soil sample RG0029 is anomalously high and may contain a component of contamination (Table 1). Selenium detected in the other site soil samples is naturally occurring.

Vanadium

As discussed in Section 2.1, vanadium has a strong affinity to adsorb on iron oxides in oxic soils, so a positive correlation between vanadium and iron is expected for uncontaminated samples under those conditions. A plot of vanadium versus iron reveals a strong collinear trend for the site and background samples (Figure 13). Some site samples exhibit higher vanadium concentrations than many of the background samples, but they also contain proportionally higher iron and lie on the background trend. These observations indicate that vanadium in the site samples is associated with iron oxides at a relatively constant ratio, and is natural.

Conclusion
Vanadium detected in the site soil samples is naturally occurring.

Zinc

Zinc in soils is commonly associated with clay minerals and hydrous iron and aluminum oxides (Kabata-Pendias, 2001), so positive correlations for zinc versus aluminum and zinc versus iron are expected for uncontaminated samples. The background samples and most of the site samples form a linear trend with a positive slope in a plot of zinc versus iron (Figure 14). Subsurface soil sample RG0008 contains the second-highest zinc of the site samples (234 J mg/kg), but it also contains proportionally higher iron and lies on the linear trend. Zinc in these samples is associated with iron oxides at a relatively constant ratio, and is natural. Surface soil sample RG0028 and subsurface soil sample RG0021, however, contain elevated zinc (275 J and 233 J mg/kg, respectively) but only moderate iron (as well as only moderate aluminum and manganese), and lie above the linear background trend. These samples contain an excess amount of zinc beyond that which can be explained by the reference element content, and may contain a component of contamination. Surface soil sample RG0028 was collected from sample location RNG-203-GP02, and subsurface soil sample RG0021 was collected from sample location RNG-203-MW12 at a depth of 10 to 12 feet bgs.

Conclusion
The zinc concentrations in surface soil sample RG0028 and subsurface soil sample RG0021 are anomalously high relative to the reference elements, and may contain a component of contamination (Table 1). Zinc detected in the other site soil samples is naturally occurring.

4.0 Results of the Geochemical Evaluation of Multiple Elements in Groundwater

This section presents the results of the geochemical evaluation of aluminum, barium, cadmium, calcium, chromium, cobalt, manganese, nickel, sodium, and vanadium in the unfiltered groundwater samples from Range K. Correlation plots are provided in Attachment 1.

Field-measured pH readings for the 18 site groundwater samples range from 4.93 to 7.51 standard units, with a median of 7.21 and mean of 6.89. These values indicate near-neutral to neutral conditions at most of the sample locations, with slightly acidic conditions at two locations (pH of 4.93 for the September 2001 sample from well RNG-203-MW01 and pH of 4.99 for the June 2000 sample from well RNG-203-MW02). Field-measured DO readings range from 0 to 10.94 mg/L, with a median of 0.45 mg/L and mean of 1.60 mg/L, and ORP readings range from -146 to +185 millivolts (mV), with a median of -19 mV and mean of -9.4 mV. These values suggest moderate to reducing redox conditions at most of the sample locations, although conditions are oxidizing at some locations. Turbidity measurements range from 1.4 to 387 nephelometric turbidity units (NTU), with a median of 9.1 NTU and mean of 47 NTU. Although most of the samples did not contain a significant mass of suspended particulates (turbidity was 32 NTU or lower for 15 of the 18 samples), three site samples did contain a relatively high mass of suspended particulates (turbidity of 80 NTU and higher). It should be noted that field readings are not available for the background samples.

Aluminum

Aluminum was detected in 13 of the 18 unfiltered groundwater samples (7 of these concentrations have "B" validation qualifiers, but they are treated as estimated detected concentrations for the purposes of this geochemical evaluation). As discussed previously, aluminum concentrations in excess of approximately 1 mg/L in neutral pH groundwater indicate the presence of suspended clays. Aluminum will be present in solution at a pH below about 4.0, but all of the Range K pH readings are higher than this and are generally in the neutral range (see the discussion of field readings, above).

Iron concentrations in excess of approximately 1 mg/L in neutral-pH, moderate to oxidizing groundwater conditions indicate the presence of suspended iron oxides. A plot of aluminum versus iron can be used as a qualitative indicator of the amount of suspended particulates in the groundwater samples (Figure 15). The majority of site and background samples form a linear trend with a positive slope, indicating that both elements are present in particulate form in these samples. The site samples with the highest aluminum concentrations also exhibit proportionally higher iron, and lie on the linear trend formed by the other samples. Elevated aluminum in these samples is due to the presence of suspended particulates such as clays, and is natural.

This conclusion is corroborated by the field-measured turbidity readings and by comparisons of filtered and unfiltered splits. Turbidity measurements for a few samples are relatively high, with the site values ranging from 1.4 to 387 NTU (with a median of 9.1 NTU and mean of 47 NTU). The unfiltered samples with the highest aluminum concentrations also exhibit proportionally higher turbidity (Figure 16). Most of the 14 filtered splits are nondetect for aluminum (at a reporting limit of 0.2 mg/L); the three samples with detectable aluminum in their filtered splits (RG3007, -14, and -22) exhibit filtered/unfiltered ratios ranging from 0.07 to 0.59. The positive correlation between unfiltered aluminum concentrations versus turbidity and the decrease in aluminum concentrations upon filtration support the contention that aluminum in the site samples is associated with filterable, suspended clays, and is natural.

There is one site sample in Figure 15 that contains low aluminum (an estimated 0.0892 mg/L) but elevated iron (2.56 mg/L), and which lies below and to the right of the linear particulate trend. There are also three background samples with similarly low Al/Fe ratios. The low Al/Fe ratios indicate that some portion of the iron in these samples is in solution; however, the aluminum in these samples is well within the background range.

It is worth noting that suspended clays and iron oxides adsorb specific trace elements (as discussed in Section 2.2), so samples that plot on the upper end of the trend in Figure 15 – including site sample RG3006, which contains the highest aluminum of both site and background data sets (13.4 mg/L) – are expected to contain proportionally higher concentrations of associated trace elements.

Conclusion

Aluminum detected in the site groundwater samples is naturally occurring.

Barium

As discussed in Section 2.2, barium is usually present in groundwater as a divalent cation and tends to concentrate on clay surfaces, which maintain a negative surface charge. A plot of barium versus aluminum reveals a weak linear trend for the background samples (Figure 17). The site samples all lie on the background trend but they exhibit poor correlation ($R^2 = 0.002$). Five samples are not depicted in Figure 17 because they lack detectable aluminum (RG3009, -11, -12, -19, and -21). The poor correlation between barium versus aluminum concentrations and the absence of detectable aluminum in multiple samples indicate that suspended particulates are not a primary mechanism controlling barium concentrations in these samples. A plot of unfiltered barium concentrations versus filtered/unfiltered ratios is provided in Figure 18. The site samples form a vertical trend centered around a filtered/unfiltered ratio of 1, indicating that the barium in these samples is in solution and is not associated with filterable particulates.

Barium concentrations are often controlled by equilibrium with the mineral barite ($BaSO_4$), which is sensitive to redox conditions. Under oxidizing conditions, sulfate is the stable form of sulfur, so barium concentrations are limited by the solubility of barite. Under reducing conditions, sulfate can be reduced to sulfide, allowing barium concentrations to increase. Field readings for the site samples indicate a range of redox conditions at the site, from mildly reducing to oxidizing. A plot of unfiltered barium concentrations versus ORP is provided in Figure 19. A linear trend with a negative slope is apparent, and the samples with the highest

barium concentrations also have the lowest ORP (lowest redox potential). Reducing conditions may be natural, or they can be caused by the anaerobic microbial degradation of chlorinated solvents or fuels (see Section 2.2). Six site samples contain detectable VOCs – including TCE, *cis*-1,2-dichloroethene, and vinyl chloride in some samples – but no correlation between barium and VOC concentrations is observed. This suggests that the elevated barium is not due to reductive dissolution caused by VOC contamination, and that the low redox is natural.

Conclusion
Barium detected in the site groundwater samples is naturally occurring.

Cadmium

Cadmium was detected in 2 of the 18 unfiltered groundwater samples. As noted in Section 2.2, divalent cations such as cadmium have an affinity to adsorb on clay minerals, which maintain a negative surface charge. A plot of cadmium versus aluminum is provided in Figure 20. Site sample RG3006 contains the highest cadmium concentration of both site and background data sets (0.0114 mg/L), but it also contains the highest aluminum concentration (13.4 mg/L). This indicates that the elevated cadmium is due to the presence of suspended clays, and that it is natural.

Conclusion
Cadmium detected in the site groundwater samples is naturally occurring.

Calcium

Calcium was detected in all 18 unfiltered groundwater samples. Calcium and magnesium are major dissolved constituents in groundwater, and are derived from the weathering of carbonate and silicate minerals. A plot of calcium versus magnesium reveals a generally linear trend with a positive slope for the background samples (Figure 21). The three site samples with the lowest calcium concentrations (5.27 to 9.36 mg/L) exhibit Ca/Mg ratios similar to those of the background samples, and they lie on the background trend. The 15 site samples with high calcium concentrations (67.1 to 173 mg/L) lie slightly above the background trend, although all of these samples are well below the background maximum of 452 mg/L. Calcium concentrations in groundwater are commonly controlled by the solubility of calcite ($CaCO_3$), and are subject to solubility constraints (calcite precipitation) at high concentrations. Under such solubility-controlled conditions the Ca/Mg ratios are not expected to be constant.

The three site samples with the lowest calcium concentrations also have the lowest pH values (4.93 to 5.57). The site samples with elevated calcium, in contrast, have higher pH values, in the neutral range (6.88 to 7.51). The dissolution of calcite adds Ca^{2+} and CO_3^{2-} to the water. This particular form of dissolved carbon is only stable at pH above 10.3, so the CO_3^{2-} (carbonate) will react with free protons (H^+) to respeciate as HCO_3^- (bicarbonate) which is the stable form of dissolved carbon over a pH range of 6.4 to 10.3. Removing free protons from solution will raise the pH, yielding higher calcium concentrations at higher pH conditions. When the water becomes saturated with calcite, the dissolution process stops, and the calcium concentration are buffered at a constant value. This appears as a horizontal line of points in Figure 21.

Conclusion
Calcium detected in the site groundwater samples is naturally occurring.

Chromium

Chromium was detected in 2 of the 18 unfiltered groundwater samples. Comparison to background is precluded by the lack of detectable chromium in the background samples. As noted in Section 2.2, chromium can be present in groundwater as a mixture of aqueous species with different charges, and thus it can adsorb on different surfaces, including clay and iron oxide minerals. A plot of chromium versus aluminum is provided in Figure 22. Site sample RG3006 contains the higher chromium concentration of the two site samples (0.0409 mg/L), but it also contains the highest aluminum concentration of both site and background data sets (13.4 mg/L). This indicates an association between chromium and suspended clay particulates, which is expected due to the high affinity for Cr(III) adsorption on clays (if the chromium were present as Cr[IV], then it would be present in solution and would not exhibit a positive correlation with aluminum). These observations indicate that chromium in the site samples is associated with suspended particulates such as clays at a relatively constant ratio, and is natural.

Conclusion
Chromium detected in the site groundwater samples is naturally occurring.

Cobalt

Cobalt was detected in 5 of the 18 unfiltered groundwater samples. Under oxidizing groundwater conditions, cobalt concentrations are commonly controlled by adsorption on iron oxides and manganese oxides (Hem, 1985). Under reducing conditions, however, the iron oxides and manganese oxides will enter into solution. As a result, the dissolved concentrations of iron and manganese will increase, along with the concentrations of trace elements (such as cobalt) that were sorbed on the mineral surfaces. Field readings for the samples with detectable cobalt indicate a range of redox conditions, from mildly reducing to oxidizing (site sample RG3001 contains the highest cobalt concentration, and has DO and ORP readings of 1.02 mg/L and +80 mV, indicating moderate redox conditions). Aluminum was detected in all five samples, which suggests the presence of suspended particulates such as clays. Given these observations, some portion of the iron in these samples is expected to be present in particulate form (depending on the sample), and the cobalt concentrations are expected to be at least partly controlled by adsorption on suspended particulates such as iron oxides.

A plot of cobalt versus iron is provided in Figure 23. A linear trend is not observed for the samples, which may be explained by the uncertainty associated with estimated concentrations (four of the five site detections are "J"-qualified values below the reporting limits of 0.02 and 0.05 mg/L). Sample RG3001 contains the highest cobalt concentration of the site and background samples (0.056 mg/L), but it also contains the highest iron (27.7 mg/L). This suggests that the elevated cobalt is due to the presence of suspended particulates (such as iron oxides), and that the cobalt is natural.

Conclusion
Cobalt detected in the site groundwater samples is naturally occurring.

Manganese

Manganese was detected in all 18 unfiltered groundwater samples. Manganese usually displays complex behavior in natural systems because of three possible valence states (+2, +3, and +4), which each have different solubilities and sorptive properties (Hem, 1985). Manganese is similar to iron in that it is soluble under reducing conditions but has very low solubilities under oxidizing conditions. One difference between manganese and iron is that the critical redox potential for dissolution of manganese oxides is higher than the redox potential for dissolution of iron oxides. This means that dissolved manganese concentrations are a more sensitive indicator of local redox depressions than dissolved iron concentrations. Field readings for the site samples indicate a range of redox conditions at the site, from mildly reducing to oxidizing. Under these conditions, some portion of the manganese concentrations will be in solution and some portion will be present as suspended particulates. The reducing conditions may be natural, or they can be caused by the anaerobic microbial degradation of chlorinated solvents or fuels (see Section 2.2). Six site samples contain detectable VOCs – including TCE, *cis*-1,2-dichloroethene, and vinyl chloride in some samples – but no correlation between elevated manganese and VOC concentrations (or elevated iron and VOC concentrations) is observed. This suggests that manganese concentrations in the site samples are not being controlled by reductive dissolution caused by the VOC contamination.

A plot of manganese versus iron is provided in Figure 24. A generally linear trend with a positive slope is observed for the background samples, and all of the site samples lie on this trend. None of the site samples contains excess manganese relative to background. This indicates a natural source for the manganese in the site samples.

Manganese was detected in all 14 filtered splits in the site data set. A plot of unfiltered manganese concentrations versus filtered/unfiltered ratios is provided in Figure 25. Most of the samples cluster on a vertical line centered around a filtered/unfiltered ratio of 1. Manganese in these samples is primarily in solution, which is due to the relatively low redox in the groundwater at those sample locations. As noted above, the reducing conditions are most likely natural. A few samples exhibit filtered/unfiltered ratios below 1 (0.60 to 0.82), suggesting that some portion of the manganese in these samples is present as partially filterable particulates.

<u>Conclusion</u>

Manganese detected in the site groundwater samples is naturally occurring.

Nickel

Nickel was detected in 5 of the 18 unfiltered groundwater samples. Comparison to background is precluded by the lack of detectable nickel in the background samples. Nickel is commonly present as the divalent cation Ni^{2+} when redox conditions are moderate to oxidizing and pH values are below about 9 standard units (Brookins, 1988). This species has an affinity to adsorb on the surfaces of iron oxides such as hydrous ferric oxide (Deutsch, 1997), and a positive correlation between nickel and iron concentrations is commonly observed under these conditions. Field readings for the samples with detectable nickel indicate a range of redox conditions (from mildly reducing to oxidizing) and pH values of 4.93 to 7.32. Aluminum was detected in all five samples, which suggests the presence of suspended particulates such as clays. Given these observations, some portion of the iron in these samples is expected to be present in

particulate form (depending on the sample), and the nickel concentrations are expected to be at least partly controlled by adsorption on suspended particulates such as iron oxides.

A plot of nickel versus iron is provided in Figure 26. The samples exhibit a linear trend with a positive slope. The sample with the highest nickel concentration also contains the highest iron concentration of the site and background data sets and lies on the linear trend. This suggests that nickel in the site samples is associated with suspended particulates (such as iron oxides) at a relatively constant ratio, and is natural.

Conclusion
Nickel detected in the site groundwater samples is naturally occurring.

Sodium

Sodium was detected in all 18 unfiltered groundwater samples. Sodium and magnesium are major dissolved constituents in groundwater, and their concentrations typically covary in groundwater samples. A plot of sodium versus magnesium is provided in Figure 27. The site samples have sodium and magnesium concentrations within the background range, and lie on the general background trend in the plot. This indicates a natural source for sodium in the site samples.

Conclusion
Sodium detected in the site groundwater samples is naturally occurring.

Vanadium

Vanadium was detected in 2 of the 18 unfiltered groundwater samples. As discussed in Section 2.2, vanadium is usually present under oxidizing conditions as an oxyanion and tends to concentrate on iron oxide surfaces, which maintain a positive surface charge. A positive correlation between vanadium and iron concentrations is expected for uncontaminated samples under those conditions. Field readings for the two samples with detectable vanadium (RG3001 and RG3006) indicate moderate to mildly reducing redox conditions (DO and ORP of 1.02 mg/L and +80 mV for sample RG3001; 0.29 mg/L and +35 mV for sample RG3006), and no correlation is observed between vanadium and iron in the site and background samples. However, a plot of vanadium versus aluminum reveals a linear trend with a positive slope (Figure 28). The site sample with the higher vanadium concentration (RG3006; 0.0455 J mg/L V) contains the highest aluminum of both data sets (13.4 mg/L), and lies on the linear trend. These observations indicate that vanadium in the samples is associated with suspended particulates (such as clays) at a relatively constant ratio, and is natural.

Conclusion
Vanadium detected in the site groundwater samples is naturally occurring.

5.0 Summary

This section summarizes the results of the geochemical evaluations of selected elements in soil and groundwater samples from Range K.

Soil. Geochemical evaluation indicates that all detected concentrations of aluminum, arsenic, barium, calcium, chromium, cobalt, copper, iron, magnesium, potassium, and vanadium in the site surface and subsurface soil samples are naturally occurring. Anomalously high concentrations of beryllium, cadmium, nickel, and zinc are present in at least one surface soil sample each. Selenium concentrations detected in the surface soil samples are naturally occurring. Anomalously high concentrations of beryllium, cadmium, nickel, selenium, and zinc are present in at least one subsurface soil sample each. Table 1 lists the soil samples that contain anomalously high element concentrations.

Groundwater. Geochemical evaluation indicates that all detected concentrations of aluminum, barium, cadmium, calcium, chromium, cobalt, manganese, nickel, sodium, and vanadium in the unfiltered groundwater samples are naturally occurring.

6.0 References

Barclift, D., J. Heath, and A. Drucker, 2000, "Focus on Environmental Background Data Analysis," ***Soil Sediment & Groundwater***, August/September, pp. 10-17.

Belzile, N., Y. W. Chen, and R. Xu, 2000, "Early diagenetic behavior of selenium in freshwater sediments," ***Applied Geochemistry***, Vol. 15, pp. 1439-1454.

Bowell, R. J., 1994, "Sorption of arsenic by iron oxides and oxyhydroxides in Soils," ***Applied Geochemistry***, Vol. 9, pp. 279-286.

Brookins, D. G., 1988, ***Eh-pH Diagrams for Geochemistry***, Springer-Verlag.

Cornell, R. M. and U. Schwertmann, 2003, ***The Iron Oxides: Structure, Properties, Reactions, Occurrences and Uses***, Second Edition, Wiley-VCH, Weinheim.

Daskalakis, K. D. and T. P. O'Connor, 1995, "Normalization and Elemental Sediment Contamination in the Coastal United States," ***Environmental Science & Technology***, Vol. 29, No. 2, pp. 470-477.

Deutsch, W. J., 1997, ***Groundwater Geochemistry: Fundamentals and Applications to Contamination***, Lewis Publishers, Boca Raton.

Drever, J. I., 1997, ***The Geochemistry of Natural Waters***, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Electric Power Research Institute (EPRI), 1984, ***Chemical Attenuation Rates, Coefficients, and Constants in Leachate Migration, Volume 1: A Critical Review***, EPRI EA-3356, Palo Alto, California.

Electric Power Research Institute (EPRI), 1986, ***Speciation of Selenium and Arsenic in Natural Waters and Sediments, Volume 2: Arsenic Speciation***, EPRI EA-4641, Palo Alto, California.

Hem, J. D., 1985, ***Study and Interpretation of the Chemical Characteristics of Natural Water***, U. S. Geological Survey, Water Supply Paper 2254, 3rd Edition.

IT Corporation, 2002, ***Draft Installation-Wide Work Plan, Fort McClellan, Calhoun County, Alabama, Revision 2***, Prepared for the U.S. Army Corps of Engineers, Mobile District, February.

Kabata-Pendias, A., 2001, ***Trace Elements in Soils and Plants,*** Third Edition, CRC Press.

Myers, J. and K. Thorbjornsen, 2004, "Identifying Metals Contamination in Soil: A Geochemical Approach," ***Soil & Sediment Contamination: an International Journal***, Vol. 13, No. 1, pp. 1-16.

Nickson, R. T., J. M. McArthur, P. Ravenscroft, W. G. Burgess, and K. M. Ahmed, 2000, "Mechanism of arsenic release to groundwater, Bangladesh and West Bengal," ***Applied Geochemistry***, Vol. 15, pp. 403-413.

Post, J. E., 1999, "Manganese oxide minerals: Crystal structures and economic and environmental significance," ***Proceedings of the National Academy of Sciences***, Vol. 96, pp. 3447-3454.

Pourbaix, 1974, ***Atlas of Electrochemical Equilibria in Solutions***, National Association of Corrosion Engineers, Houston, Texas.

Science Applications International Corporation, 1998, ***Final Background Metals Survey Report, Fort McClellan, Anniston, Alabama***, July.

Schiff, K. and S. B. Weisberg, 1997, "Iron as a Reference Element for Determining Trace Metal Enrichment in California Coastal Shelf Sediments," *in*: S. Weisberg, C. Francisco, and D. Hallock, (eds.), ***Southern California Coastal Water Research Project Annual Report 1995-96***, pp. 68-78.

Stumm, W. and J. Morgan, 1996, ***Aquatic Chemistry***, Third Edition, Wiley-Interscience, New York.

Sullivan, K. A. and R. C. Aller, 1996, "Diagenetic cycling of arsenic in Amazon shelf sediments," ***Geochimica et Cosmochimica Acta***, Vol. 60, No. 9, pp. 1465-1477.

U.S. Environmental Protection Agency, 1995, ***Determination of Background Concentrations of Inorganics in Soils and Sediments at Hazardous Waste Sites***, Office of Research and Development, EPA/540/S-96/500, December.

U.S. Navy, 2002, ***Guidance for Environmental Background Analysis, Volume 1: Soil***, NFESC User's Guide UG-2049-ENV, Naval Facilities Engineering Command, Washington, D.C., April.

Vesely, J., S. A. Norton, P. Skrivan, V. Majer, P. Kram, T. Navratil, and J. M. Kaste, 2002, "Environmental Chemistry of Beryllium," *in:* Grew, E. S. (ed.), ***Reviews in Mineralogy and Geochemistry, Volume 50, Beryllium: Mineralogy, Petrology, and Geochemistry***, Mineralogical Society of America, Washington, D.C.

ATTACHMENT 1

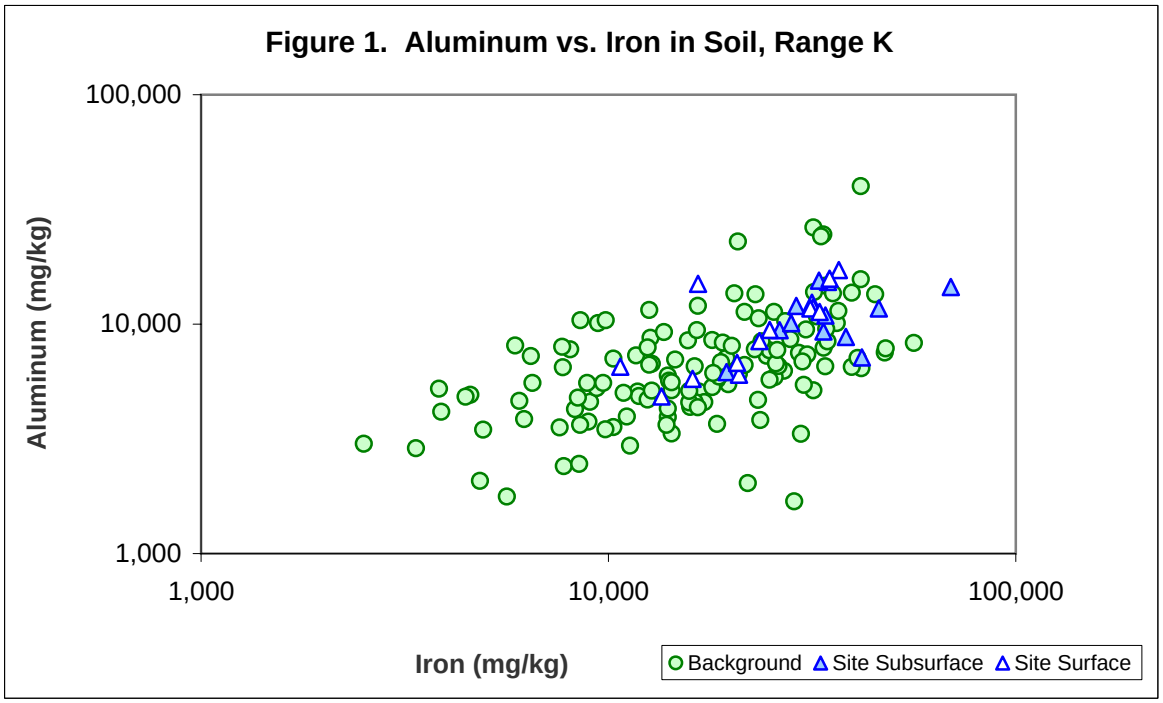


Figure 1. Aluminum vs. Iron in Soil, Range K
100,000
10,000
1,000
Aluminum (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Subsurface
Site Surface

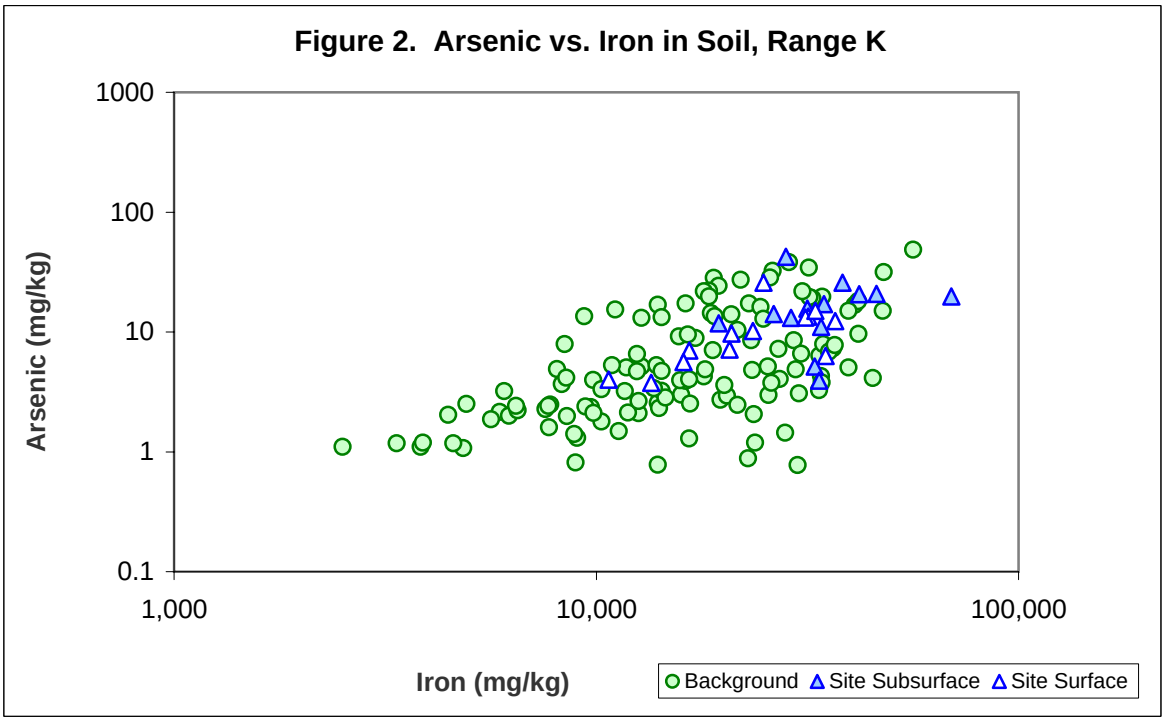


Figure 2. Arsenic vs. Iron in Soil, Range K
1000
100
10
1
0.1
Arsenic (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Subsurface
Site Surface

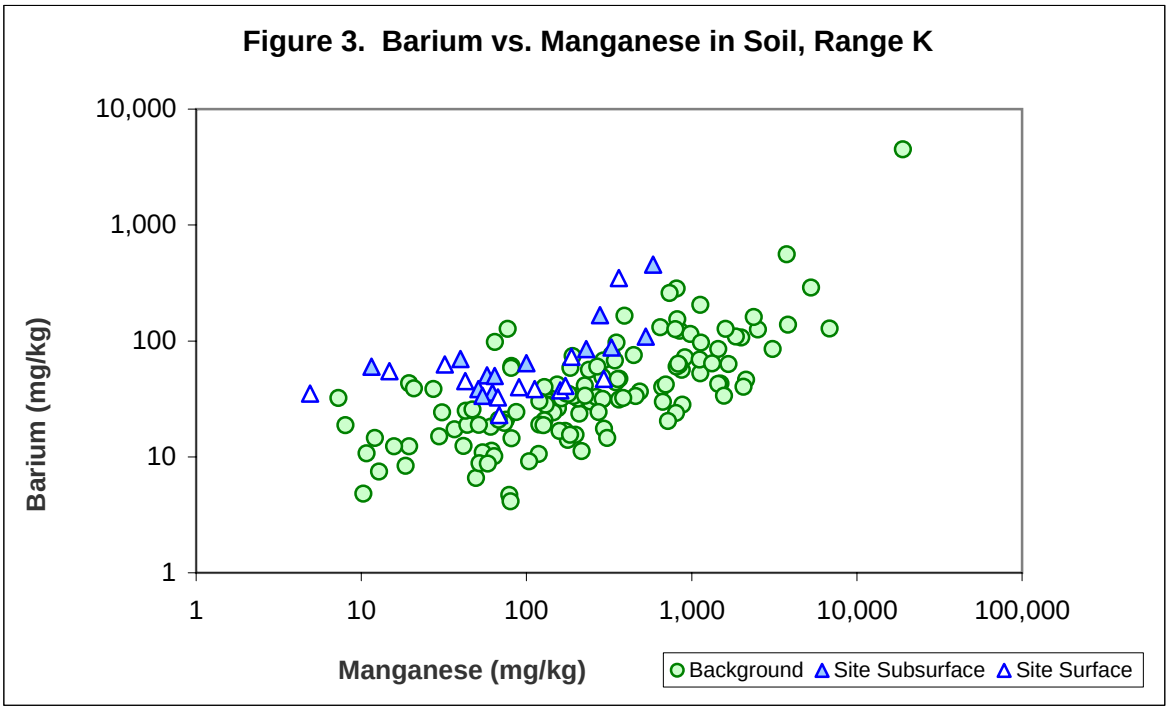


Figure 3. Barium vs. Manganese in Soil, Range K
10,000
1,000
100
10
1
Barium (mg/kg)
1
10
100
1,000
10,000
100,000
Manganese (mg/kg)
Background
Site Subsurface
Site Surface

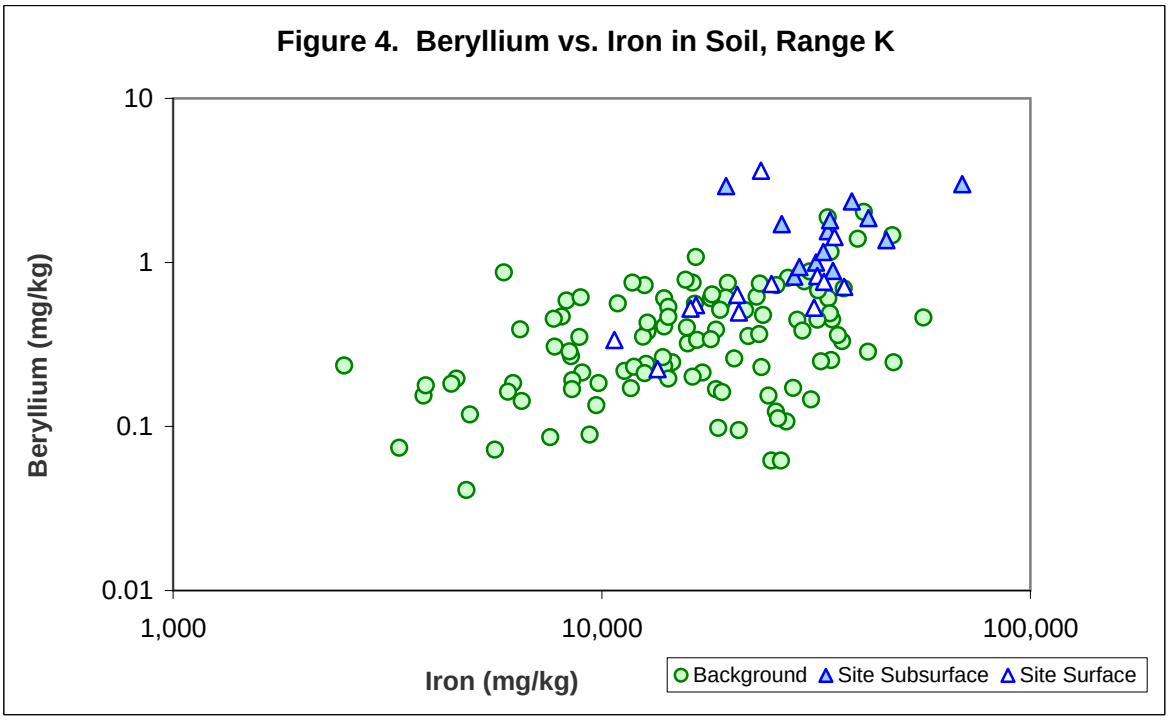


Figure 4. Beryllium vs. Iron in Soil, Range K
10
1
0.1
0.01
Beryllium (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Subsurface
Site Surface

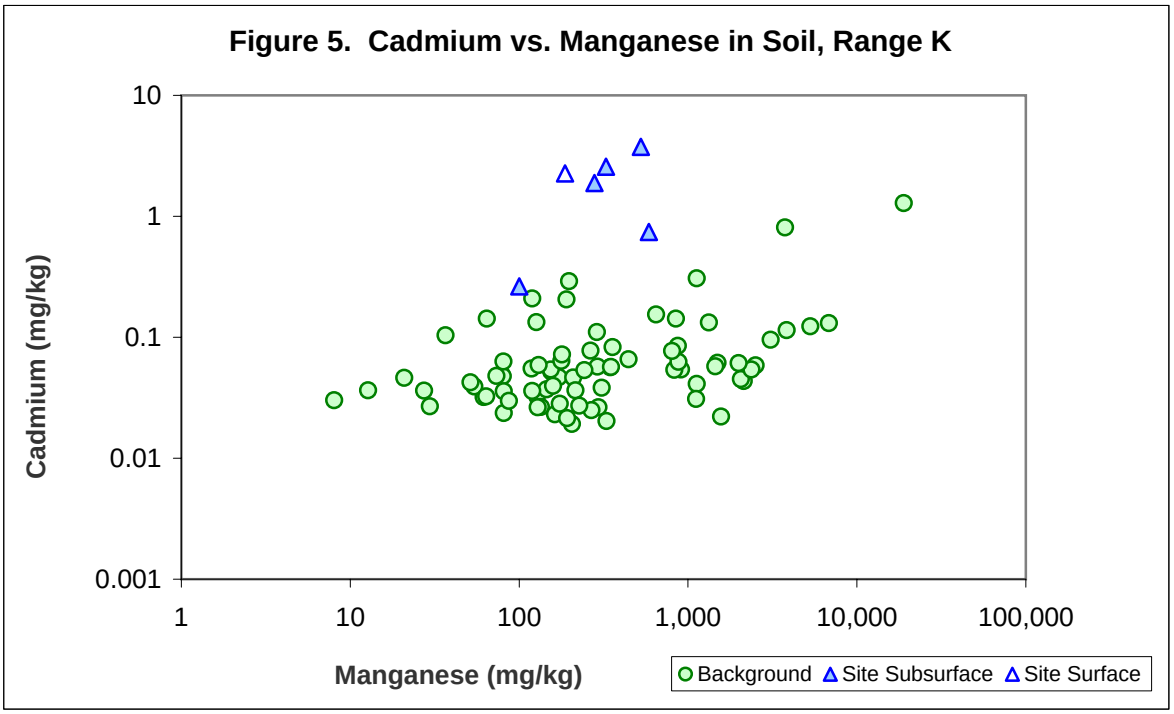


Figure 5. Cadmium vs. Manganese in Soil, Range K
Cadmium (mg/kg)
10
1
0.1
0.01
0.001
1
10
100
1,000
10,000
100,000
Manganese (mg/kg)
Background
Site Subsurface
Site Surface

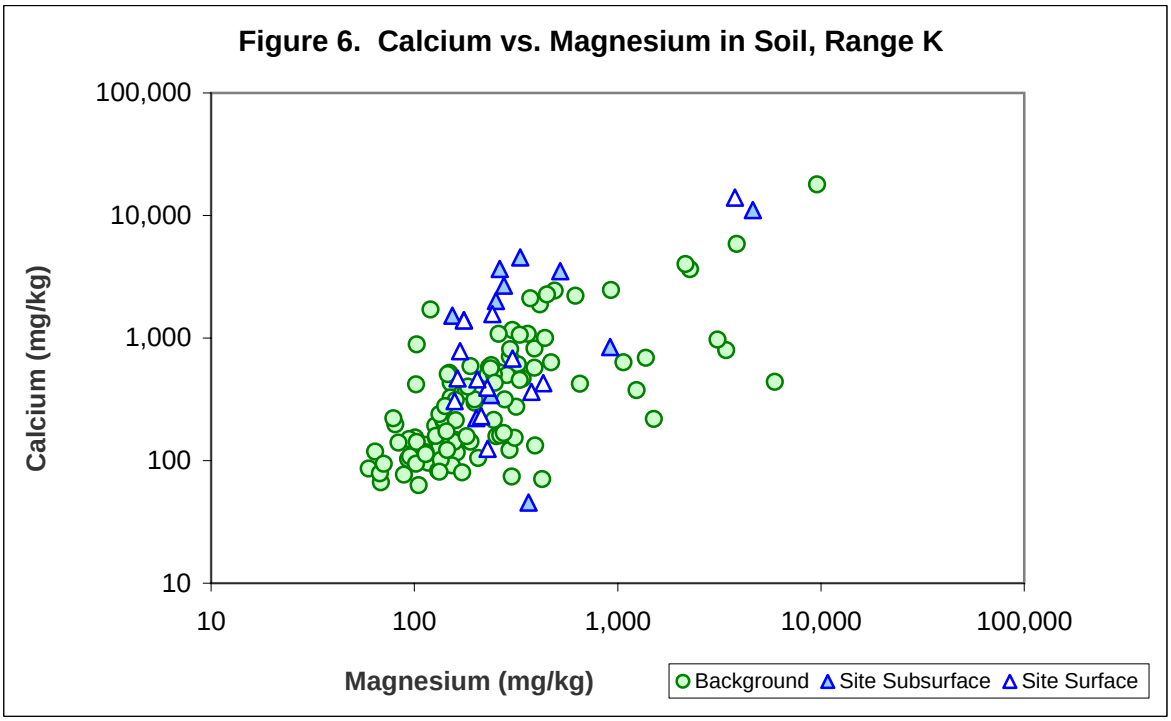


Figure 6. Calcium vs. Magnesium in Soil, Range K
Calcium (mg/kg)
100,000
10,000
1,000
100
10
10
100
1,000
10,000
100,000
Magnesium (mg/kg)
Background
Site Subsurface
Site Surface

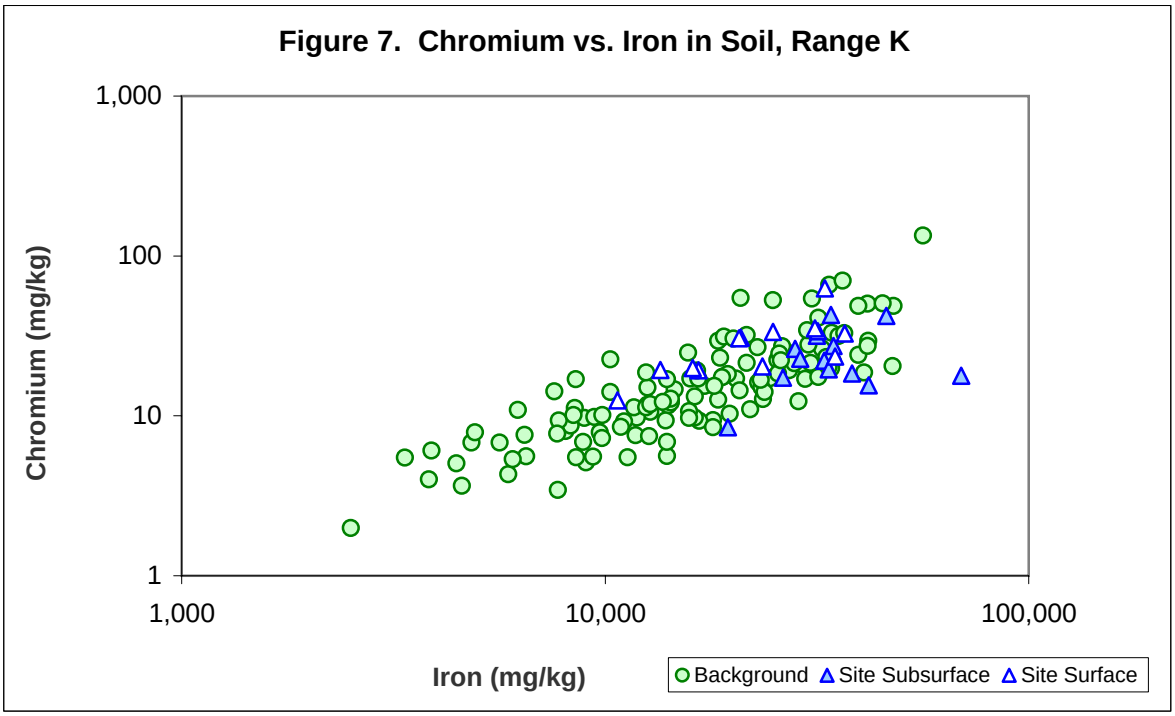


Figure 7. Chromium vs. Iron in Soil, Range K
1,000
100
10
1
Chromium (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Subsurface
Site Surface

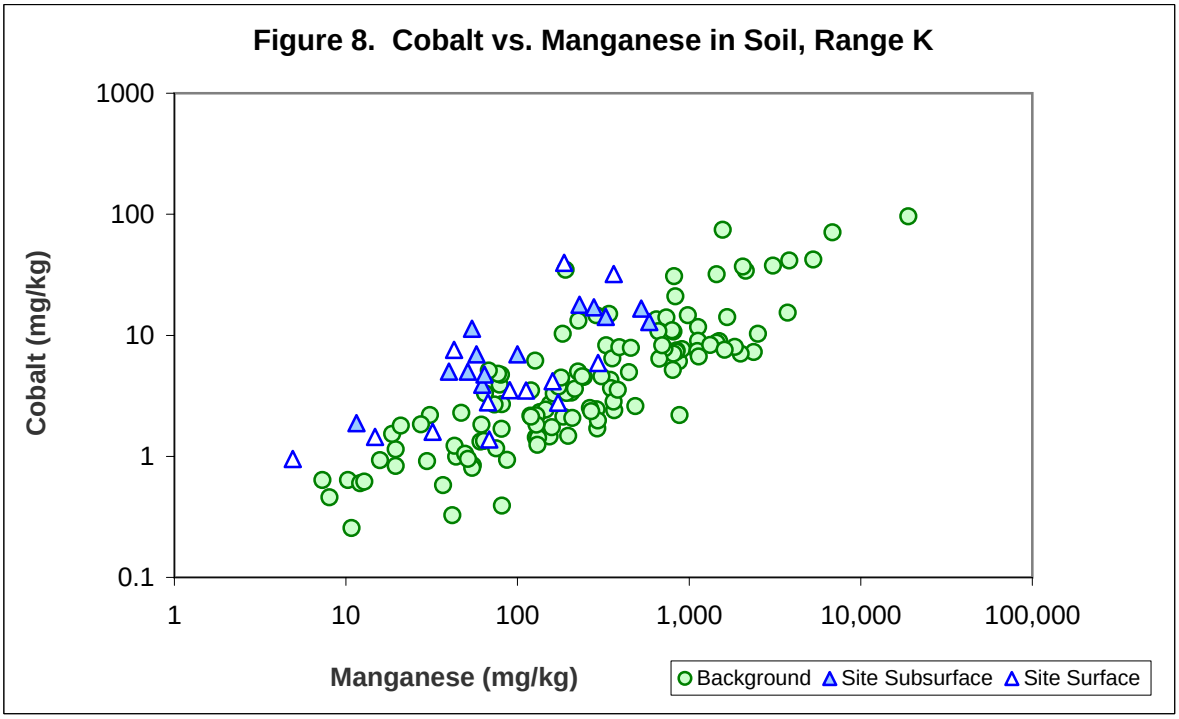


Figure 8. Cobalt vs. Manganese in Soil, Range K
1000
100
10
1
0.1
Cobalt (mg/kg)
1
10
100
1,000
10,000
100,000
Manganese (mg/kg)
Background
Site Subsurface
Site Surface

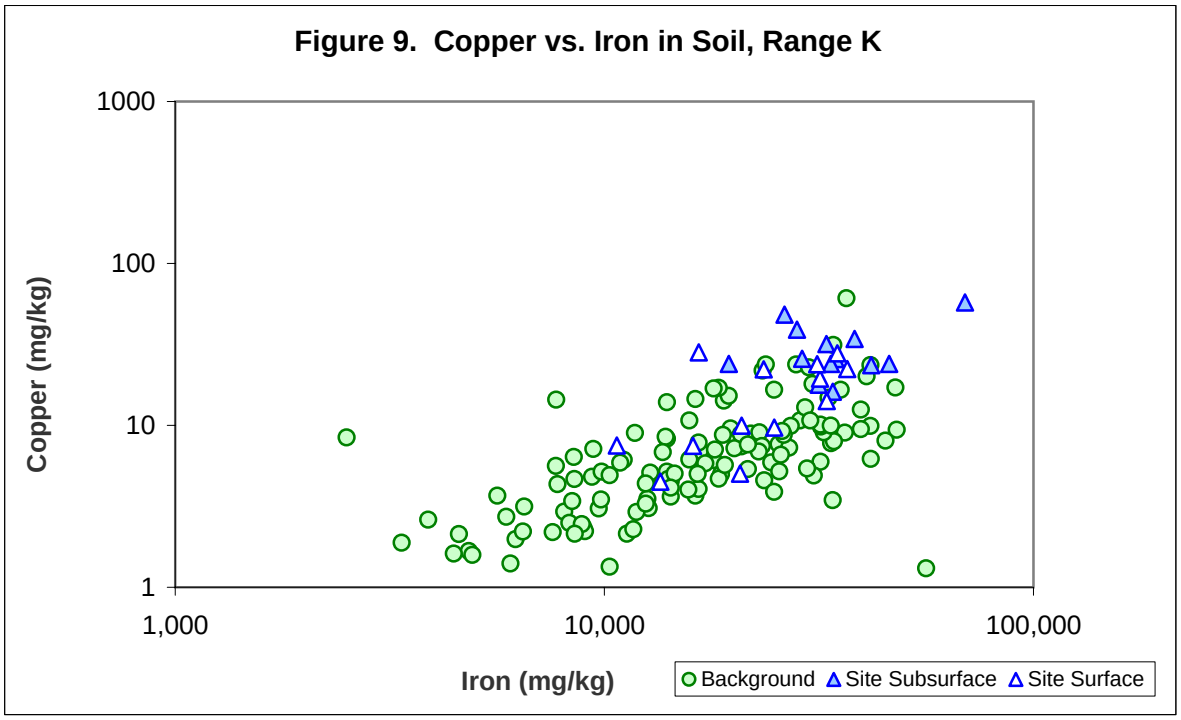


Figure 9. Copper vs. Iron in Soil, Range K
1000
100
10
1
Copper (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Subsurface
Site Surface

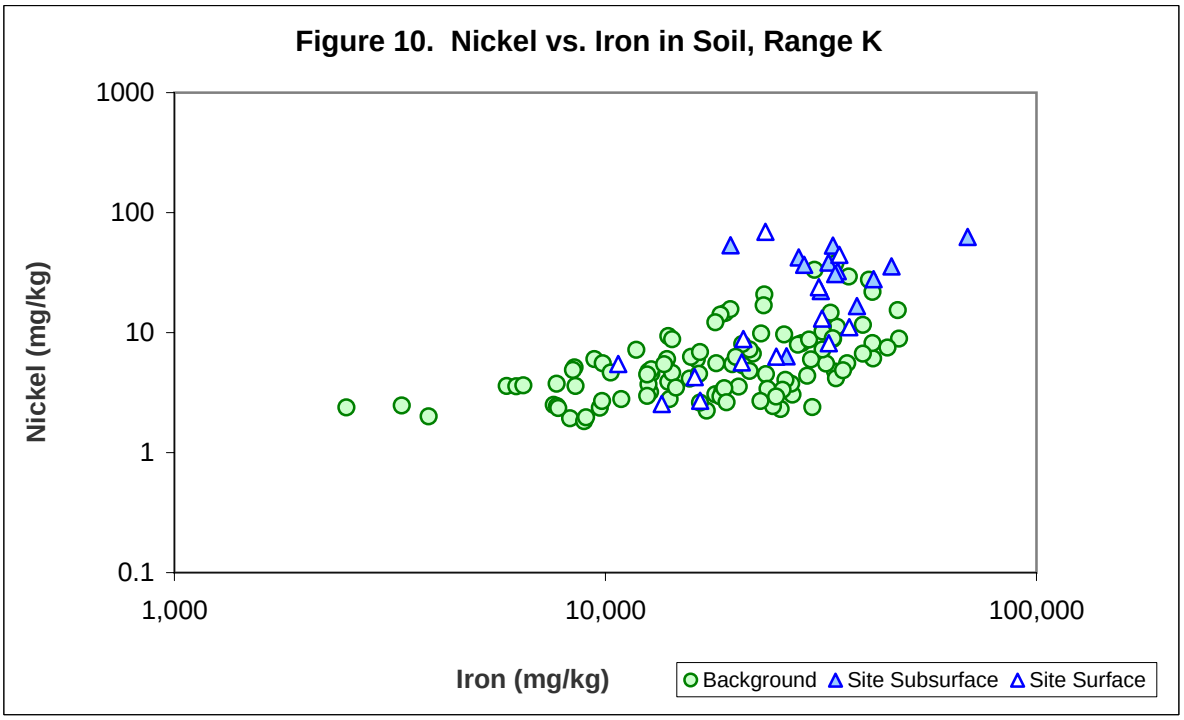


Figure 10. Nickel vs. Iron in Soil, Range K
1000
100
10
1
0.1
Nickel (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Subsurface
Site Surface

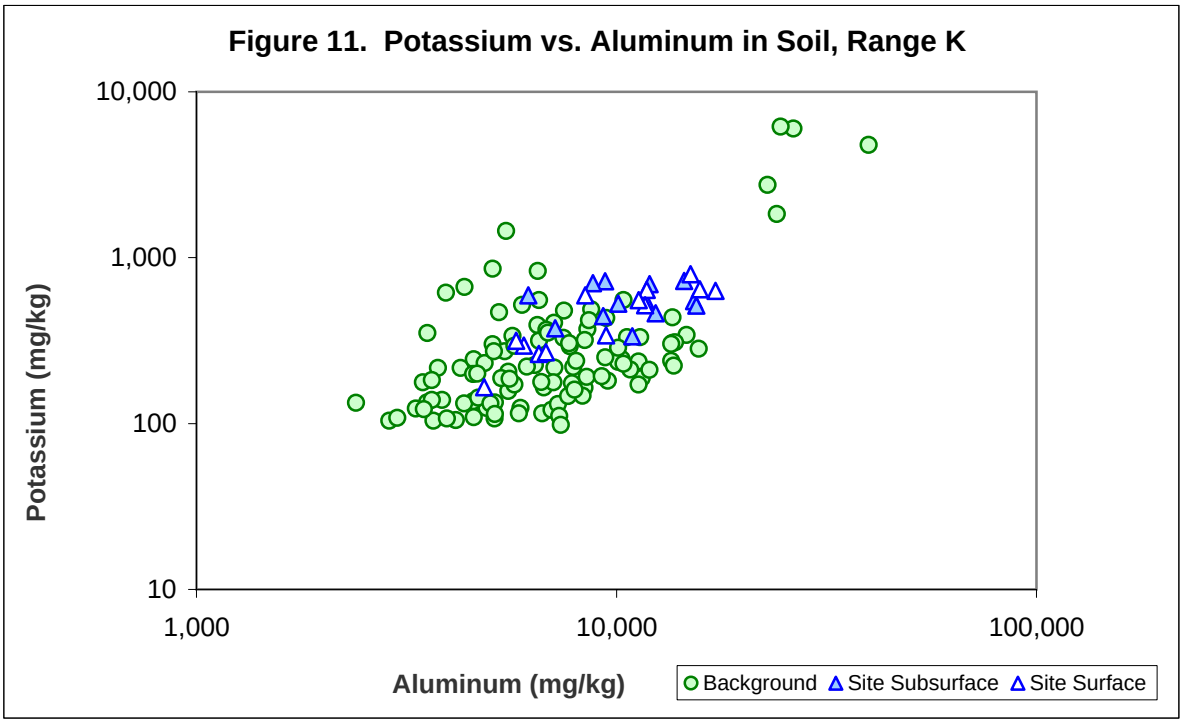


Figure 11. Potassium vs. Aluminum in Soil, Range K
10,000
1,000
100
10
Potassium (mg/kg)
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site Subsurface
Site Surface

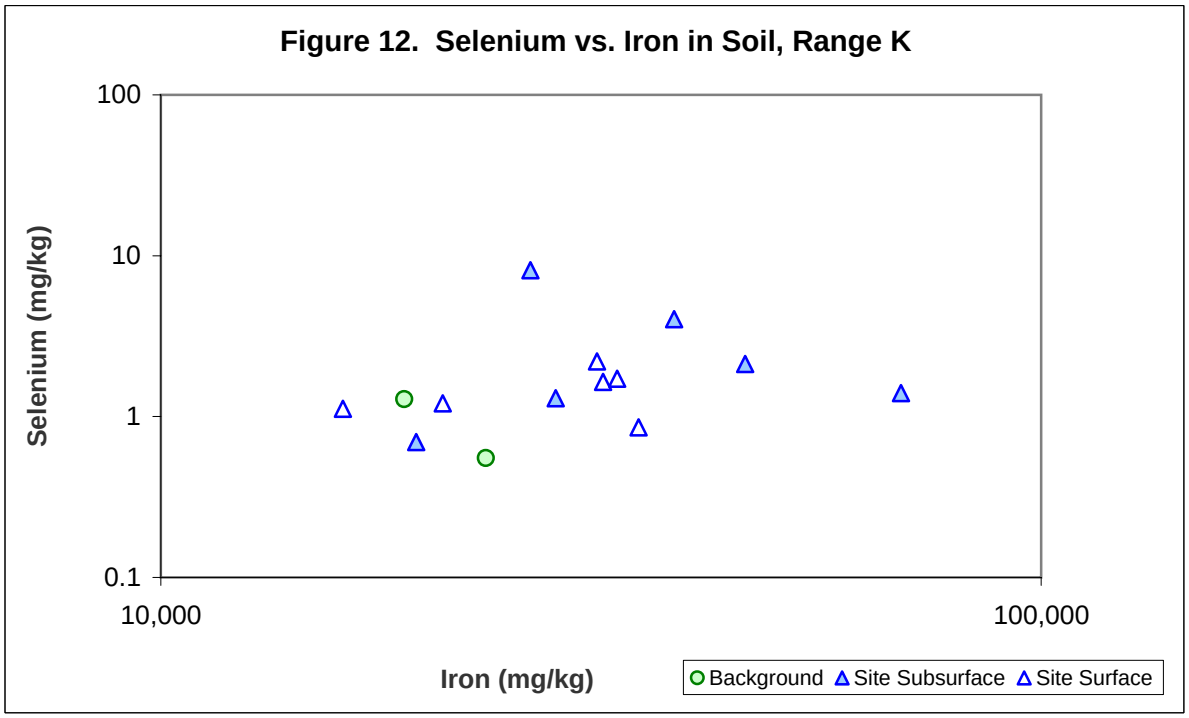


Figure 12. Selenium vs. Iron in Soil, Range K
100
10
1
0.1
Selenium (mg/kg)
10,000
100,000
Iron (mg/kg)
Background
Site Subsurface
Site Surface

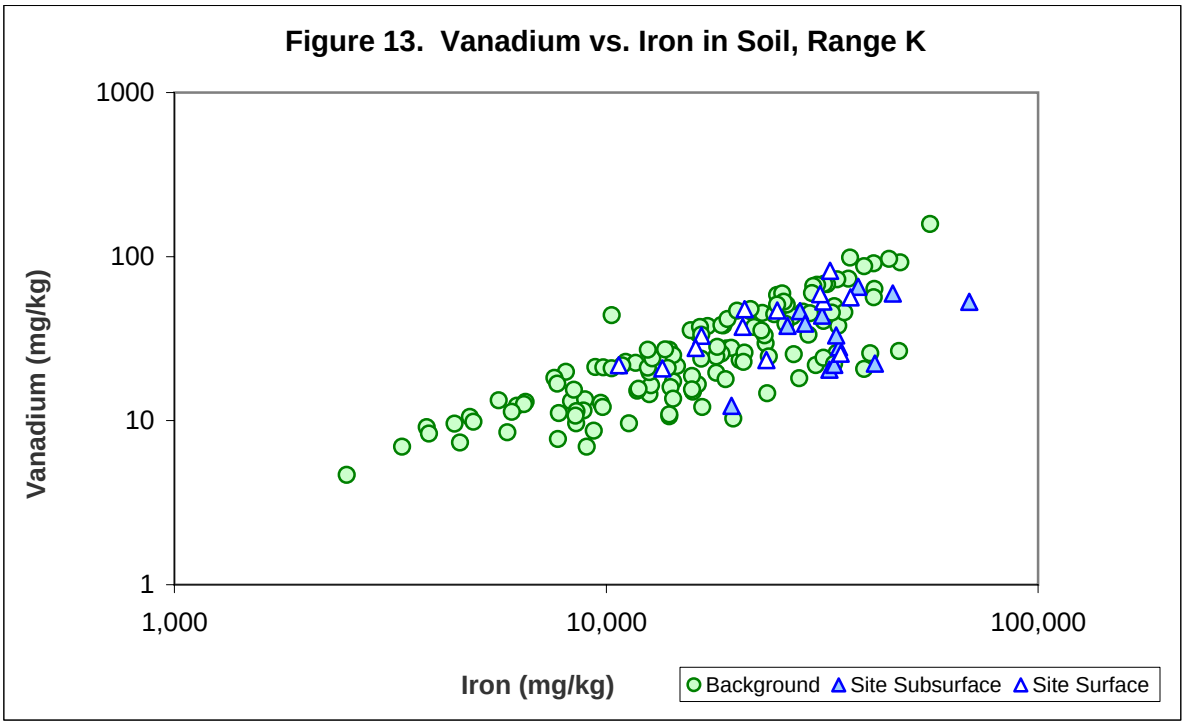


Figure 13. Vanadium vs. Iron in Soil, Range K
1000
100
10
1
Vanadium (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Subsurface
Site Surface

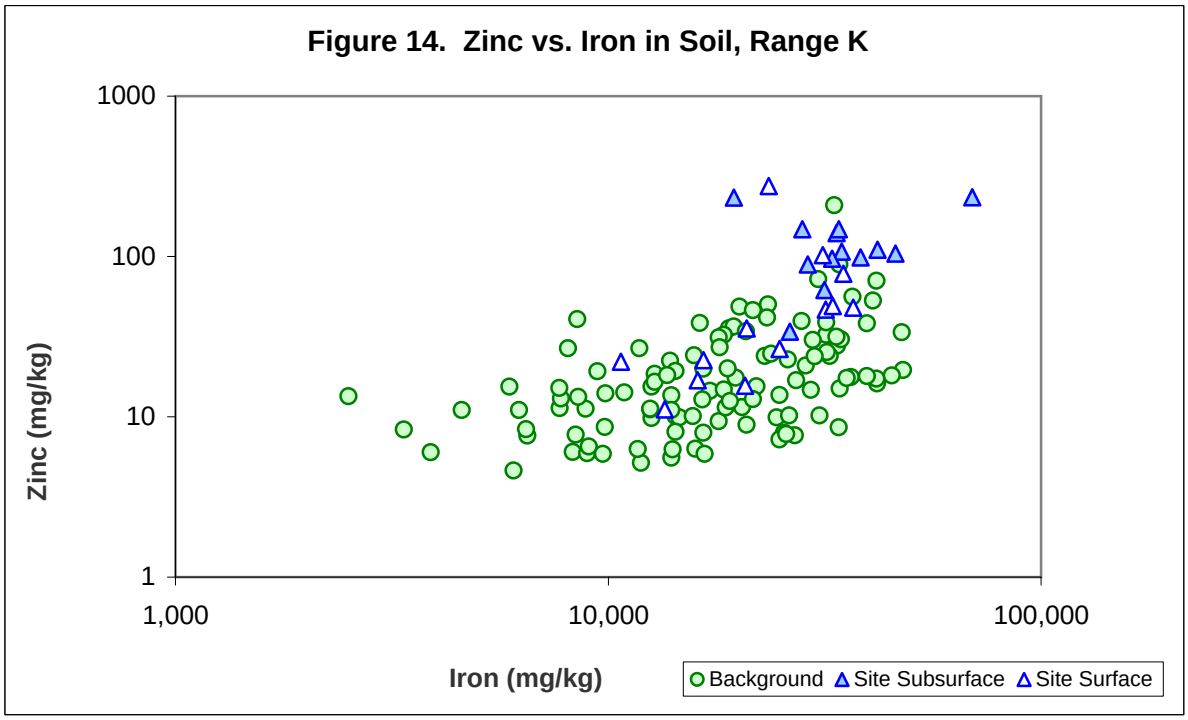


Figure 14. Zinc vs. Iron in Soil, Range K
1000
100
10
1
Zinc (mg/kg)
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Subsurface
Site Surface

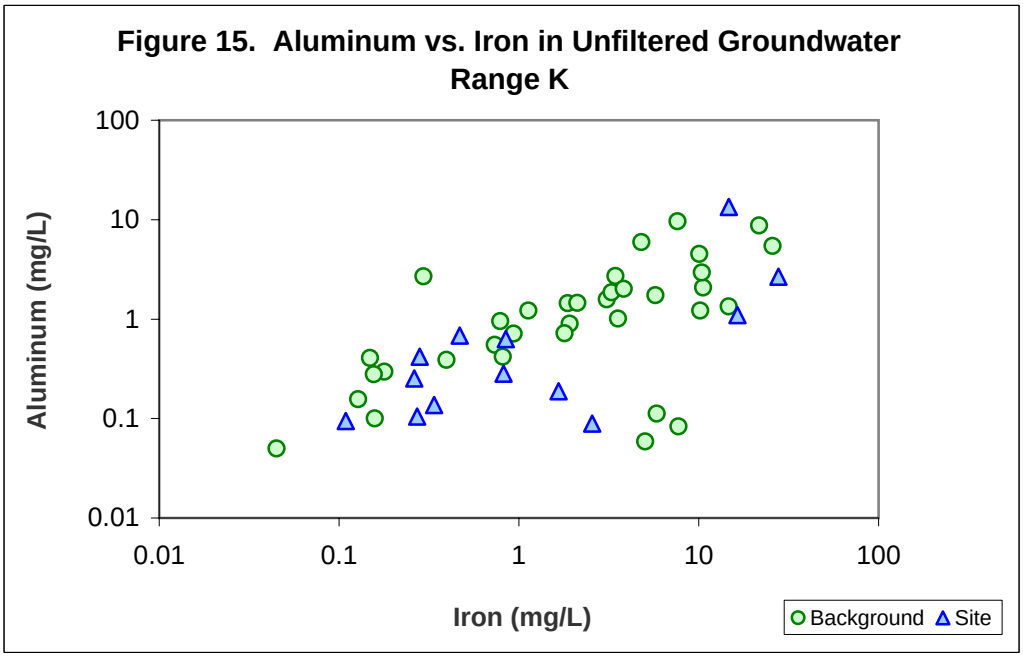


Figure 15. Aluminum vs. Iron in Unfiltered Groundwater
Range K
Aluminum (mg/L)
100
10
1
0.1
0.01
0.01
0.1
1
10
100
Iron (mg/L)
Background
Site

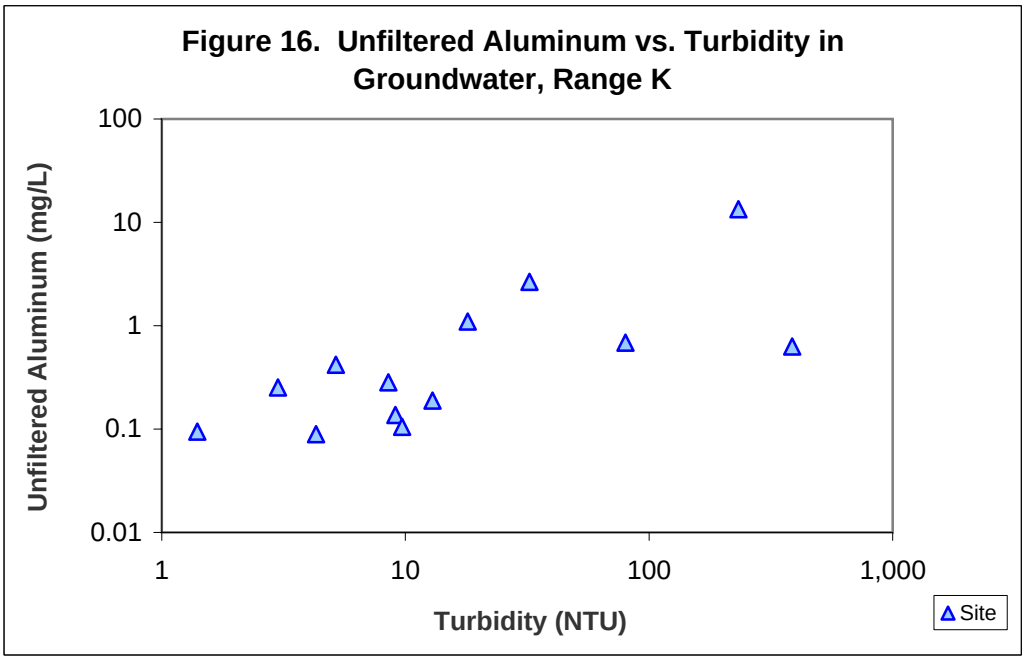


Figure 16. Unfiltered Aluminum vs. Turbidity in
Groundwater, Range K
Unfiltered Aluminum (mg/L)
100
10
1
0.1
0.01
1
10
100
1,000
Turbidity (NTU)
Site

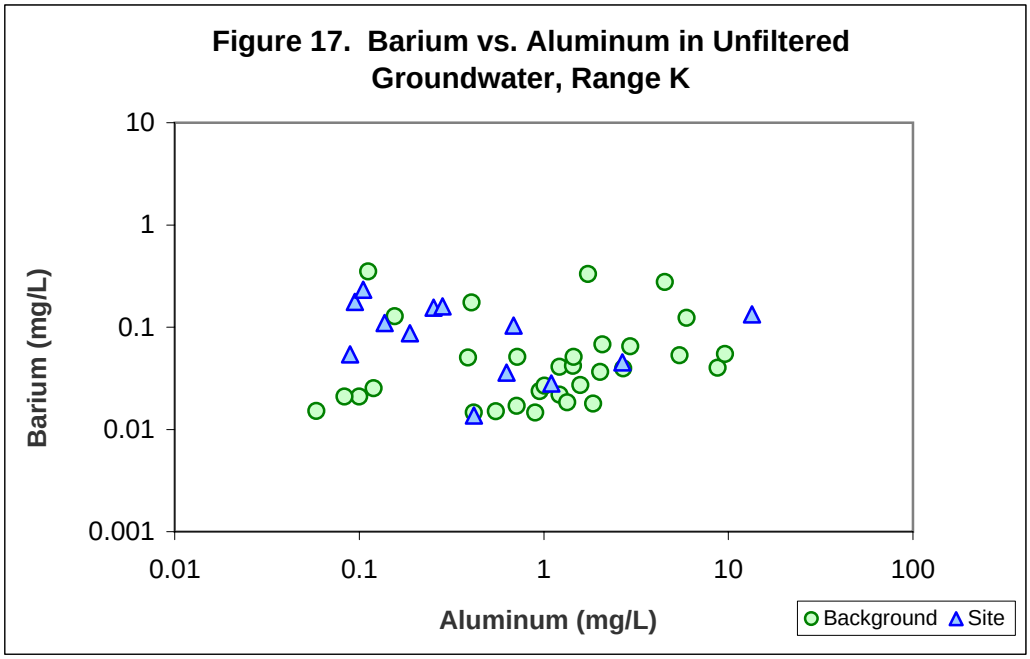


Figure 17. Barium vs. Aluminum in Unfiltered Groundwater, Range K
Barium (mg/L)
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
Aluminum (mg/L)
Background
Site

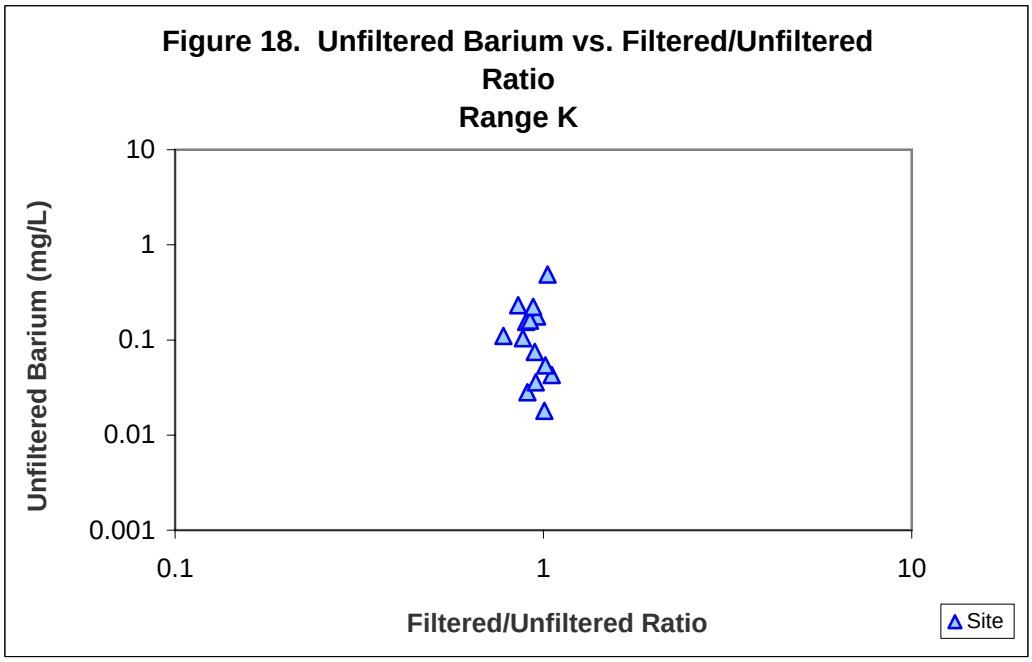


Figure 18. Unfiltered Barium vs. Filtered/Unfiltered Ratio
Range K
Unfiltered Barium (mg/L)
10
1
0.1
0.01
0.001
0.1
1
10
Filtered/Unfiltered Ratio
Site

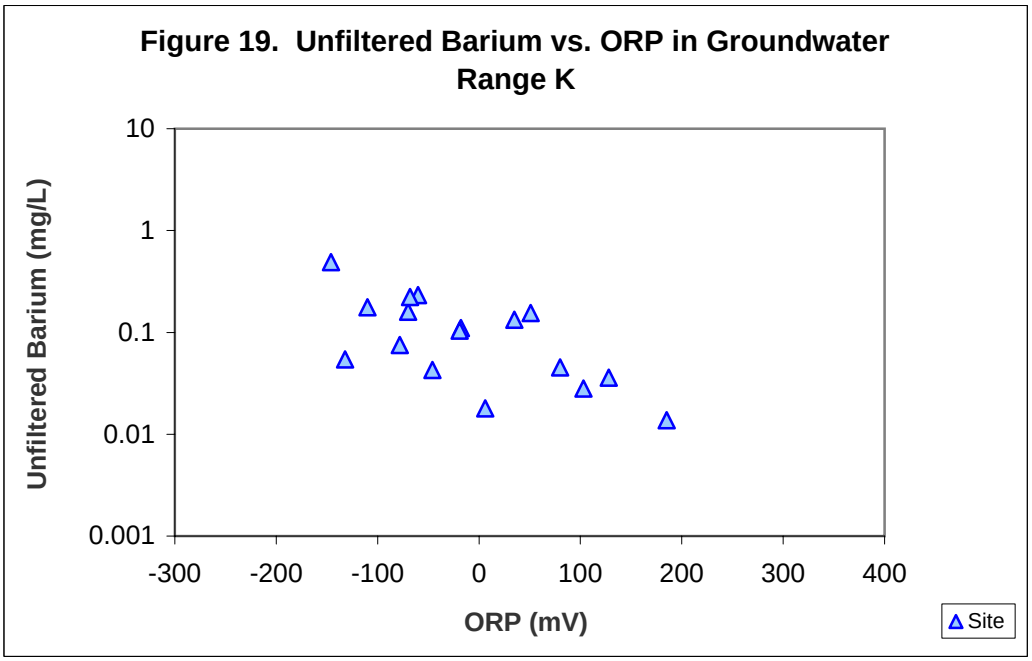


Figure 19. Unfiltered Barium vs. ORP in Groundwater
Range K
Unfiltered Barium (mg/L)
10
1
0.1
0.01
0.001
-300
-200
-100
0
100
200
300
400
ORP (mV)
Site

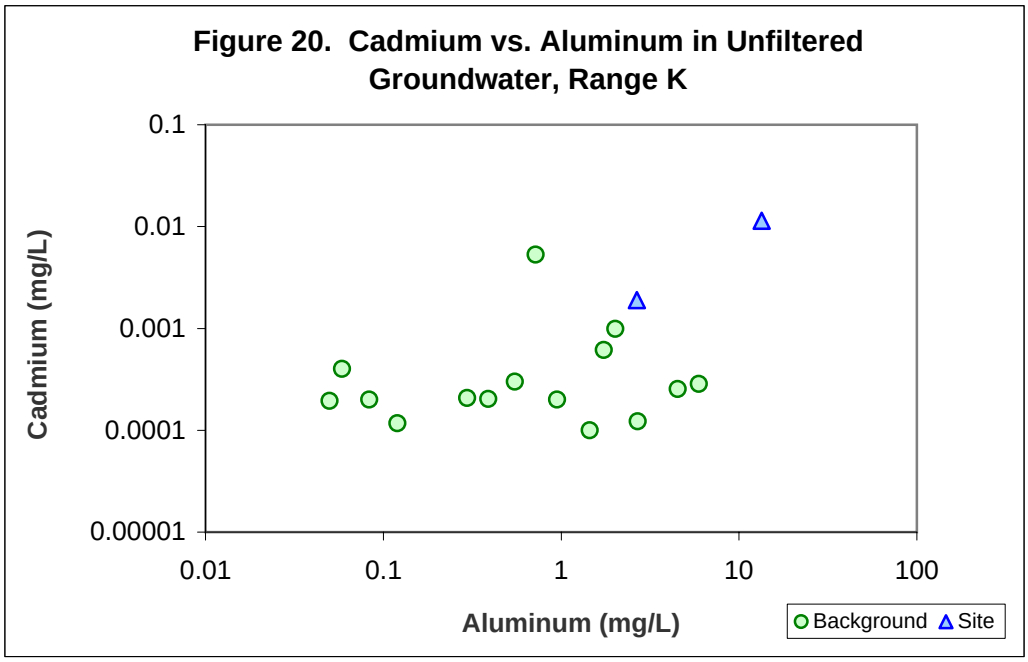


Figure 20. Cadmium vs. Aluminum in Unfiltered
Groundwater, Range K
Cadmium (mg/L)
0.1
0.01
0.001
0.0001
0.00001
0.01
0.1
1
10
100
Aluminum (mg/L)
Background
Site

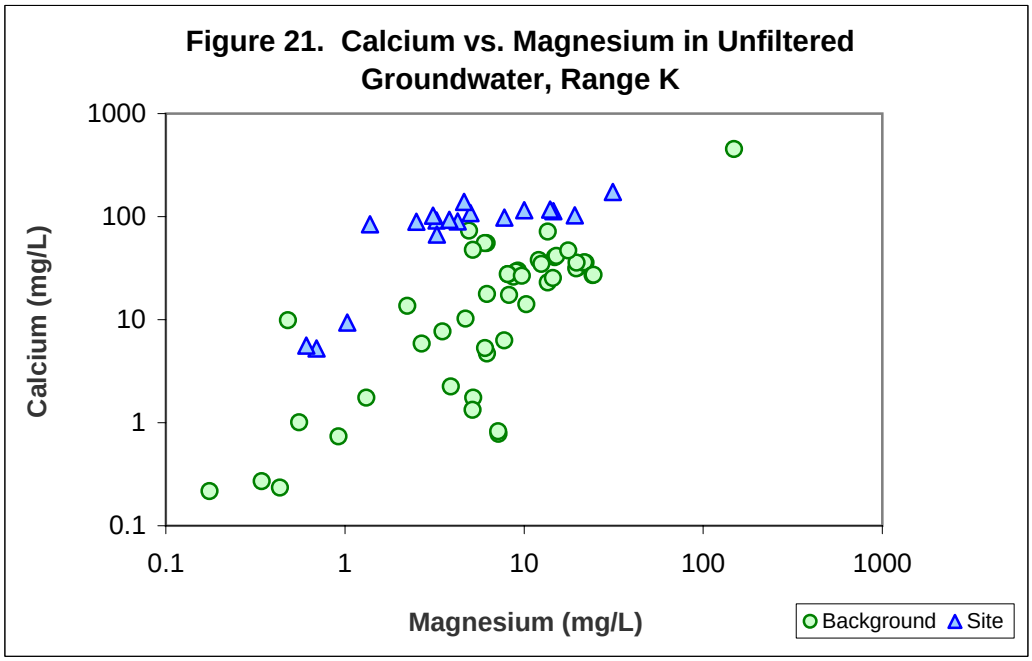


Figure 21. Calcium vs. Magnesium in Unfiltered Groundwater, Range K
Calcium (mg/L)
1000
100
10
1
0.1
0.1
1
10
100
1000
Magnesium (mg/L)
Background
Site

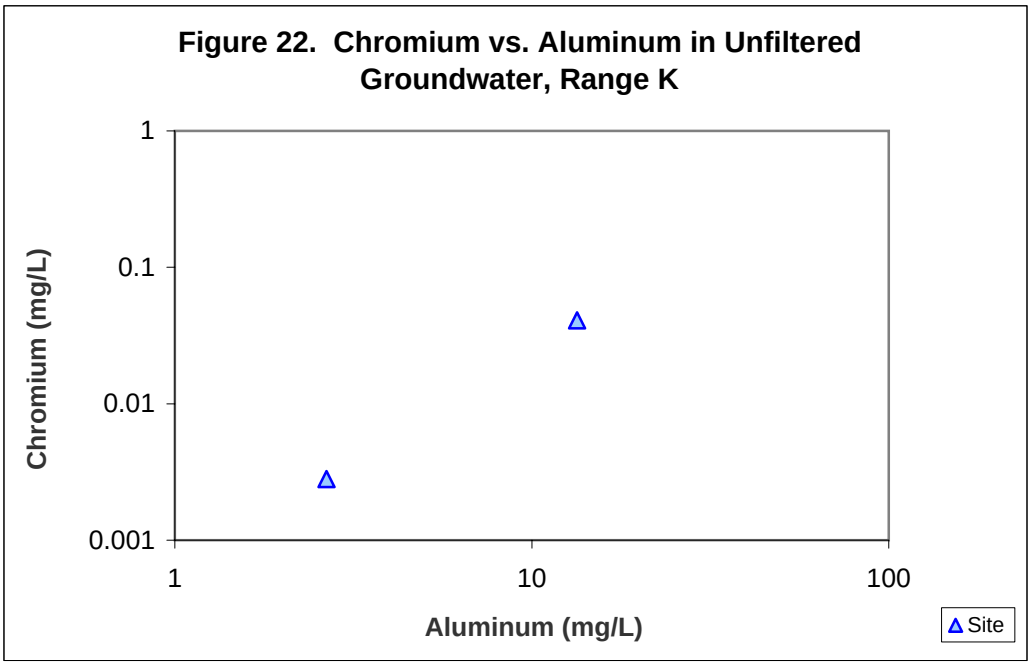


Figure 22. Chromium vs. Aluminum in Unfiltered Groundwater, Range K
Chromium (mg/L)
1
0.1
0.01
0.001
1
10
100
Aluminum (mg/L)
Site

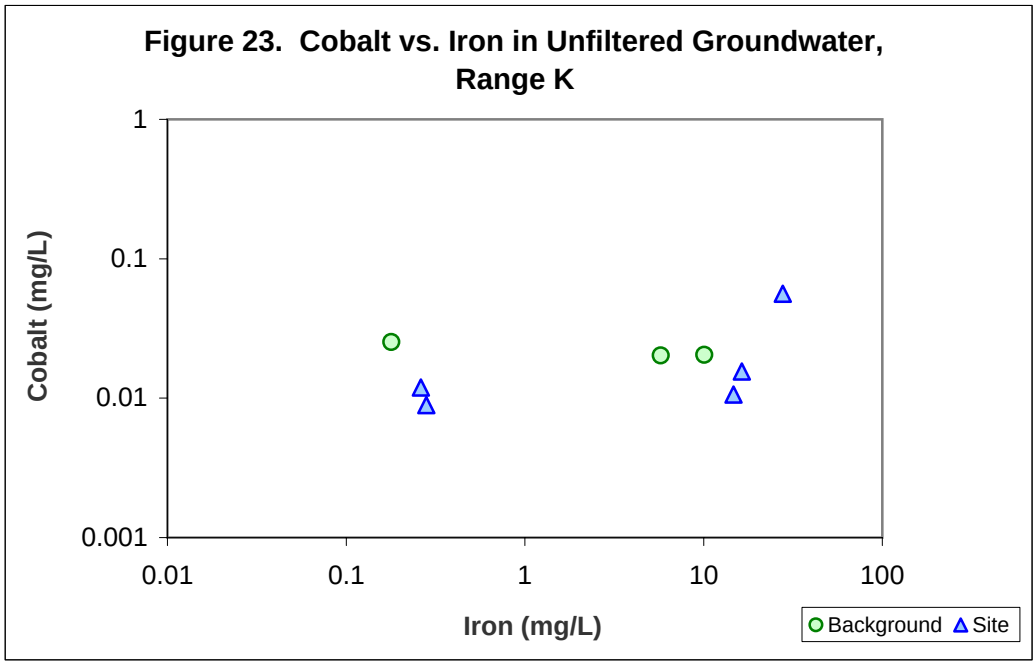


Figure 23. Cobalt vs. Iron in Unfiltered Groundwater, Range K
Cobalt (mg/L)
1
0.1
0.01
0.001
0.01
0.1
1
10
100
Iron (mg/L)
Background
Site

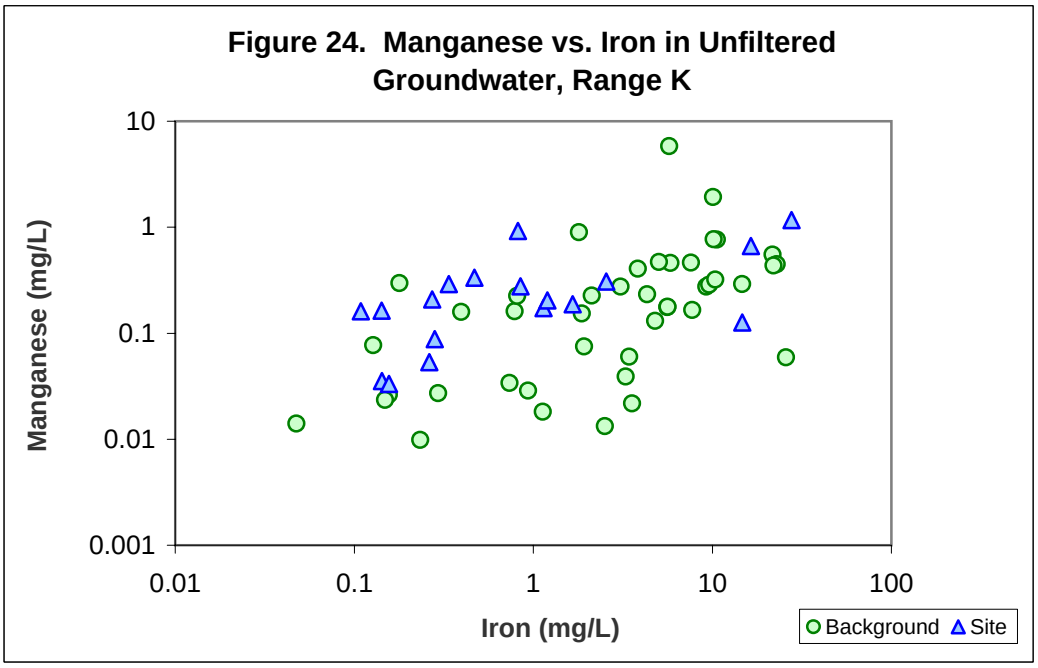


Figure 24. Manganese vs. Iron in Unfiltered Groundwater, Range K
Manganese (mg/L)
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
Iron (mg/L)
Background
Site

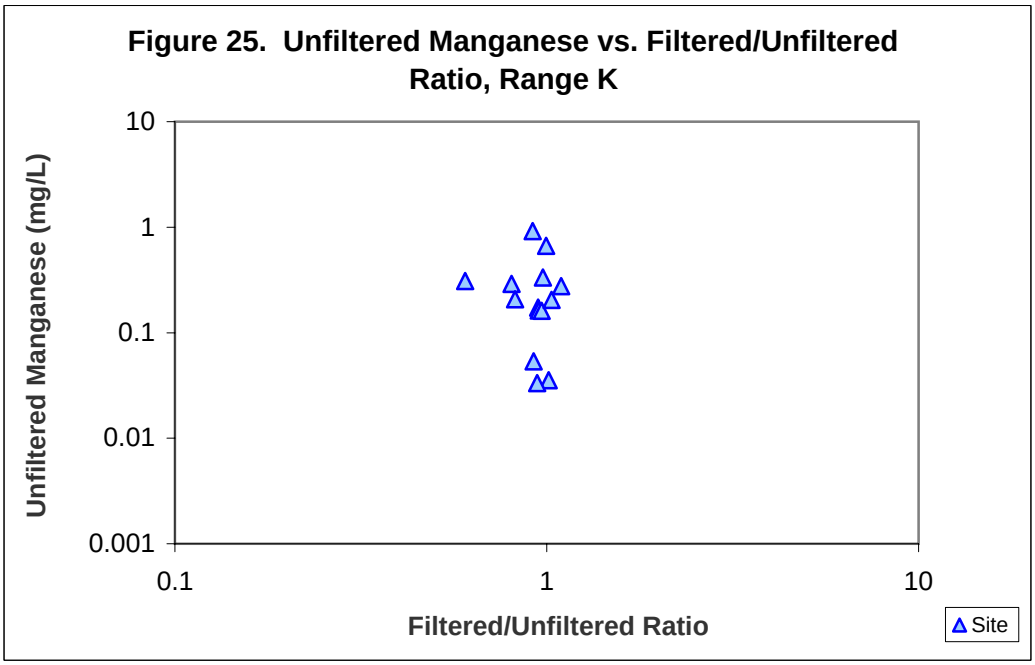


Figure 25. Unfiltered Manganese vs. Filtered/Unfiltered Ratio, Range K
Unfiltered Manganese (mg/L)
10
1
0.1
0.01
0.001
0.1
1
10
Filtered/Unfiltered Ratio
Site

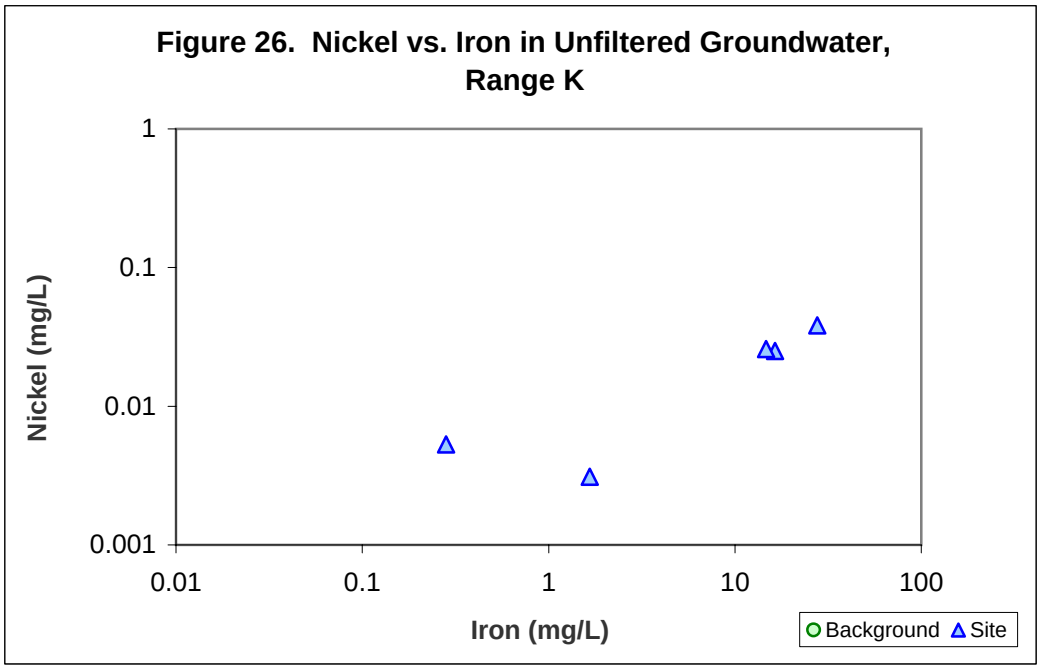


Figure 26. Nickel vs. Iron in Unfiltered Groundwater, Range K
Nickel (mg/L)
1
0.1
0.01
0.001
0.01
0.1
1
10
100
Iron (mg/L)
Background
Site

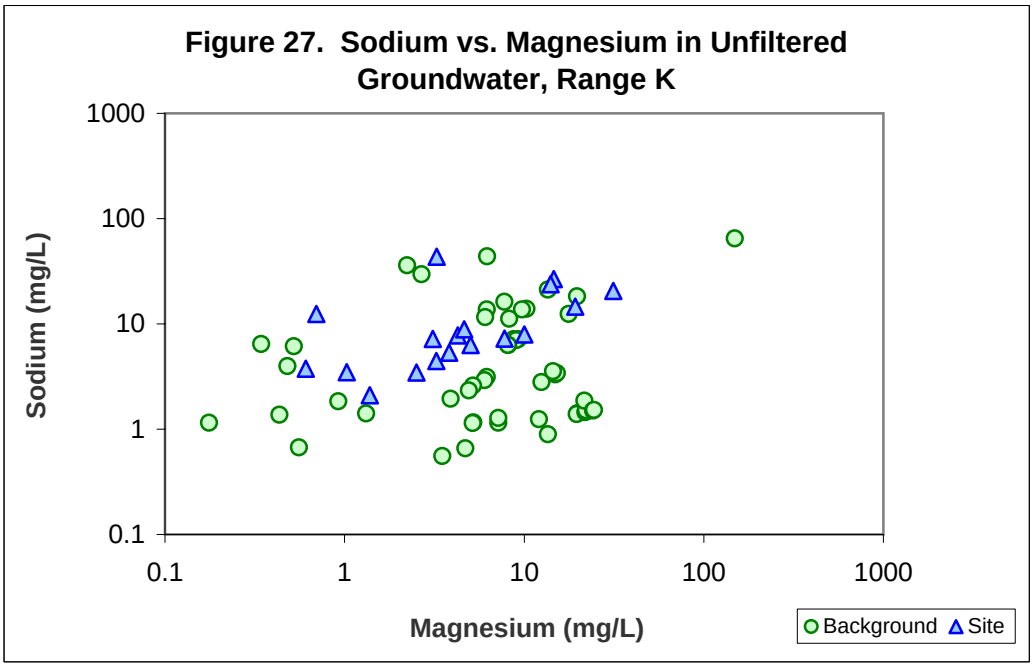


Figure 27. Sodium vs. Magnesium in Unfiltered Groundwater, Range K
Sodium (mg/L)
1000
100
10
1
0.1
0.1
1
10
100
1000
Magnesium (mg/L)
Background
Site

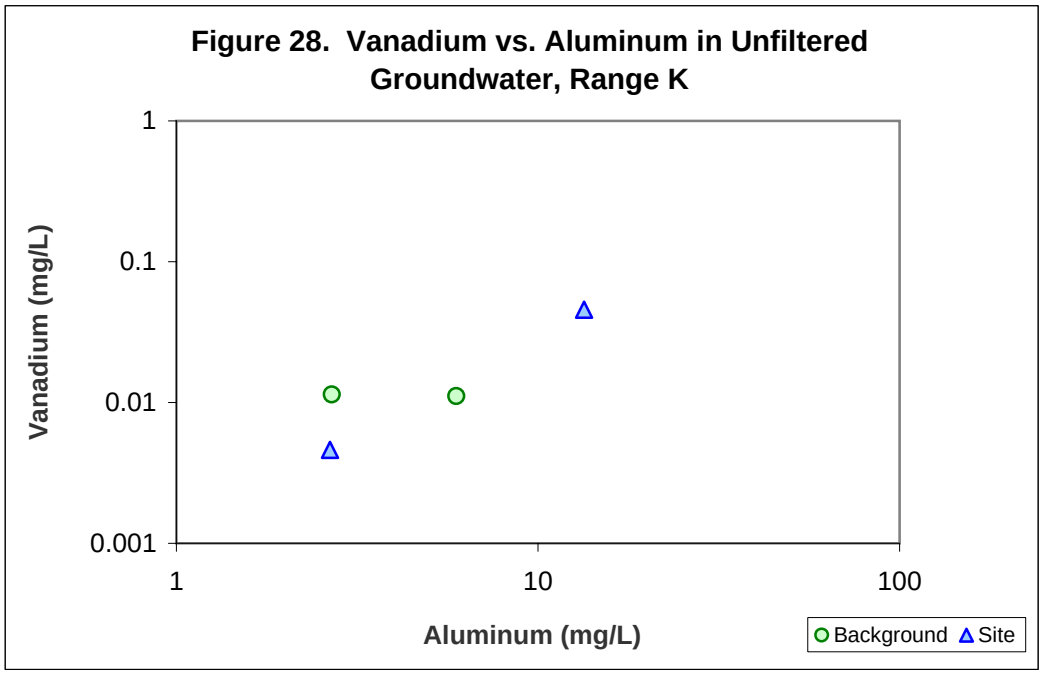


Figure 28. Vanadium vs. Aluminum in Unfiltered Groundwater, Range K
Vanadium (mg/L)
1
0.1
0.01
0.001
1
10
100
Aluminum (mg/L)
Background
Site

RESPONSE TO COMMENTS

Response to Alabama Department of Environmental Management Comments
Draft Remedial Investigation Report, Range K, Parcel 203(7)
Fort McClellan, Calhoun County, Alabama (dated March 2004)

Comments from Stephen A. Cobb, Chief, Governmental Hazardous Waste Branch, Land Division, dated July 2, 2004.

Comment: **The Alabama Department of Environmental Management (ADEM or the Department) has reviewed the subject *RI Report* for Range K at Pelham Range. The report documents Fort McClellan's characterization of site soil and groundwater to define the extent of contamination that resulted from chemical agent training, decontamination training, and other range activities conducted by the Department of the Army. Specifically, the RI results indicated the presence of chlorinated volatile organic compounds (VOCs). Also, Fort McClellan asserts that site groundwater should not be developed as a potable water source because groundwater contamination may pose an unacceptable cancer risk to the national guardsperson, groundskeeper, or residential receptor. Based on the results of the RI report the Department agrees that the extent of soil and groundwater contamination at Range K has been adequately defined. ADEM concurs that the Department of the Army should proceed with the next phase of study at Range K, leading to the submittal of a remedial action plan.**

Response: Comment noted.

Response to Comments from the U.S. Environmental Protection Agency
Draft Remedial Investigation Report, Range K,
Former Agent Training Area, Parcel 203(7) (dated March 19, 2004)
Fort McClellan, Calhoun County, Alabama

Comments from Doyle T. Brittain, EPA Senior Remedial Project Manager, dated May 10, 2004.

General Comment:

The Environmental Protection Agency (EPA) has conducted a preliminary review of the subject document. The document is not ready for detailed EPA review and specific comments. The transmittal letter states *The RI results were discussed by the BCT on several occasions throughout the course of the investigation.*

1. **The document does not contain a Response to Comments Section showing a serious attempt on the part of Fort McClellan to consider previous comments made by EPA.**

2. **The document does not reflect any consideration to the numerous and lengthy comments that EPA has repeatedly made for over a year about soil geochemistry and naturally occurring contaminants.**

3. **The document does not take into consideration comments that EPA has repeatedly made regarding land use controls.**

At such time as Fort McClellan demonstrates a concerted effort to consider comments that EPA has previously made, EPA will make a concerted effort to review and comment on that revised document.

Response to No. 1: The RI report submitted for review is a draft document. EPA has not had the opportunity to generate comments on an earlier version.

Response to No. 2: In December of 2003, the Army invited the technical personnel of the regulatory agencies and the contractor to attend a BCT meeting to discuss the comments on the Baby Bains Gap Road SLERA and the Ranges West of Iron Mountain Road – specifically to address the geochemical evaluation process. This meeting was held at FTMC on January 7, 2004 and was attended by Shaw's technical staff including Karen Thorbjornsen, Paul Goetchius, Rich Prann, Randy McBride, Jeanne Yacoub, Greg Sisco, and Steve Moran. EPA risk assessors were not in attendance at this meeting. Doyle Brittain indicated that EPA was not prepared to participate in technical discussions or decisions without having his

technical personnel at the meeting. Again, the Army suggested a meeting between the risk assessors to discuss and resolve the key issues. EPA and ADEM were requested to "bring the resources they need to resolve any residual technical issues on these parcels." The BCT agreed to meet in February in Montgomery.

In February 2004, the BCT met at the offices of ADEM in Montgomery primarily to review the Ranges West of Iron Mountain Road and any unresolved issues relative to the statistical and geochemical process. Karen Thorbjornsen and Paul Goetchius of Shaw participated via telephone conference on the second day of the meeting to respond to EPA comments on the aggregation of data and the heterogeneity of soil types at RWIMR. EPA did not provide any comments or ask any questions during this telephone conference. EPA also declined to have its technical representatives participate (via telephone) in the question and response discussion with Ms. Thorbjornsen and Mr. Goetchius.

Again, the Army respectfully requests a meeting with EPA and their technical personnel that reflects a good-faith effort between all parties involved in resolving these technical issues.

Reference: Final Approved BCT Minutes, January and February 2004.

Response to No. 3: Land Use Controls (LUC) are a form of remedial action and are not typically discussed in an RI report. Any discussion about LUCs would occur in a feasibility study.

Response to U.S. Army Center for Health Promotion and Preventive Medicine Comments on the Draft Remedial Investigation Report Range K, Former Agent Training Area, Parcel 203(7) Fort McClellan, Calhoun County, Alabama (dated March 2004)

Comments from Larry Tannenbaum, Environmental Health Risk Assessment Program, dated May 14, 2004.

Comment 1: **Page ES-1, Executive Summary. As early as the second paragraph of this section of the subject document, the reader learns that Range K is only 2 acres in size. This is strong evidence that Range K does not qualify for a terrestrial ecological assessment, because the site is ecologically irrelevant due to its small size. It should be noted that a growing number of States (e.g., Massachusetts, Pennsylvania, Texas, Washington) do not entertain ecological risk assessments for sites that are the size of Range K. We acknowledge that the report indicates (see page ES-3; next-to-last paragraph) that "additional lines of evidence", such as statistical and geochemical evaluations, have led to the conclusion that ecological risk is not an issue for Range K. An unaddressed but highly significant reason that ecological risk is not a concern at Range K, is that the site is too small to qualify for an assessment in the first place.**

Recommendation: In the revised RI report, please consider withdrawing the terrestrial ecological risk assessment. If not, please address the implications of analysis of a small site. See Comment #10.

Response 1: The reviewer is correct that several States have stipulations regarding the minimum size of a site to qualify for ecological risk assessment. The EPA has no such minimum size requirement for conducting ecological risk assessments. A discussion of the site's small size and its ecological relevance will be included in the Summary and Conclusions section of the SLERA.

Comment 2: **Page 6-1, Section 6.0, Streamlined Human Health Risk Assessment. Although it is understood why the on-site resident was evaluated in the human health risk assessment ("for the additional information provided by the theoretical upper-bound on long-term risk"; see Sections 6.1.1.2 on page 6-4), the text of the first bullet point here, describing "residential" land use, even "broadly" (as the text notes), is not accurate. Making use of parks, playgrounds, golf courses, stores, commercial facilities, etc. are not legitimately "residential" exposures. Residents might *engage* in such activities, but true residents do not apportion enough of their time to these activities to be rightfully categorized as residential exposures.**

<u>Recommendation:</u> In the revised RI report, please amend the text accordingly, following the point made in the comment.

Response 2: Agreed; the reviewer is correct. The bulleted section describing the broad land-use categories will be revised as follows:

"For example, it was determined that current or future land-use of most FTMC sites may be categorized broadly as follows:

- Residential: restricted to living areas, such as single- or multiple-dwelling homes and retirement centers.

- Commercial/Industrial: including schools, parks, playgrounds, golf courses, employment areas, office buildings, stores, malls, medical facilities, research facilities, motor pools and garages, transportation facilities, military facilities, training fields, landfills, dumps, disposal sites, and all other areas and activities other than residential.

- Open space: including "unused" land or buffer space, wetlands, wooded or meadow areas, and all other areas not used for residential or industrial activities. Hiking, hunting, fishing or other recreational use may occur.

The most highly exposed receptor for each land-use category..."

Comment 3: **<u>Page 6-5, Section 6.1.2.2, Select Site-Related Chemicals.</u> The bullet paragraph "Tier 2" alludes to two different statistical tests used to determine whether site chemical concentrations are comparable to those of background. The two statistical tests however, are not described or even mentioned by name.**

<u>Recommendation :</u> Although the information may be provided elsewhere (Volume II of the subject document), please have the text here (page 6-5) identify and briefly describe the two statistical tests.

Response 3: Agreed; the bullets describing Tier 1 and Tier 2 will be revised as follows:

- ***Tier 1.*** The maximum detected concentration (MDC) of the metal is compared with the BSC, which is two-times the mean background concentration as estimated by SAIC (1998). If the MDC does not exceed the BSC, concentrations of that metal at all points within the geographic area represented by the data set are considered to be comparable to background and that metal is not evaluated further. Metals whose MDCs exceed their BSCs are carried to Tier 2.

- ***Tier 2.*** Two different statistical tests described in detail in Appendix I are used to determine whether the site concentrations are comparable to

background concentrations. One test is the slippage test, which is used as a test of upper tails. The other is the Wilcoxon Rank Sum Test (WRST), which evaluates the likelihood that the site and background data sets are drawn from different populations. Metals that pass statistical testing are ordinarily not evaluated further, unless knowledge about site activities or the nature of the data set suggest that the metal could be site related. Such chemicals, as well as those that fail the statistical tests, are carried to Tier 3.

Comment 4: **<u>Page 6-7, Section 6.1.3, Exposure Assessment.</u> The page's first paragraph correctly notes that a construction worker may be exposed to a much smaller area (i.e., have a much smaller EU) than that of a recreational site user or a groundskeeper. Since this Section is addressing exposure assessment, to be complete, the text here should note that the exposure duration of a construction worker ordinarily, is notably shorter than that of the other potential site receptor described in the paragraph. Also, the end of the Section's last paragraph is somewhat confusing. It may be impractical to divide a given parcel into reasonable EUs where "future site use is not that precisely known". Is the implication that representative EUs for current site use receptors *can* be established?**

<u>Recommendation:</u> For completeness, please consider expanding Section 6.1.3 so as to have the text integrate the concept of exposure duration (ED), and to note, as does this Comment, that the size of a receptor's EU and his/her ED, are independent terms. Please address the query regarding the establishment of appropriate EU sizes, and amend the text as necessary for elucidation.

Response 4: This comment addresses two separate issues. The first is the recommendation to integrate discussion about ED and EU. The second is the possible implication that EUs for current site use receptors *can* be established, although EUs for future site use cannot. Regarding the first issue, the Army disagrees that there is any need to expand the text to integrate ED (or any of the other exposure variable values) with EU, or to stress the independence of ED and EU. The first paragraph of Section 6.0 clearly states the assumption that the reader is familiar with the FTMC facility, with risk assessment in general, and with the *IWWP*, where the exposure variables such as ED are developed and defended. The second issue is largely irrelevant because the only receptors evaluated under the current site-use assumption are the national guardsperson and the recreational site user (please see Section 6.1.1.3). As stated in the second paragraph of Section 6.1.3, these receptors are expected to be exposed to a large area and establishing EUs smaller than the entirety of Range K is not necessary. The text in question will not be revised.

Comment 5: **<u>Page 6-8, Section 6.1.5.1, Protocol and Policy: Chemicals Other Than Lead.</u> The Section's second sentence should be expanded. It is true that "it is often helpful to distinguish cancer risk and noncancer hazard", but the**

two endpoints must be distinguished. The reader should understand that the two toxicological endpoints cannot be expressed jointly.

<u>Recommendation:</u> In the revised RI report, please have the text here note that evaluations for cancer risk and noncancer hazard, by the nature of the biological processes involved, and by the respective calculations, must be distinguished. See next Comment.

Response 5: Agreed; the sentence in question will be revised as follows: "In the risk characterization discussion, however, it is often helpful to distinguish cancer risk and noncancer hazard, because the two are estimated separately and the estimates are not combined."

Comment 6: **<u>Page 6-9, Section 6.1.5.1, Protocol and Policy: Chemicals Other Than Lead.</u> The text of line 1 should be modified for accuracy.**

<u>Recommendation:</u> Please rewrite the sentence as: "...rounding risk and hazard estimates to one significant..."

Response 6: Agreed.

Comment 7: **<u>Page 6-10, Section 6.1.6, Uncertainty Evaluation.</u> The use of the word "excluded" on line 35, referring to metals screening, is not clear.**

<u>Recommendation:</u> In the revised RI report, please indicate if the word "excluded" as used, is intended to mean "screened out" (i.e., eliminated from further consideration).

Response 7: The sentence in question will be revised as follows: "Uncertainty arises by eliminating background metals from further evaluation in the quantitative risk assessment."

Comment 8: **<u>Page 6-15, Section 6.2.3, National Guardsperson – Future Site Use.</u> This paragraph, unlike the one before it and the ones that follow it, does not have a sentence that specifically says that Range K does not pose an unacceptable risk to the receptor (here, the future national guardsperson).**

<u>Recommendation:</u> Although the text of the subject paragraph is linked to the preceding paragraph (for the national guardsperson – current site use), please add the recommended language.

Response 8: The total ILCR from exposure to groundwater of 1.81E-4 exceeds the EPA risk management range. Furthermore, it is noted that STCs of three VOCs exceed their respective MCLs. It is concluded that exposure to groundwater is unlikely to induce adverse noncancer health effects, but does pose an unacceptable cancer risk for the future national guardsperson. The main difference between

the national guardsperson current and future site-use scenarios is the inclusion of exposure to groundwater developed as a potable source in the future. It would be inappropriate to conclude that Range K does not pose unacceptable risk to this receptor. The text will not be revised.

Comment 9: **<u>Page 6-20, Section 6.2.5, Conclusions.</u> The risk summary table presented should indicate current and future receptors.**

<u>Recommendation:</u> In the revised RI report, please modify the table to indicate current and future receptors. Note that for some receptors, such as the national guardsman, both current and future scenarios were evaluated.

Response 9: Agreed; the table in question will be revised as follows:

Risk Summary by Receptor[a]			
Risk or Hazard Consideration	Surface Soil	Subsurface Soil	Groundwater
National Guardsperson, Current Site Use			
Cancer risk[b]	Acceptable	Acceptable	NE
Noncancer hazard[c]	Acceptable	Acceptable	NE
National Guardsperson, Future Site Use			
Cancer risk[b]	Acceptable	Acceptable	**1,1,2,2-TCA**, (1,1,2-TCA, TCE, VC)
Noncancer hazard[c]	Acceptable	Acceptable	Acceptable
Recreational Site User, Current Site Use			
Cancer risk[b]	Acceptable	NE	NE
Noncancer hazard[c]	Acceptable	NE	NE
Recreational Site User, Future Site Use			
Cancer risk[b]	Acceptable	Acceptable	NE
Noncancer hazard[c]	Acceptable	Acceptable	NE
Groundskeeper, Future Site Use			
Cancer risk[b]	Acceptable	Acceptable	**1,1,2,2-TCA**, (beta-BHC, 1,1,2-TCA, TCE, VC)
Noncancer hazard[c]	Acceptable	Acceptable	Acceptable
Construction Worker, Future Site Use			
Cancer risk[b]	Acceptable	Acceptable	Acceptable
Noncancer hazard[c]	Acceptable	Acceptable	Acceptable
On-Site Resident, Future Site Use			
Cancer risk[b]	Acceptable	Acceptable	**1,1,2,2-TCA, TCE, VC**, (beta-BHC, heptachlor, DEHP, 1,1,2-TCA, 1,1-DCE, benzene, PERC)
Noncancer hazard[c]	Acceptable	Acceptable	**TCE**, (nitrobenzene, 1,4-oxathiane, 1,1,2,2-TCA, cis-1,2-DCE)
[a]Cancer risk and noncancer hazard are presented as "acceptable" (see footnotes b and			

Risk Summary by Receptor[a]			
Risk or Hazard Consideration	Surface Soil	Subsurface Soil	Groundwater
c), or the chemicals of concern (COC) for unacceptable results are listed. Risk-drivers are in **bold type**, lesser COCs are in parentheses. [b]Cancer risk is termed "acceptable" if the total ILCR summed across all relevant media rounded to one significant figure does not exceed 1E-4. [c]Noncancer hazard is termed "acceptable" if the total HI for all target organs rounded to one significant figure does not exceed the threshold level of 1. NE = Receptor not exposed to this medium.			

Comment 10: **<u>General Comments, Section 7.0, Screening-Level Ecological Risk Assessment.</u> Most or all of the mammals or birds that could be considered for an assessment at Range K are irrelevant for evaluation. This is attributable to the minimal site size (of just 2 acres). More specifically, the larger mammals would contact the site infrequently. They would not have sufficient contact with the affected site media to constitute a valid concern. Also given the natural density of many of the species, less than one species representative would be expected to be present at Range K. To our knowledge, no site has even been remediated on the basis of an anticipated health effect in a small rodent. Although a small rodent species might be present in sufficient numbers to initially justify a risk assessment undertaking, the fact that such species do not trigger remedial actions would argue against them being evaluated. Note also that for a wider-ranging receptor, Range K could not supply a sufficiency of small rodents to meet the receptor's dietary needs.**

<u>Recommendation:</u> Given the size of Range K, please consider replacing the ecological risk assessment work that was done with a brief narrative that notes that a) the site has biota present, b) there are no overt signs of stress or impact in site biota, and c) there are no indications of animal counts dwindling down at this historically-contaminated parcel. Please modify the text to say that although species such as the Bobcat and the Red-tailed hawk might occur at the site, they would not be anticipated to be present frequently enough (due to their very large home ranges) to warrant an evaluation. See Comment #12.

Response 10: As presented in the response to Comment No. 1, a discussion of the site's small size and its ecological relevance will be included in the Summary and Conclusions section of the SLERA.

Comment 11: **<u>Page 7-5, Section 7.4.1.2, Fate and Transport in Surface Water.</u> The Section's last sentence should be modified for clarity.**

Recommendation: **Please add to the end of the identified sentence "...detected in ground water, to the point where ecological considerations are absent."**

Response 11: The last sentence of Section 7.4.1.2 will be revised to read "However, the increased flow in the drainage feature during storm events would greatly dilute the concentrations of constituents detected in groundwater to levels that are likely ecologically irrelevant."

Comment 12: **Pages 7-6 to 7-52, Sections 7.4.2 to 7.4.2.24, Ecotoxicity. This Section is unnecessarily lengthy for several reasons. First, the document understands that there are no contaminants of concern for ecological receptors. Second, as noted in the Comments above, the site is ecologically irrelevant due to its small size. Third, the subject document acknowledges that there are no permanent waterbodies at Range K, obviating the need for chemical-specific paragraphs on aquatic toxicity, as occurs over these many pages.**

Recommendation: **Given that the subject document itself acknowledges that there are no permanent (i.e., ecologically relevant) waterbodies, please remove the many paragraphs entitled "Aquatic Life" that occur over these pages.**

Response 12: Although there are no permanent water bodies at Range K, EPA has requested that the Army assess the potential for groundwater discharge to ephemeral drainage features at Fort McClellan, where feasible. Because of the potential groundwater discharge to the drainage features at Range K, and the subsequent surface water exposures, the "Aquatic Life" portions of the toxicity profiles are relevant to this assessment and will remain in the SLERA.

Comment 13: **Page 7-71 to 7-75, Section 7.7, Uncertainty Analysis. This Section is deficient in that a treatment on the limitations of the Hazard Quotient (HQ) method is entirely lacking. The closest the Section comes to addressing this matter is the discussion on the use of NOAELs and LOAELs.**

Recommendation: **In the revised RI report, please enhance the Uncertainty Section by mentioning five critical limitations of the HQ method, namely:**

- **The HQ is not a measure of risk;**
- **The HQ is not a population-based measure;**
- **HQs are not linearly scaled;**
- **Extremely low chemical concentrations in environmental media can "trigger" an HQ-of-1.0 exceedance;**
- **HQs are often generated that are unrealistically high and toxicologically impossible.**

The following reference supplies a comprehensive review on this subject: Tannenbaum, L.V., Johnson, M.S., and Bazar, M., 2003. Application of the Hazard Quotient Method in Remedial Decisions: A Comparison of Human and Ecological Risk Assessments. Human and Ecological Risk Assessment, Volume 9 (1): 387-401.

Response 13: A discussion of the uncertainties inherent in the HQ method will be included in the Uncertainty Analysis of the SLERA.

Comment 14: **Page 8-3, Section 8.1.5, Screening Level Ecological Risk Assessment. The text (line 32) refers to constituents in ground water having exceeded ESVs. Why were ground-water concentrations screened in any fashion against ESVs. Ecological receptors are not exposed to ground water. If the concern is over ground water discharge to surface water, surface water concentrations should have been determined, and these could have been screened against ESVs.**

Recommendation: In the revised RI report, please delete the reference to ground water constituents screening for ecological risk assessment purposes.

Response 14: The EPA has requested that the Army assess the potential discharge of groundwater to surface water bodies by comparing groundwater constituent concentrations to surface water ESVs. EPA has made this request even when surface water data exist for a site, in order to assess the potential for future groundwater discharge to surface water. Because the drainage features at Range K are ephemeral and surface water was not present at the time of sampling, no surface water samples were collected at Range K.