APPENDIX J

STATISTICAL AND GEOCHEMICAL EVALUATIONS OF SITE METALS DATA

Technical Memorandum

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To: Fort McClellan (FTMC) Risk Assessment File

Date: 24 June 2003

Subject: ***Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC: Revision 2.***

Note: Early Shaw E & I experience with the previously agreed-upon 28 April 2003 memo describing the protocol for background screening revealed considerable inefficiency arising from characteristics of the background data sets and occasionally the site data sets. Primary among these is a high percentage of non-detects, which renders the statistical tests described in Tier 2 invalid. Conversations between Shaw E & I and EPA Region IV led to revision of the Tier 2 statistical procedure whereby comparison with the 95th upper tolerance limit could be substituted for the previously designated tests under certain conditions.

The purpose of this memo is to describe the protocol for background screening – comparing site data with background data – for the purpose of selecting site-related chemicals. This memo is intended to reflect agreement reached between the USACE (via Shaw E & I) and EPA Region IV during informal discussion on 24 to 26 March 2003, as amended by further conversations between Shaw E & I and EPA Region IV. Background screening is part of the chemical of potential concern (COPC) or chemical of potential ecological concern (COPEC) selection step of a risk assessment.

Background screening will be performed as a multi-tiered process as follows:

Tier 1: *(Tier 1 remains unchanged from the 28 April 2003 memo.)* The maximum detected concentration (MDC) of site data is compared with the background screening criterion (BSC). Chemicals for which the MDC of site data does not exceed the BSC are considered to be present at background concentrations, are not selected as site-related chemicals and are not considered further in the risk assessment. Chemicals for which the MDC of site data exceeds the BSC are carried forward to Tier 2.

Tier 2: Tier 2 is performed in two steps: (a) The Slippage test is performed as the preferred high value test. In those cases where the Slippage test is inappropriate, comparison of site data with the background 95 UTL (or 95th percentile for background data sets for which estimation of a UTL is inappropriate) is performed instead of the Slippage test. (b) The Wilcoxon Rank Sum test (WRST) is performed. In those cases where the WRST cannot be performed (generally due to a large number of non-detects in the background or site data set), comparison of site data with the

background UTL is performed as described above. Metals that "fail" any of the statistical tests that were performed are evaluated under Tier 3.

Tier 3: *(Tier 3 remains unchanged from the 28 April memo.)* Tier 3 consists of a geochemical evaluation to determine whether concentrations of site metals are naturally occurring or elevated due to contamination. Geochemical evaluations are based on the natural association between a trace element and one or more specific soil-forming minerals that concentrate that trace element. The correlation of the trace element of interest with a major element representing the abundance of the specific mineral that concentrates the trace element is evaluated. The selection of the major reference element is dependent on a number of general and site-specific factors as discussed below.

Some elements, under certain environmental conditions, display exclusive associations with specific reference elements. For instance, in oxic, neutral-pH soils, arsenic, selenium, and vanadium are almost exclusively associated with iron oxides, so iron is usually used as a reference element for these trace elements (Bowell, 1994; Schiff and Weisberg, 1997). The reason for this association is well understood, and is based on aqueous speciation and surface chemistry effects. These three elements are present in oxic soil pore fluid as negatively charged oxyanions ($HAsO_4^{-2}$, $HSeO_3^-$, $H_2VO_4^-$) (Pourbaix, 1974; EPRI, 1986; Brookins, 1988). Iron oxides maintain a positive surface charge that strongly attracts these oxyanions, resulting in the observed linear correlations (Bowell, 1994).

Cadmium, nickel, lead, and zinc exist in the pore fluid of most soils as positively charged divalent cations (Cd^{+2}, Ni^{+2}, Pb^{+2}, Zn^{+2}) (Brookins, 1988; Pourbaix, 1974). These trace elements have a strong affinity to adsorb on clay minerals which maintain a negative surface charge (EPRI, 1984). These elements are usually evaluated against aluminum, which is a major component of all clay minerals.

Chromium can be present in soil pore fluid as a mixture of aqueous species with different charges such as $Cr(OH)_2^+$, $Cr(OH)_3^0$, and $Cr(OH)_4^-$, depending on the pH of the pore fluid (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. Higher soil pH conditions will favor the anionic Cr species which adsorb on iron oxides, and lower soil pH conditions will favor the cationic Cr species which preferentially adsorb on clay minerals.

Manganese oxides have a specific affinity to adsorb barium, cobalt, and lead (Kabata-Pendias, 2001). In most soils, the manganese concentrations are too low for it to form discrete manganese oxide minerals. However, in oxic, manganese-rich soils, minerals such as pyrolusite (MnO_2) and nsutite ($MnO_{1.9}$) will form that strongly adsorb Ba, Co, and Pb. Under reducing, low CO_2 conditions, the minerals MnO•OH, Mn_2O_3 and Mn_3O_4 will form, which also concentrate these trace elements. Under reducing, high CO_2 conditions however, Mn will be present as rhodochrosite ($MnCO_3$) which does not have as strong adsorptive properties as the Mn-oxides (EPRI, 1984).

Soils that contain fragments of limestone often show linear correlations between barium, cadmium, cobalt, nickel, strontium, lead, and zinc versus calcium. This is because these divalent metals readily substitute for calcium in calcite ($CaCO_3$) and dolomite [$(Ca,Mg)CO_3$], which are the major minerals present in limestone. This association is also common in arid regions where the divalent metals co-precipitate with calcite and gypsum ($CaSO_4 \cdot 2H_2O$) in caliche horizons.

Arkosic soils that contain unweathered fragments of feldspar have very different trace/major element associations, reflecting the mineralogy of the primary igneous or metamorphic source material. For instance, beryllium is associated with alkali feldspars which all contain sodium, potassium and aluminum, so the correlations of beryllium versus those major elements would be evaluated.

Total organic carbon is a good reference element for mercury, which has a strong affinity for adsorption on natural organic material. Mercury often shows better correlations with total organic carbon than with inorganic reference elements.

In reducing environments such as swamps, bogs, and wetlands where organic content is high, anaerobic sulfate-reducing conditions can become established. Under these conditions, trace elements such as arsenic, cadmium, nickel, lead, and zinc will co-precipitate with iron as sulfide minerals. These trace metals in this environment would be expected to be correlated with iron and sulfide in soil samples.

Care must be taken in the selection of reference elements to ensure that those elements are themselves not directly or indirectly impacted by contamination. Aluminum is usually a good reference element because it is not sensitive to redox conditions, and direct aluminum contamination is rare. A further advantage of aluminum is its low solubility over the neutral pH range, but it does become soluble at pH conditions below 4 and above 9. The release of strong acids or bases will leach aluminum from soil and solubilize aluminum in groundwater, so evaluation of the pH conditions is important.

Examining the correlation between iron versus aluminum in soil is an important tool in geochemical evaluations. Both elements tend to concentrate in the finer grain size fractions as oxide and clay minerals, respectively. Concentrations of iron and aluminum may vary from sample to sample by orders of magnitude reflecting differences in grain size, but they are usually present at a fixed ratio. Site samples that plot off of the trend established by the background samples and exhibit anomalously high Fe/Al ratios, may have some excess component of iron, suggesting contamination from rust, machine shop sweepings, ferric chloride sludge, etc. If iron contamination is identified in some samples, then those samples should be identified as such and removed from the evaluation, or an alternate reference element should be selected.

Iron and manganese in groundwater are subject to reductive dissolution effects which should be evaluated before they are used as reference elements. The release of organic contaminants such as hydrocarbon 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 in groundwater by local depressions in oxidation-reduction potential or dissolved oxygen 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 dichloroethene and/or vinyl chloride, which are reductive dechlorination products resulting from the microbial degradation of trichloroethene or tetrachloroethene under anaerobic conditions.

An additional technique that is used to identify the presence of local reducing conditions in groundwater is a correlation plot of iron versus aluminum. These two elements are usually highly correlated in oxic groundwater because they are both insoluble and tend to be present as suspended particulates at a fairly constant ratio. If local reducing conditions are present, then samples from those areas will have a higher Fe/Al ratio than oxic areas because iron becomes soluble under reducing conditions but aluminum does not. Results can be independently confirmed by evaluating manganese versus aluminum because manganese and iron have similar redox behavior.

All available laboratory and field data are examined to determine if there is a local reducing environment that is driving the dissolution of iron and manganese oxides, as this effect may cause erroneous geochemical evaluation results if this process is not taken into account. Data are also evaluated for pH anomalies and the presence of organic contaminants that may alter the geochemical environment.

References

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STATISTICAL
(TIERS 1 AND 2)

Statistical Comparison of Site and Background Data
Former Decontamination Complex
Parcels 93(7), 46(7), 70(7), and 140(7)
Fort McClellan, Alabama

1.0 Introduction

This report provides the Tier 1 and Tier 2 (Shaw E&I, 2003) site-to-background comparison results for the Former Decon Complex (Parcels 46, 70, and 93), Fort McClellan, in Calhoun County, Alabama. 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 and the Wilcoxon Rank Sum Test (WRS). If either or both of these statistical test cannot be done, the evaluation will include the Hot Measurement Test.

The methodology and results of the Tier 1 and Tier 2 comparisons are summarized in Tables 1 through 5, and described in more detail in the following sections. Site samples used in the site-to-background comparison include 32 surface soil samples (0 to 1 foot below ground surface [bgs]), 26 subsurface soil samples (5 to 16 feet bgs), 20 groundwater samples, 6 sediment, and 6 surface water 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, groundwater, sediment, and surface water for Fort McClellan (SAIC, 1998).

2.0 Comparison Methodology

This section describes the statistical techniques that were employed in the Former Decon Complex (Parcels 46, 70, and 93) 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

Table 1

Summary of Tier 1 and Tier 2 Site to Background Comparison for Surface Soil
Former Decon Complex (Parcels 46, 70, and 93)
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Site MDC Exceeds 2 X bkgd mean[a]	Slippage Test[b]	Wilcoxon Rank Sum Test[b]	Site MDC > Background 95th UTL/Percentile[c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	32 / 32	Yes	Passed	Failed	NA	Yes
Antimony	1 / 32	Yes	NA[d]	NA[e]	No	
Arsenic	31 / 32	Yes	Passed	Passed	NA	
Barium	28 / 32	Yes	Passed	Passed	NA	
Beryllium	9 / 32	Yes	Passed	NA[e]	No	
Cadmium	4 / 32	Yes	NA[d]	NA[e]	Yes	Yes
Calcium	31 / 32	Yes	Failed	Fail	NA	Yes
Chromium	31 / 32	Yes	Passed	Fail	NA	Yes
Cobalt	12 / 32	Yes	Passed	NA[e]	No	
Copper	31 / 32	Yes	Passed	Fail	NA	Yes
Iron	32 / 32	Yes	Passed	Passed	NA	
Lead	32 / 32	Yes	Passed	Fail	NA	Yes
Magnesium	29 / 32	Yes	Failed	Fail	NA	Yes
Manganese	32 / 32	Yes	Passed	Passed	NA	
Mercury	11 / 32	Yes	Passed	NA[e]	Yes	Yes
Nickel	16 / 32	Yes	Passed	NA[e]	Yes	Yes
Potassium	7 / 32	Yes	Passed	NA[e]	No	
Selenium	5 / 32	Yes	Passed	NA[e]	Yes	Yes
Silver	0 / 32	No	NA	NA	NA	
Sodium	3 / 32	No	NA	NA	NA	
Thallium	0 / 32	No	NA	NA	NA	
Vanadium	30 / 32	No	NA	NA	NA	
Zinc	18 / 32	Yes	Passed	Failed	NA	Yes

NA = not applicable; MDC = maximum detected concentration; UTL = upper tolerance limit

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 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
Former Decon Complex (Parcels 46, 70, and 93)
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Site MDC Exceeds 2 X Background Mean[a]	Slippage Test[b]	Wilcoxon Rank Sum Test[b]	Site MDC > Background 95th UTL/Percentile[c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	26 / 26	Yes	Pass	Fail	NA	Yes
Antimony	0 / 26	No	NA	NA	NA	
Arsenic	24 / 26	No	NA	NA	NA	
Barium	23 / 26	Yes	Pass	Fail	NA	Yes
Beryllium	16 / 26	Yes	Pass	Fail	NA	Yes
Cadmium	0 / 26	No	NA	NA	NA	
Calcium	11 / 26	Yes	Pass	NA[e]	Yes	Yes
Chromium	26 / 26	No	NA	NA	NA	
Cobalt	15 / 26	Yes	Pass	Fail	NA	Yes
Copper	26 / 26	Yes	Pass	Fail	NA	Yes
Iron	26 / 26	Yes	Pass	Pass	NA	
Lead	26 / 26	No	NA	NA	NA	
Magnesium	16 / 26	Yes	Pass	Fail	NA	Yes
Manganese	26 / 26	No	NA	NA	NA	
Mercury	4 / 26	No	NA	NA	NA	
Nickel	15 / 26	Yes	Fail	Pass	NA	Yes
Potassium	8 / 26	Yes	Pass	NA[e]	Yes	Yes
Selenium	10 / 26	Yes	NA[d]	NA[e]	Yes	Yes
Silver	0 / 26	No	NA	NA	NA	
Sodium	4 / 26	Yes	Pass	NA[e]	Yes	Yes
Thallium	0 / 26	No	NA	NA	NA	
Vanadium	19 / 26	No	NA	NA	NA	
Zinc	10 / 26	Yes	Pass	NA[e]	Yes	Yes

NA = not applicable; MDC = maximum detected concentration; UTL = upper tolerance limit

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 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
Former Decon Complex (Parcels 46, 70, and 93)
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Site MDC Exceeds 2 X Background Mean[a]	Slippage Test[b]	Wilcoxon Rank Sum Test[b]	Site MDC > Background 95th UTL/Percentile[c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	6 / 20	Yes	Passed	Failed	NA	Yes
Antimony	0 / 20	No	NA	NA	NA	
Arsenic	3 / 20	Yes	Passed	NA[e]	No	
Barium	16 / 20	Yes	Passed	Failed	NA	Yes
Beryllium	2 / 20	Yes	NA[d]	NA[e]	Yes	Yes
Cadmium	0 / 20	No	NA	NA	NA	
Calcium	18 / 20	Yes	Passed	Failed	NA	Yes
Chromium	6 / 20	Yes	NA[d]	NA[e]	Yes	Yes
Cobalt	3 / 20	Yes	Passed	NA[e]	Yes	Yes
Copper	3 / 20	Yes	Passed	NA[e]	No	
Iron	20 / 20	Yes	Passed	Failed	NA	Yes
Lead	5 / 20	Yes	NA[d]	NA[e]	Yes	Yes
Magnesium	19 / 20	Yes	Passed	Failed	NA	Yes
Manganese	20 / 20	Yes	Passed	Failed	NA	Yes
Mercury	5 / 20	Yes	NA[d]	NA[e]	No	
Nickel	4 / 20	Yes	NA[d]	NA[e]	Yes	Yes
Potassium	15 / 20	Yes	Passed	Failed	NA	Yes
Selenium	3 / 20	Yes	NA[d]	NA[e]	No	
Silver	0 / 20	No	NA	NA	NA	
Sodium	20 / 20	Yes	Passed	Failed	NA	Yes
Thallium	2 / 20	Yes	NA[d]	NA[e]	No	
Vanadium	3 / 20	Yes	NA[d]	NA[e]	Yes	Yes
Zinc	3 / 20	Yes	Passed	NA[d]	No	

NA = not applicable; MDC = maximum detected concentration; UTL = upper tolerance limit

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 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 4

Summary of Tier 1 and Tier 2 Site to Background Comparison for Sediment
Former Decon Complex (Parcels 46, 70, and 93)
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Site MDC Exceeds 2 X Background Mean[a]	Slippage Test[b]	Wilcoxon Rank Sum Test[b]	Site MDC > Background 95th UTL/Percentile[c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	6 / 6	Yes	Passed	Failed	NA	Yes
Antimony	0 / 6	No	NA	NA	NA	
Arsenic	6 / 6	Yes	Passed	Failed	NA	Yes
Barium	6 / 6	Yes	Passed	Failed	NA	Yes
Beryllium	4 / 6	Yes	Passed	Failed	NA	Yes
Cadmium	1 / 6	Yes	Passed	NA[d]	Yes	Yes
Calcium	6 / 6	Yes	Failed	Failed	NA	Yes
Chromium	6 / 6	Yes	Passed	Failed	NA	Yes
Cobalt	3 / 6	No	NA	NA	NA	
Copper	6 / 6	Yes	Passed	Failed	NA	Yes
Iron	6 / 6	Yes	Passed	Failed	NA	Yes
Lead	6 / 6	Yes	Passed	Failed	NA	Yes
Magnesium	3 / 6	Yes	Passed	Failed	NA	Yes
Manganese	6 / 6	Yes	Passed	Passed	NA	
Mercury	4 / 6	No	NA	NA	NA	
Nickel	5 / 6	No	NA	NA	NA	
Potassium	2 / 6	No	NA	NA	NA	
Selenium	2 / 6	Yes	Passed	NA[d]	Yes	Yes
Silver	0 / 6	No	NA	NA	NA	
Sodium	0 / 6	No	NA	NA	NA	
Thallium	0 / 6	No	NA	NA	NA	
Vanadium	5 / 6	Yes	Passed	Passed	NA	
Zinc	6 / 6	Yes	Passed	Failed	NA	Yes

NA = not applicable; MDC = maximum detected concentration; UTL = upper tolerance limit

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 WRS test cannot be performed.

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

Table 5

Summary of Tier 1 and Tier 2 Site to Background Comparison for Surface Water
Former Decon Complex (Parcels 46, 70, and 93)
Fort McClellan, Calhoun County, Alabama

Metals	Frequency of Detection	Site MDC Exceeds 2 X Background Mean[a]	Slippage Test[b]	Wilcoxon Rank Sum Test[b]	Site MDC > Background 95th UTL/Percentile[c]	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	3 / 6	No	NA	NA	NA	
Antimony	0 / 6	No	NA	NA	NA	
Arsenic	1 / 6	Yes	Passed	NA[e]	No	
Barium	2 / 6	No	NA	NA	NA	
Beryllium	0 / 6	No	NA	NA	NA	
Cadmium	0 / 6	No	NA	NA	NA	
Calcium	6 / 6	Yes	Passed	Failed	NA	Yes
Chromium	0 / 6	No	NA	NA	NA	
Cobalt	0 / 6	No	NA	NA	NA	
Copper	0 / 6	No	NA	NA	NA	
Iron	6 / 6	No	NA	NA	NA	
Lead	0 / 6	No	NA	NA	NA	
Magnesium	5 / 6	Yes	Passed	Passed	NA	
Manganese	6 / 6	Yes	Passed	Passed	NA	
Mercury	2 / 6	Yes	NA[d]	NA[e]	No	
Nickel	0 / 6	No	NA	NA	NA	
Potassium	2 / 6	Yes	Passed	NA[e]	No	
Selenium	0 / 6	No	NA	NA	NA	
Silver	0 / 6	No	NA	NA	NA	
Sodium	0 / 6	No	NA	NA	NA	
Thallium	0 / 6	No	NA	NA	NA	
Vanadium	0 / 6	No	NA	NA	NA	
Zinc	2 / 6	No	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 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.

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 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, 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 in Appendix H.

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 Former Decon Area soil, groundwater, sediment, and surface water samples. Tables 1 through 5 summarize the Tier 1 and Tier 2 test results for each media as discussed in the following sections. Slippage test results and WRS test results are discussed in detail below. The corresponding box plots are also discussed below and are provided in Attachment 1.

3.1 Surface Soil

Twenty-three TAL metals were evaluated in the Former Decon Complex (Parcels 46, 70, 93) surface soil. Silver and thallium had no detects in surface soil in this area, so no further discussion of these chemicals is included. Sodium and vanadium had no detected concentrations above the background screening value, passing the Tier 1 evaluation. They will not be discussed any further.

The remaining nineteen elements were carried forward for Tier 2 evaluation. The statistical test results and box plots are discussed in detail below. Box plots are provided in Attachment 1.

Table 1 summarizes the Tier 1 and Tier 2 test results for surface soil.

Aluminum

Tier 1 Evaluation

Two of the site samples exceed the background screening value of 1.6E+4 milligrams per kilogram (mg/kg).

Slippage Test

The critical value, K_c, for aluminum is three. Aluminum has no samples exceeding the maximum background measurement (K=0). Because $K < K_c$ aluminum passes the Slippage test.

WRS Test

The WRS test p-level of 0.0055 indicates significant difference between the site and background distributions.

Box Plot
Box plots for the site and background data sets are provided in Figure 1-1. The site minimum, interquartile range, and maximum are all less than the corresponding background values. This visual shows that although there is a difference between site and background, the site values are actually lower than those of background.

Conclusion
Aluminum is considered within range of background.

Antimony

Tier 1 Evaluation
One site sample contained a detected concentration of antimony above the background screening value of 2.0E+0 mg/kg.

Slippage Test
The maximum result for antimony in background sample data is a nondetect so this test cannot be performed for this element.

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

Box Plot
The shape and location of the site box plot are defined by the high percentage of nondetects (97 percent), and the replacement values of one-half the reporting limit. The site minimum, interquartile range, and maximum exceed the corresponding values of background (Figure 1-1).

Hot Measurement Test
No site samples exceed the background 95th percentile of 7.14 mg/kg.

Conclusion
Antimony is considered within background.

Arsenic

Tier 1 Evaluation
One of the site samples exceeds the background screening value of 14 mg/kg.

Slippage Test
K_c for arsenic is three and no hits exceed the maximum background measurement. Because $K < K_c$ arsenic passes the Slippage test.

WRS Test
The p-level of 0.29 indicates good agreement between site and background distributions.

Box Plot
The site minimum, median, 75th percentile, and maximum are all lower than their respective background values (Figure 1-2). The site 25th percentile is similar to that of background.

Conclusion
Arsenic is considered within the range of background.

Barium

Tier 1 Evaluation
Four site samples exceed the background screening value of 1.2E+2 mg/kg.

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

WRS Test
The p-level of 0.63 indicates strong agreement between the site and background distributions.

Box Plot
The site 25th percentile, median, 75th percentile, and maximum are all lower than the corresponding background values (Figure 1-2). The two minimums are similar.

Conclusion
Barium is considered within the range of background.

Beryllium

Tier 1 Evaluation
Three detected concentrations of beryllium in site samples exceeded the background screening value of 8.0E-1 mg/kg.

Slippage Test
The critical value, K_c is four, and two site samples exceed the maximum background measurement. Because $K < K_c$ beryllium 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 slightly less than the corresponding background value (Figure 1-3). The shape and location of the site box plot are defined by the high percentage of nondetects (72 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
No site samples exceed the background 95th UTL of 1.189 mg/kg.

Conclusion
Based on statistical testing, beryllium is considered within the range of background.

Cadmium

Tier 1 Evaluation
Four samples exceed the background screening value of 0.29 mg/kg.

Slippage Test
The maximum background value for cadmium is a nondetect, so the Slippage test was not performed.

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

Box Plot
The site minimum and interquartile range are elevated as compared to the corresponding background value (Figure 1-3). The shape and location of the site box plot are defined by the high percentage of nondetects (87 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
The site MDC exceeded the background 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
Thirty samples exceed the background screening value of 1.7E+3 mg/kg.

Slippage Test
K_c for calcium is three, and twelve site samples exceed the maximum background measurement. Because $K > K_c$, calcium fails the Slippage test.

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

Box Plot
The site 25th percentile, median, 75th percentile, and maximum are all higher than their respective background values (Figure 1-4).

Conclusion
Calcium will be carried forward for Tier 3 geochemical evaluation.

Chromium

Tier 1 Evaluation
Four site samples exceed the background screening value of 3.7E+1 mg/kg.

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

WRS Test
The p-level of 0.09 indicates a significant difference between the site and background distributions.

Box Plot
The site 25th percentile, median, 75th percentile, and maximum are slightly higher than those of background (Figure 1-4). The site minimum is similar to 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
One of the detected concentrations in the site data set exceeds the background screening value of 1.5E+1 mg/kg.

Slippage Test
K_c for cobalt is three and no site samples exceed the maximum background measurement. Because $K < K_c$ cobalt 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, 75th percentile, and maximum are slightly less than the corresponding background value (Figure 1-5). The shape and location of the site box plot is defined by the high percentage of nondetects (62 percent) and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
No site samples exceed the background 95th UTL of 32.5 mg/kg.

Conclusion
Based on statistical test results, cobalt is considered within the range of background.

Copper

Tier 1 Evaluation
Nine detected concentrations in the site samples exceeded the background screening value of 13 mg/kg.

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

WRS Test
The p-level of 0.0012 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
Three detects of iron in site samples exceed the background screening value of 3.4E+4 mg/kg.

Slippage Test
The critical value, K_c, for iron is three. Two site samples exceed the maximum background measurement. Because $K < K_c$ iron passes the Slippage test.

WRS Test
The p-level of 0.22 indicates good agreement between the site and background distributions.

Box Plot
The site interquartile range is visibly lower with respect to background (Figure 1-6).

Conclusion
Iron is considered within the range of background.

Lead

Tier 1 Evaluation
Seven detected concentrations of lead in site samples exceed the background screening value of 40 mg/kg.

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

WRS Test
The p-level of 0.01 indicates a difference between the site and background distributions.

Box Plot
The site minimum, interquartile range, and maximum are all slightly higher than that of background (Figure 1-6).

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

Magnesium

Tier 1 Evaluation
Twenty-seven site samples exceed the background screening value of 1052 mg/kg.

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

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

Box Plot
The interquartile range and the maximum of the site data set are elevated with respect to background (Figure 1-7). The site minimum is similar to that of background minimum.

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

Manganese

Tier 1 Evaluation
Two site samples had detects exceeding the background screening value of 1.6E+3 mg/kg.

Slippage Test
The critical value, K_c, for manganese is three. No detects in site samples exceed the maximum background measurement. Because $K < K_c$, manganese passes the Slippage test.

WRS Test
The p-level of 0.44 indicates good agreement between the site and background distributions.

Box Plot
The site median, 75th percentile, and maximum are all lower than their respective background values (Figure 1-7). The site minimum and 25th percentile are similar to that of background.

Conclusion
Manganese is considered within the range of background.

Mercury

Tier 1 Evaluation
Five of the detected concentrations exceed the background screening value of 8.0E-2 mg/kg.

Slippage Test
K_c for mercury is three, and no site samples had detects exceed the maximum background measurement. Because $K < K_c$ mercury passes the Slippage test.

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

Box Plot
The site 25th percentile and median are lower than the corresponding background value (Figure 1-8). The shape and location of the background and site box plots are influenced by the high percentage of nondetects (66 percent in both cases), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
The site MDC exceeded the background 95th percentile of 0.125 mg/kg.

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

Nickel

Tier 1 Evaluation
Six of the detected concentrations of nickel exceed the background screening value of 1.0E+1 mg/kg.

Slippage Test
K_c for nickel is three, and three site samples exceed maximum background measurement. Because $K \leq K_c$ nickel passes the Slippage test.

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

Box Plot
The site median is slightly lower than the corresponding background values (Figure 1-8). The shape and location of the site box plot is influenced by the percentage of nondetects (50 percent), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
The site MDC exceeded the background 95th percentile (19.96 mg/kg).

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

Potassium

Tier 1 Evaluation
Three site samples exceed the background screening value of 8.0E+2 mg/kg.

Slippage Test
K_c for potassium is three and no site samples exceed the maximum background measurement. Because $K < K_c$, potassium 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 minimum and interquartile range are higher than the corresponding background values (Figure 1-9). The shape and location of the site box plot is influenced by the high percentage of nondetects (78 percent), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
The site MDC was less than the background 95th percentile of 1830 mg/kg.

Conclusion
Potassium is considered within the range of background.

Selenium

Tier 1 Evaluation
Five detected concentrations in the site data set exceed the background screening value of 0.48 mg/kg.

Slippage Test
K_c for selenium is 3. Two site samples exceed maximum background measurement. Because $K < K_c$, selenium passes the Slippage test.

WRS Test
No WRS test was performed because the site and background 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 1-9). The shape and location of the background and site box plots are influenced by the high percentage of nondetects (99 percent and 84 percent respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

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

Zinc

Tier 1 Evaluation
Fourteen site samples exceed the background screening value of 4.1E+1 mg/kg.

Slippage Test
K_c for zinc is 3, and just one site sample exceeds the maximum background measurement. Because $K < K_c$, zinc 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, interquartile range, and maximum are slightly higher than their respective background values (Figure 1-10).

Conclusion
Zinc will be carried forward for Tier 3 geochemical evaluation.

3.2 Subsurface Soil

Twenty-three TAL metals were evaluated in the Former Decon Complex (Parcels 46, 70, 93) subsurface soil. Antimony, cadmium, silver, and thallium had no detected concentrations in subsurface soil site samples, so no further discussion of these chemicals is included. Arsenic, chromium, lead, manganese, mercury, and vanadium had no detected concentrations above the background screening value, passing the Tier 1 evaluation. They will not be discussed any further.

The remaining thirteen elements were carried forward for Tier 2 evaluation. The statistical tests and box plots are discussed in detail below. Box plots are provided in Attachment 1.

Table 2 summarizes the Tier 1 and Tier 2 test results for subsurface soil.

Aluminum

Tier 1 Evaluation

Seven site samples exceed the background screening value of 1.4E+4 mg/kg.

Slippage Test

The critical value, K_c, for aluminum is three. Aluminum has no samples exceeding the maximum background measurement. Because $K < K_c$ aluminum passes the Slippage test.

WRS Test

The WRS test p-level of 0.19 indicates weak agreement between the site and background distributions.

Box Plot

Box plots for the site and background data sets are provided in Figure 1-11. The site 25th percentile is lower than that of background but the minimum and median are slightly higher than the corresponding background values. The site 75th percentile is higher than that of background and the site maximum is lower than background.

Conclusion

Because aluminum in subsurface soil cannot be considered within the range of background based exclusively on statistical comparisons, it will be carried forward for Tier 3 geochemical evaluation.

Barium

Tier 1 Evaluation

Three site samples exceed the background screening value of 2.3E+2 mg/kg.

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 0.0024 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum, 25th percentile, and median are elevated as compared to the corresponding background values (Figure 1-11). The site 75th percentile is slightly higher than the corresponding background value and the site maximum is significantly 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
Ten detected concentrations of beryllium in site samples exceeded the background screening value of 8.6E-1 mg/kg.

Slippage Test
K_c for beryllium is 3, and three site samples exceed the maximum background measurement. Because $K \leq K_c$ beryllium 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 the maximum are higher than the corresponding background values (Figure 1-12).

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

Calcium

Tier 1 Evaluation
Ten site samples exceed the background screening value of 6.4E+2 mg/kg.

Slippage Test
K_c for calcium is three, and no site samples exceed the maximum background measurement. Because $K < K_c$, calcium 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 minimum and interquartile range are higher than the corresponding background values (Figure 1-12). The shape and location of the site box plot is influenced by the percentage of nondetects (58 percent), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
The site MDC exceeded the background 95th UTL of 1,710 mg/kg.

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

Cobalt

Tier 1 Evaluation
Four detected concentrations in the site data set exceed the background screening value of 1.8E+1 mg/kg.

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

WRS Test
The p-level of 0.017 indicates a 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).

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
Eight detected concentrations in the site samples exceed the background screening value of 1.9E+1 mg/kg.

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

WRS Test
The p-level of 0.035 indicates a difference between the site and background distributions.

Box Plot
The site minimum, 25th percentile, and median are slightly higher than the corresponding background values (Figure 1-13). The site 75th percentile is significantly higher than background, and the site maximum is 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

Three detects of iron in site samples exceed the background screening value of 4.5E+4 mg/kg.

Slippage Test

The critical value, K_c, for iron is three. Three site samples exceed the maximum background measurement. Because $K \leq K_c$ iron passes the Slippage test.

WRS Test

The p-level of 0.054 indicates a difference between the site and background distributions.

Box Plot

The site minimum and interquartile range are slightly lower with respect to background (Figure 1-14). The p-level of 0.054 shows a difference, but the box plot shows the difference being site data is lower than background.

Conclusion

Iron is considered within the range of background.

Magnesium

Tier 1 Evaluation

Thirteen site samples exceed the background screening value of 7.7E+2 mg/kg.

Slippage Test

K_c for magnesium is three, and three site samples exceed the maximum background measurement. Because $K \leq K_c$, magnesium 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 the maximum are elevated with respect to background (Figure 1-14).

Conclusion

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

Nickel

Tier 1 Evaluation

Ten of the detected concentrations of nickel exceed the background screening value of 1.3E+1 mg/kg.

Slippage Test
K_c for nickel is three, and four site samples exceed maximum background measurement. Because $K > K_c$ nickel fails the Slippage test.

WRS Test
The p-level of 0.3 indicates good agreement between the site and background distributions.

Box Plot
The site 25th percentile and the median are similar to the corresponding background values (Figure 1-15).

Conclusion
Because nickel in subsurface soil failed the Slippage test, it will be carried forward for Tier 3 geochemical evaluation.

Potassium

Tier 1 Evaluation
Five site samples exceed the background screening value of 7.1E+2 mg/kg.

Slippage Test
K_c for potassium is three and no site samples exceed the maximum background measurement. Because $K < K_c$, potassium 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 minimum, 25th percentile, and median are lower than the corresponding background value (Figure 1-15). The shape and location of the site box plots are influenced by the high percentage of nondetects (69 percent), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
The maximum detected concentration of potassium exceeded the background 95th UTL of 1,420 mg/kg.

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
Ten detected concentrations in the site data set exceed the background screening value of 4.7E-1 mg/kg.

Slippage Test
The Slippage test is not performed because the maximum value for background is a nondetect.

WRS Test
No WRS test was performed because the site and background 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 1-16). The shape and location of the background and site box plots are influenced by the high percentage of nondetects (98 percent and 62 percent respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
The site MDC exceeded 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.

Sodium

Tier 1 Evaluation
One detected concentration in the site data set exceeds the background screening value of 7.0E+2 mg/kg.

Slippage Test
K_c for sodium is three and two site samples exceed the maximum background measurement. Because $K < K_c$, sodium passes the Slippage test.

WRS Test
No WRS test was performed because the site data set contains more than 50 percent nondetects.

Box Plot
The site 75th percentile and median are lower than the corresponding background value (Figure 1-16). The shape and location of the site box plots are influenced by the high percentage of nondetects (85 percent in both cases), 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 588 mg/kg.

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

Zinc

Tier 1 Evaluation

Eight site samples exceed the background screening value of 3.5E+1 mg/kg.

Slippage Test

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

WRS Test

No WRS test was performed because the site data set contains more than 50 percent nondetects.

Box Plot

The site minimum, 25th percentile and median are lower than the corresponding background value (Figure 1-17). The shape and location of the site box plot is influenced by the high percentage of nondetects (62 percent in both cases), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The site MDC of zinc exceeds the background 95th percentile of 85 mg/kg.

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 site-to-background comparisons for 23 metals in unfiltered groundwater samples.

Three metals (antimony, cadmium, and silver) had no detects in the site samples and are not considered any further. The remaining nineteen metals are carried forward for Tier 1 and Tier 2 evaluation. The results of these comparisons are discussed in detail below and summarized in Table 3. Box plots are provided in Attachment 1.

Aluminum

Tier 1 Evaluation

Three samples exceed the background screening value of 2.3E+0 mg/L.

Slippage Test

The critical value, K_c, for aluminum is three. Three site samples exceed the maximum background measurement. Because $K \leq K_c$, aluminum passes the Slippage test.

WRS Test

The p-level of 0.0537 indicates a weak agreement between the site and background distributions.

Box Plot
The site minimum, 25th percentile, and median are similar to the corresponding background values (Figure 1-18). The site 75th percentile is slightly higher than that of background, and the site maximum is significantly higher than that of background.

Conclusion
Aluminum will be carried forward for Tier 3 geochemical evaluation.

Arsenic

Tier 1 Evaluation
One detected concentration in site samples exceeds the background screening value of 1.8E-2 mg/L.

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

WRS Test
No WRS test was performed because the site and background data sets contain more than 50 percent nondetects.

Box Plot
The site minimum, interquartile range, and median are higher than the corresponding background values (Figure 1-18). The shape and location of the background and site box plots are influenced by the high percentage of nondetects (84 percent and 85 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 is considered within the range of background.

Barium

Tier 1 Evaluation
Nine site samples exceed the background screening value of 1.3E-1 mg/L.

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

WRS Test
The p-level of < 0.001 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 1-19).

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

Beryllium

Tier 1 Evaluation
One detected concentration in site samples exceeds the background screening value of 1.2E-3 mg/L.

Slippage Test
The maximum value for beryllium in background is a nondetect, so the Slippage test was not performed.

WRS Test
No WRS test was 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 1-19). The shape and location of the background and site box plot is influenced by the high percentage of nondetects (72 percent and 90 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 0.005 mg/L.

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

Calcium

Tier 1 Evaluation
Three detected concentrations in site samples exceed the background screening value of 5.6E+1 mg/L.

Slippage Test
K_c for calcium is three and no detects in site samples exceed the maximum background measurement. Because $K < K_c$, calcium passes the Slippage test.

WRS Test
The p-level of 0.17 indicates a weak agreement between the site and background distributions.

Box Plot
The site 25th percentile, median, and 75th percentile are slightly elevated as compared to their respective background values (Figure 1-20). Both site and background minimums are similar, and the site maximum is significantly lower 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
There is no background screening value for chromium. There were six detects in site samples.

Slippage Test
The maximum value for chromium is a nondetect, so the Slippage test was not performed.

WRS Test
The WRS test was not performed because the site and background 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 1-20). The shape and location of the background and site box plot is influenced by the high percentage of nondetects (100 percent and 70 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 detect in site samples exceeds the background screening value of 2.3E-2 mg/L.

Slippage Test
K_c for cobalt is three, 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 site and background data sets have > 50 percent nondetects.

Box Plot
The site minimum and median are lower than the corresponding background values (Figure 1-21). The site 25th percentile is similar to background, and the 75th percentile and maximum are higher than that of background. The shape and location of the background and site box plot is influenced by the high percentage of nondetects (94 percent and 85 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.

Copper

Tier 1 Evaluation
Two site samples exceed the background screening value of 2.5E-2 mg/L.

Slippage Test
K_c for copper is 3. Copper has no site samples that exceed the maximum background measurement. Because $K < K_c$, copper passes the Slippage test.

WRS Test
The WRS test was not performed because the site and background data sets have >50 percent nondetects.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-21). The shape and location of the background and site box plot is influenced by the high percentage of nondetects (82 percent and 85 percent respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
The MDC is less than the background 95th percentile of 0.207 mg/L.

Conclusion
Copper is considered to be within the range of background.

Iron

Tier 1 Evaluation
Nine detected concentrations in the site samples exceed the background screening value of 7.0E+0 mg/L.

Slippage Test
K_c for iron is 3, and three site samples exceed the maximum background measurement. Because $K < K_c$, iron passes the Slippage test.

WRS Test
The p-level of 0.0064 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum, 25th percentile, and median are similar to the corresponding background values (Figure 1-22). The site 75th percentile is slightly higher than that of background and the maximum is considerably higher than that of background.

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

Lead

Tier 1 Evaluation
Three samples exceed the background screening value of 8.0E-3 mg/L.

Slippage Test
The maximum result for lead in background sample data is a nondetect so this test cannot be performed for this element.

WRS Test
The WRS test was not performed because the site and background data sets have > 50 percent detects.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-22). The shape and location of the background and site box plot is influenced by the high percentage of nondetects (60 percent and 75 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 0.0434 mg/L.

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

Magnesium

Tier 1 Evaluation
Six site samples exceeds the background screening value of 2.1E+1 mg/L.

Slippage Test
The critical value, K_c, for magnesium is three. There are no site samples that exceed the maximum background measurement. Because $K < K_c$, magnesium passes the Slippage test.

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

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

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

Manganese

Tier 1 Evaluation
Eleven site samples exceed the background screening value of 5.8E-1 mg/L.

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 < 0.001 indicates a significant difference between the site and background distributions.

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

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. Five site samples have detected concentrations.

Slippage Test
The Slippage test was not performed because the maximum value in the background data is a nondetect.

WRS Test
The WRS test was not performed because the site and background data sets have > 50 percent nondetects.

Box Plot
The site interquartile range and maximum are higher than the corresponding background values (Figure 1-24). The shape and location of the background and site box plot is influenced by the high percentage of nondetects (100 percent and 75 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
Based on the Hot Measurement Test, mercury is considered to be within the range of background.

Nickel

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

Slippage Test
The Slippage test was not performed because the maximum value in the background data is a nondetect.

WRS Test
The WRS test was not performed because the site and background data sets have > 50 percent nondetects.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-24). The shape and location of the background and site box plot is influenced by the high percentage of nondetects (100 percent and 80 percent respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
Two site samples exceed 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.

Potassium

Tier 1 Evaluation
Just one detect in the site samples exceeds the background screening value of 7.2E+0 mg/L.

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

WRS Test
The p-level of 1.5E-3 indicates a difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are slightly elevated as compared to the corresponding background values (Figure 1-25). The site maximum is lower than that of background.

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

Selenium

Tier 1 Evaluation
No background screening values are available for selenium. Site samples have three detected concentrations.

Slippage Test
The slippage test was not performed because the maximum value in the background samples is a nondetect.

WRS Test
The WRS test was not performed because the site and background data sets have > 50 percent nondetects.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-25). The shape and location of the background and site box plot is influenced by the high percentage of nondetects (100 percent and 85 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 0.0971 mg/L.

Conclusion
Selenium is considered within the range of background, based on the Hot Measurement test.

Sodium

Tier 1 Evaluation
Thirteen site samples exceed the background screening value of 1.5E+1 mg/L.

Slippage Test
K_c for sodium is 3, and two site samples exceed the maximum background measurement. Because $K < K_c$, sodium 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 slightly higher than the corresponding background values (Figure 1-26). The site maximum is significantly higher than that of background.

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

Thallium

Tier 1 Evaluation
Two site samples exceed the background screening value of 1.5E-3 mg/L.

Slippage Test
The Slippage test was not performed because the maximum value in the background samples is a nondetect.

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

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-26). The shape and location of the background and site box plot is influenced by the high percentage of nondetects (88 percent and 90 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 0.010 mg/L

Conclusion
Thallium is considered within the range of background, based on the Hot Measurement test.

Vanadium

Tier 1 Evaluation
Two site samples exceed the background screening value of 1.7E-2 mg/L.

Slippage Test
The slippage test was not performed because the maximum value in the background samples is a nondetect.

WRS Test
The WRS test was not performed because the site and background data sets have less than 50 percent detects.

Box Plot
The site minimum, interquartile range, and maximum are higher than the corresponding background values (Figure 1-27). The shape and location of the background and site box plot is influenced by the high percentage of nondetects (96 percent and 85 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.

Zinc
Tier 1 Evaluation
One detect in the site samples exceeds the background screening value of 2.2E-1 mg/L.

Slippage Test
The K_c for zinc is 3. No site samples exceed the maximum background measurement. Because $K < K_c$, zinc passes the Slippage test.

WRS Test
The WRS test was not performed because the site and background data sets have less than 50 percent detects.

Box Plot
The site minimum and median are higher than the corresponding background values (Figure 1-27). The shape and location of the background and site box plot is influenced by the high percentage of nondetects (56 percent and 85 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 1.155 mg/L

Conclusion
Zinc is considered within the range of background.

3.4 Sediment

This section presents the results of the site-to-background comparisons for 23 TAL metals for the Former Decon Complex sediment samples. Antimony, silver, sodium, and thallium had no detected concentrations in sediment, so no further discussion of these elements is included. The

Tier 1 evaluation eliminated cobalt, mercury, nickel, and potassium from further consideration. These four elements had no site samples exceeding their respective background screening value. No further discussion of these metals is included.

The remaining fifteen metals underwent Tier 2 evaluation and are discussed in detail below. Box plots are provided in Attachment 1.

Table 4 summarizes the Tier 1 and Tier 2 results for sediment.

Aluminum

Tier 1 Evaluation

Four site samples exceed the background screening value of 8.6E+3 mg/kg.

Slippage Test

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

WRS Test

The WRS test p-level of 0.0016 indicates a significant difference between the site and background distributions.

Box Plot

Box plots for the site and background data sets are provided in Figure 1-28. The site minimum and interquartile range are significantly higher than the range of the corresponding background values. The site maximum is lower than that of background.

Conclusion

Because aluminum in sediment 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 1.1E+1 mg/kg.

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 0.012 indicates a difference between the site and background distributions.

Box Plot
Box plots for the site and background data sets are provided in Figure 1-28. The site minimum, 25th percentile, median, 75th percentile, and maximum are higher than the range of the corresponding background values.

Conclusion
Because arsenic in sediment 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 9.9E+1 mg/kg.

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 of 0.19 indicates weak agreement between the site and background distributions.

Box Plot
The site minimum, 25th percentile, and median are elevated as compared to the corresponding background values (Figure 1-29). The site 75th percentile and the maximum are lower than the corresponding background values.

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

Beryllium

Tier 1 Evaluation
Two site samples exceed the background screening value of 9.7E-1 mg/kg.

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

WRS Test
The p-level of 0.015 indicates a difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values, and the site maximum is lower than that of background (Figure 1-29).

Conclusion
Because beryllium in sediment 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 4.3E-1 mg/kg.

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

WRS Test
No WRS test was performed because the site data set contains > 50 percent nondetects.

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-30). The shape and location of the site box plot is influenced by the high percentage of nondetects (83 percent), 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 0.787 mg/kg.

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

Calcium

Tier 1 Evaluation
Five site samples exceed the background screening value of 1.1E+3 mg/kg.

Slippage Test
K_c for is 2, and three site samples exceed the maximum background measurement. Because $K > K_c$, calcium fails 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, interquartile range, and maximum are higher than the corresponding background values (Figure 1-30).

Conclusion
Because calcium in sediment 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 3.1E+1 mg/kg.

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

WRS Test
The p-level of 0.0092 indicates a significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are elevated with respect to the corresponding background range. The site maximum is lower than that of background (Figure 1-31).

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

Copper

Tier 1 Evaluation
Three site samples exceed the background screening value of 1.7E+1 mg/kg.

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 .0029 indicates significant difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are elevated as compared to the corresponding background. The site maximum is lower than that of background (Figure 1-31).

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

Iron

Tier 1 Evaluation

Two of the site samples exceed the background screening value of 3.5E+4 mg/kg.

Slippage Test

The critical value, 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 0.008 indicates a significant difference between the site and background distributions.

Box Plot

The site minimum and interquartile range are elevated as compared to the corresponding background. The site maximum is lower than that of background (Figure 1-32).

Conclusion

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

Lead

Tier 1 Evaluation

Three site samples exceed the background screening value of 3.8E+1 mg/kg.

Slippage Test

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

WRS Test

The p-level of 0.016 indicates a difference between the site and background distributions.

Box Plot

The site minimum and interquartile range are elevated with respect to background (Figure 1-32). The site maximum is lower than that of background.

Conclusion

Lead will be carried forward for Tier 3 geochemical evaluation.

Magnesium

Tier 1 Evaluation

One site sample exceeds the background screening value of 9.0E+2 mg/kg.

Slippage Test

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

WRS Test
The p-level of 0.015 indicates a difference between the site and background distributions.

Box Plot
The site minimum and interquartile range are elevated with respect to background (Figure 1-33).

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

Manganese

Tier 1 Evaluation
One site sample exceeds the background screening value of 7.1E+2 mg/kg.

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

WRS Test
The p-level of 0.25 indicates agreement between the site and background distributions.

Box Plot
The interquartile range is similar as compared to the respective background values. The site minimum and maximum are higher than that of background (Figure 1-33).

Conclusion
Manganese is considered within the range of background.

Selenium

Tier 1 Evaluation
Two site samples exceed the background screening value of 7.2E-1 mg/kg.

Slippage Test
The critical value, K_c, for selenium is two. One site sample exceeds the maximum background measurement. Because $K < K_c$, selenium passes the Slippage test.

WRS Test
No WRS test was performed because the site and background data sets contain > 50 percent nondetects.

Box Plot
The box plot shows the site minimum, interquartile range, and maximum elevated as compared to the respective background values (Figure 1-34). The shape and location of the background and site box plot is influenced by the high percentage of nondetects (93 percent and 67 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 1.03 mg/kg.

Conclusion
Because selenium in sediment failed statistical comparison to background, it is carried forward for Tier 3 geochemical evaluation.

Vanadium

Tier 1 Evaluation
One site sample exceeds the background screening value of 4.1E+1 mg/kg.

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 0.56 indicates strong agreement between the site and background distributions.

Box Plot
The box plot shows the site minimum, median, and 75th percentile elevated as compared to the corresponding background values. The site 25th percentile and the maximum are lower than that of background (Figure 1-34).

Conclusion
Site concentrations of vanadium are considered within the range of background.

Zinc

Tier 1 Evaluation
Five site samples exceed the background screening value of 5.3E+1mg/kg.

Slippage Test
K_c for zinc is 2. One site sample exceeds the maximum background measurement, because $K < K_c$, zinc 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 exceed their respective background values (Figure 1-35).

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

3.5 Surface Water

This section presents the results of the site-to-background comparisons for the 23 metals tested in surface water samples. Thirteen metals (antimony, beryllium, cadmium, chromium, cobalt, copper, lead, nickel, selenium, silver, sodium, thallium, and vanadium) had no detected concentrations in the site samples and are not discussed any further.

Aluminum, barium, iron, and zinc had no detected concentrations exceeding their respective background screening values. These metals are considered within the range of background based on the Tier 1 evaluation, and will not be tested or discussed further.

The remaining metals (arsenic, calcium, magnesium, manganese, mercury, and potassium) underwent Tier 2 evaluation and are discussed in detail below. Box plots are provided in Attachment 1.

Table 5 summarizes the Tier 1 and Tier 2 results for surface water.

Arsenic

Tier 1 Evaluation

One site sample exceeded the background screening value of 2.2E-3 mg/L.

Slippage Test

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

WRS Test

The WRS test was not performed because the background and site data sets have > 50 percent nondetects.

Box Plot

The site minimum and interquartile range are higher than the corresponding background values (Figure 1-36). The shape and location of the background and site box plots are influenced by the high percentage of nondetects (86 percent and 83 percent respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test

The site MDC for arsenic is less than the background 95th percentile of 0.0034 mg/L.

Conclusion

Arsenic is considered within the range of background.

Calcium

Tier 1 Evaluation

One detected concentration in site samples exceeds the background screening value of 2.5E+1 mg/L.

Slippage Test

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

WRS Test

The p-level of 0.15 indicates a slight difference between the site and background distributions.

Box Plot

The site minimum, 25th percentile, and median are higher than their respective background values (Figure 1-36). The site 75th percentile and maximum are both lower than those associated with background.

Conclusion

Because calcium in surface water 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 1.1E+1 mg/L.

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 0.29 indicates good agreement between the site and background distributions.

Box Plot

The site minimum, 25th percentile, and median are elevated as compared to the corresponding background values (Figure 1-37). The site 75th percentile and maximum are lower than the corresponding background values.

Conclusion

Magnesium is considered within the range of background.

Manganese

Tier 1 Evaluation

Two site samples exceed the background screening value of 5.6E-1 mg/L.

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

WRS Test
The p-level of 0.28 indicates agreement between the site and background distributions.

Box Plot
The site minimum, 25th percentile, and median are slightly elevated as compared to the corresponding background values (Figure 1-37). The site 75th percentile is higher than that of background, and the site maximum is lower than the corresponding background values.

Conclusion
Manganese is considered within the range of background.

Mercury

Tier 1 Evaluation
No background screening values are available for mercury. Two site samples had detected concentrations.

Slippage Test
The maximum background value is a nondetect, so the Slippage test was not performed.

WRS Test
The site and background data sets contain > 50 percent nondetects, so the WRS test could not be performed.

Box Plot
The site 25th percentile is lower than that of background, and the median and 75th percentile are the same as the corresponding background values (Figure 1-38). The shape and location of the background and site box plots are influenced by the high percentage of nondetects (100 percent and 67 percent respectively), and the replacement values of one-half the reporting limit, rather than detected concentrations.

Hot Measurement Test
The site MDC for mercury is less than the background 95th percentile of 0.000243 mg/L.

Conclusion
Mercury is considered within the range of background, based on the results of the Hot Measurement test.

Potassium

Tier 1 Evaluation
One site sample exceeds the background screening value of 2.6E+0 mg/L.

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

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

Box Plot
The site minimum and interquartile range are higher than the corresponding background values (Figure 1-38). The shape and location of the site box plot is influenced by the high 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 for potassium is less than the background 95th percentile of 4.251 mg/L.

Conclusion
Potassium is considered within the range of background, based on the results of the Hot Measurement test.

4.0 Summary and Conclusions

The statistical methodology used to compare the Former Decon Complex and background data sets for 23 elements in surface soil, subsurface soil, groundwater, sediment, and surface water 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 Wilcoxon rank sum test, and box-and-whisker plots were prepared to visually compare the two data sets and properly interpret the WRS test results. If the Slippage test and/or the WRS test could not be performed, the Hot Measurement test was done as part of the Tier 2 statistical evaluation. Analytes that underwent Tier 2 evaluation and failed any component of the statistical site-to-background comparison are carried forward for Tier 3 geochemical evaluation to determine if natural processes can explain the elevated concentrations.

Tables 1 through 5 summarize the comparison test results and the metals carried forward for geochemical evaluation.

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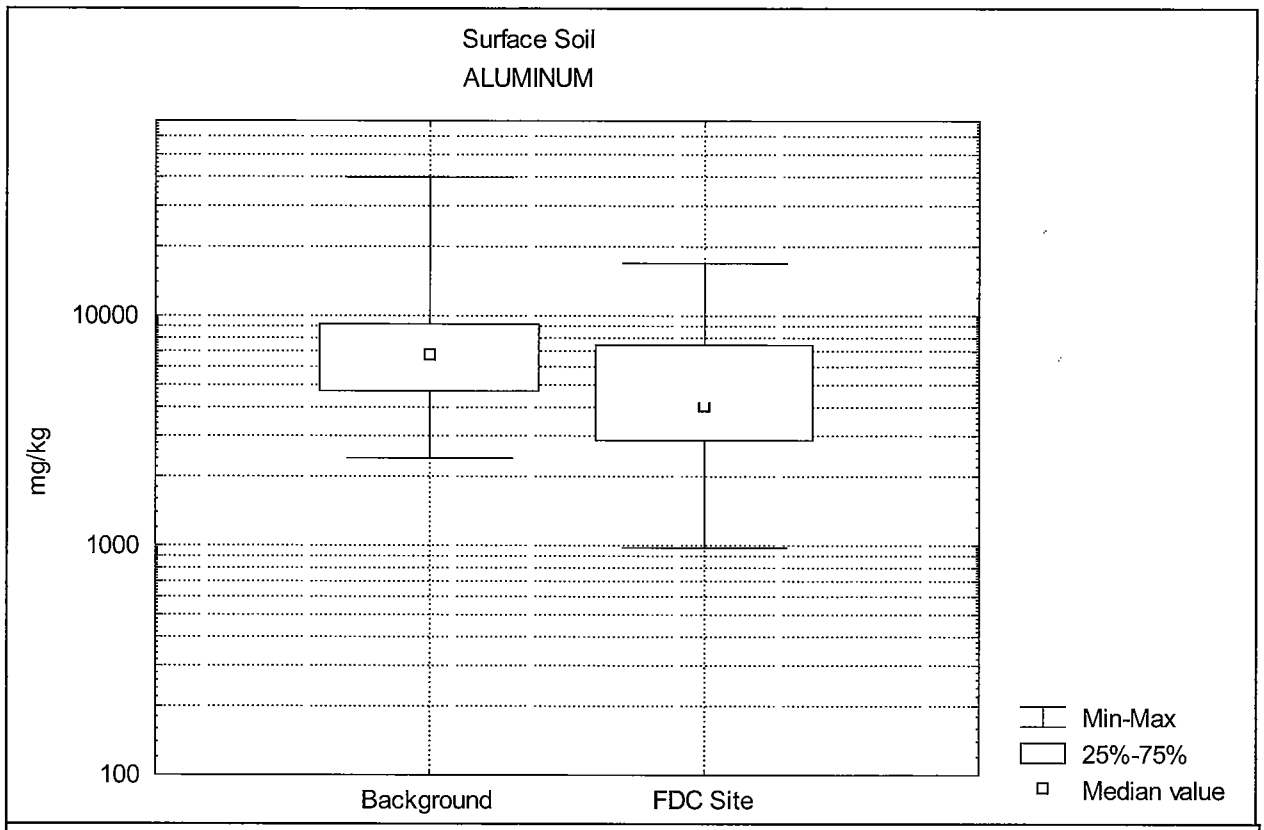
ATTACHMENT 1

Figure 1-1


Surface Soil
ALUMINUM
mg/kg
10000
1000
100
Background
FDC Site
Min-Max
25%-75%
Median value

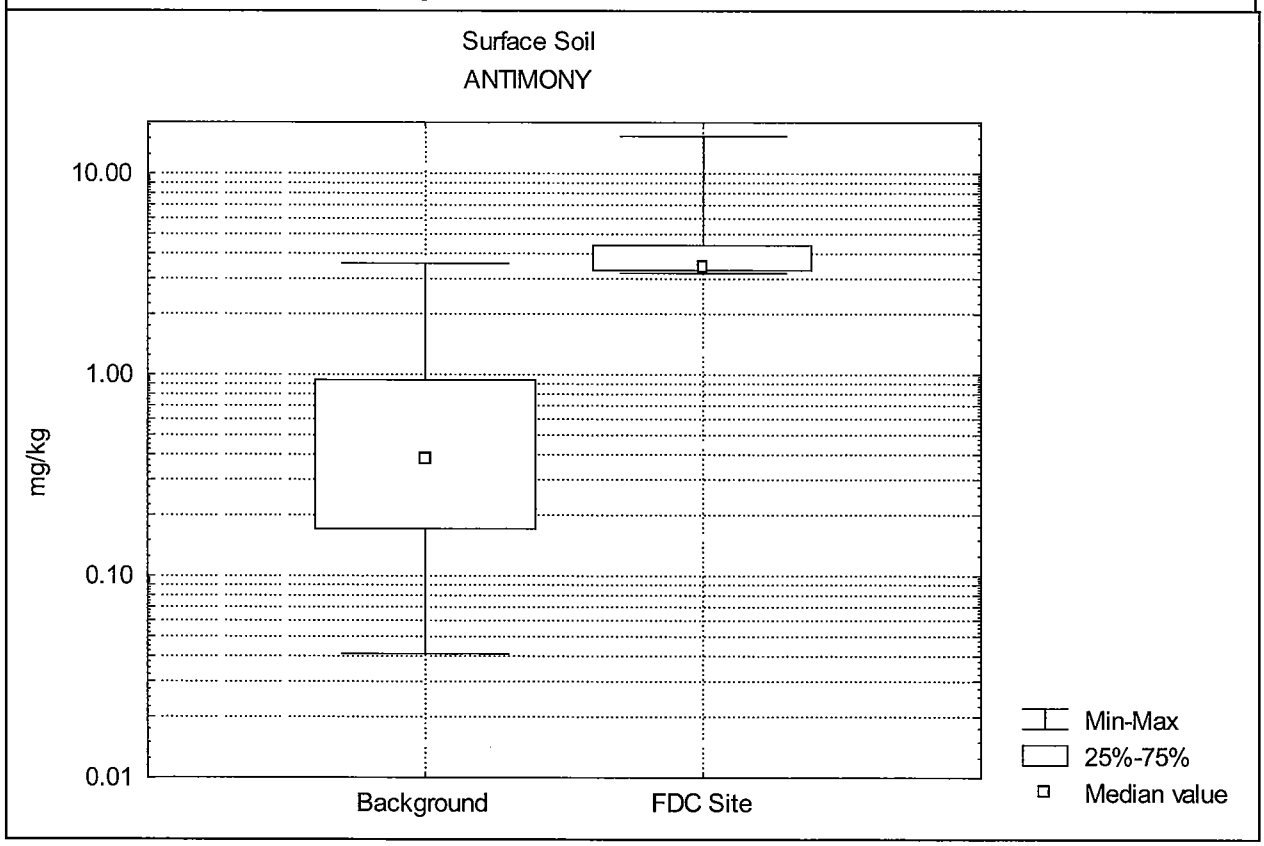
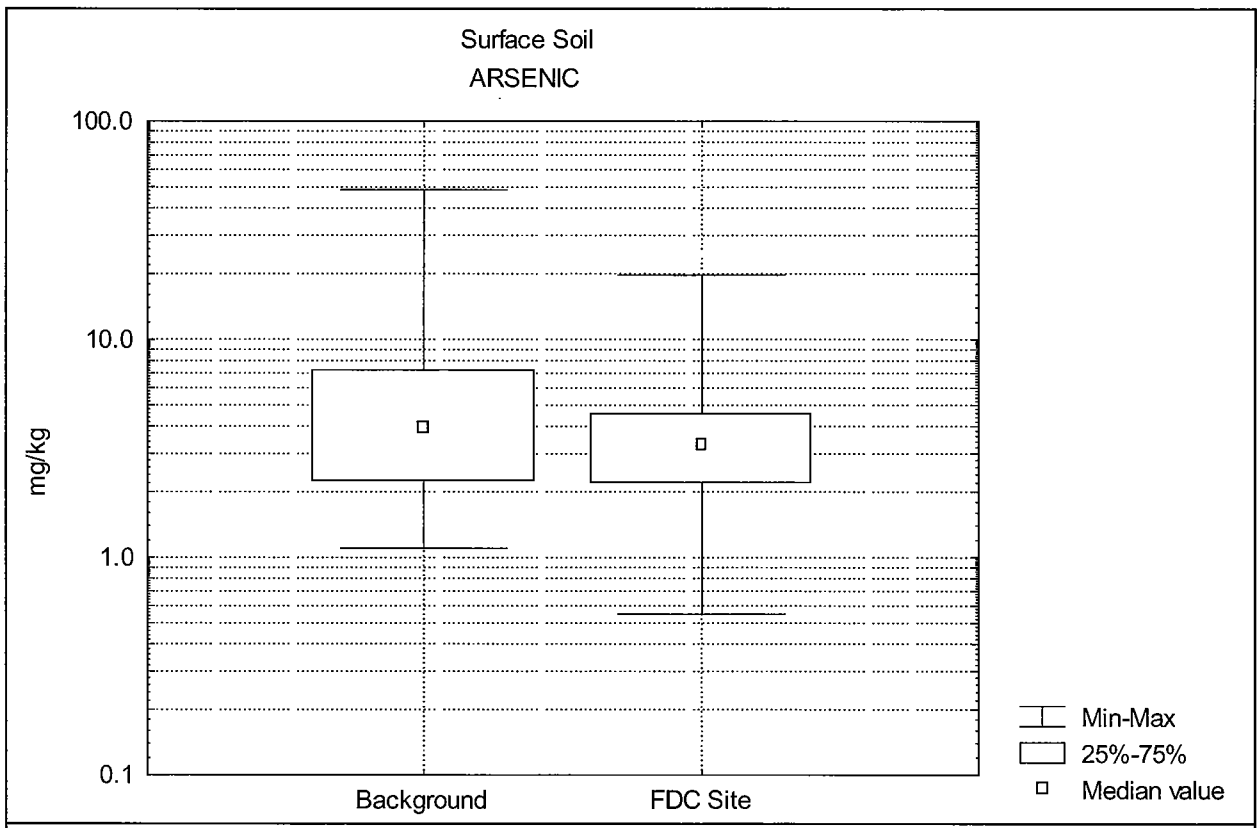

Surface Soil
ANTIMONY
mg/kg
10.00
1.00
0.10
0.01
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-2


Surface Soil
ARSENIC
100.0
10.0
1.0
0.1
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

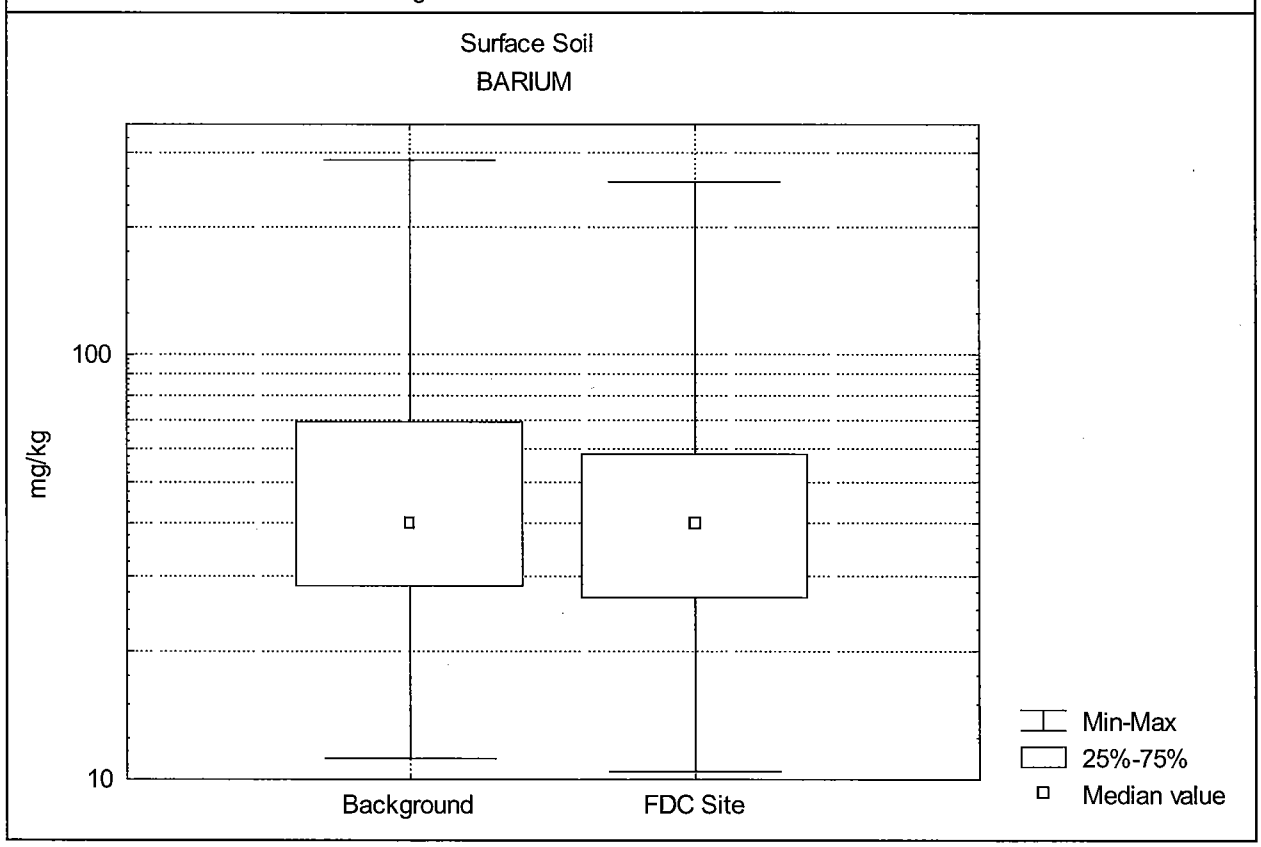
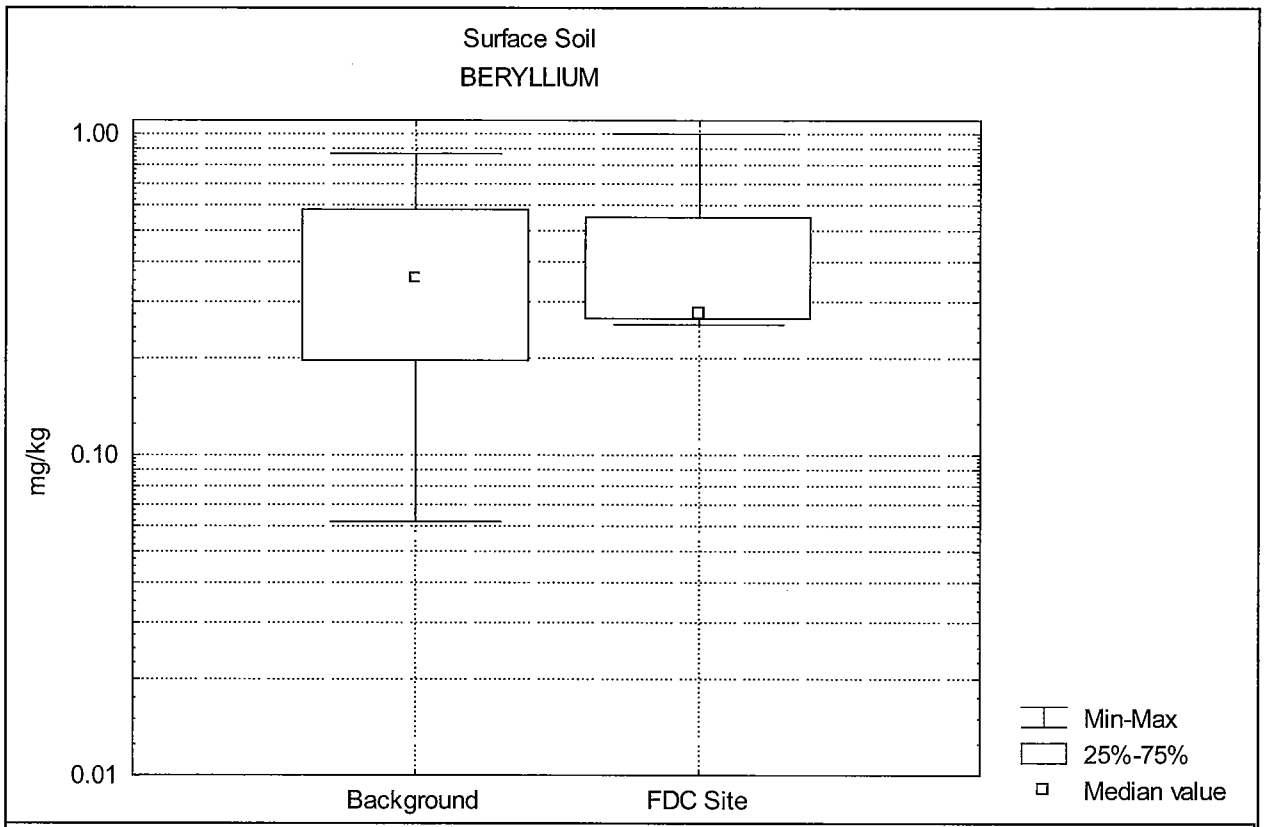

Surface Soil
BARIUM
100
10
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-3


Surface Soil
BERYLLIUM
1.00
0.10
0.01
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

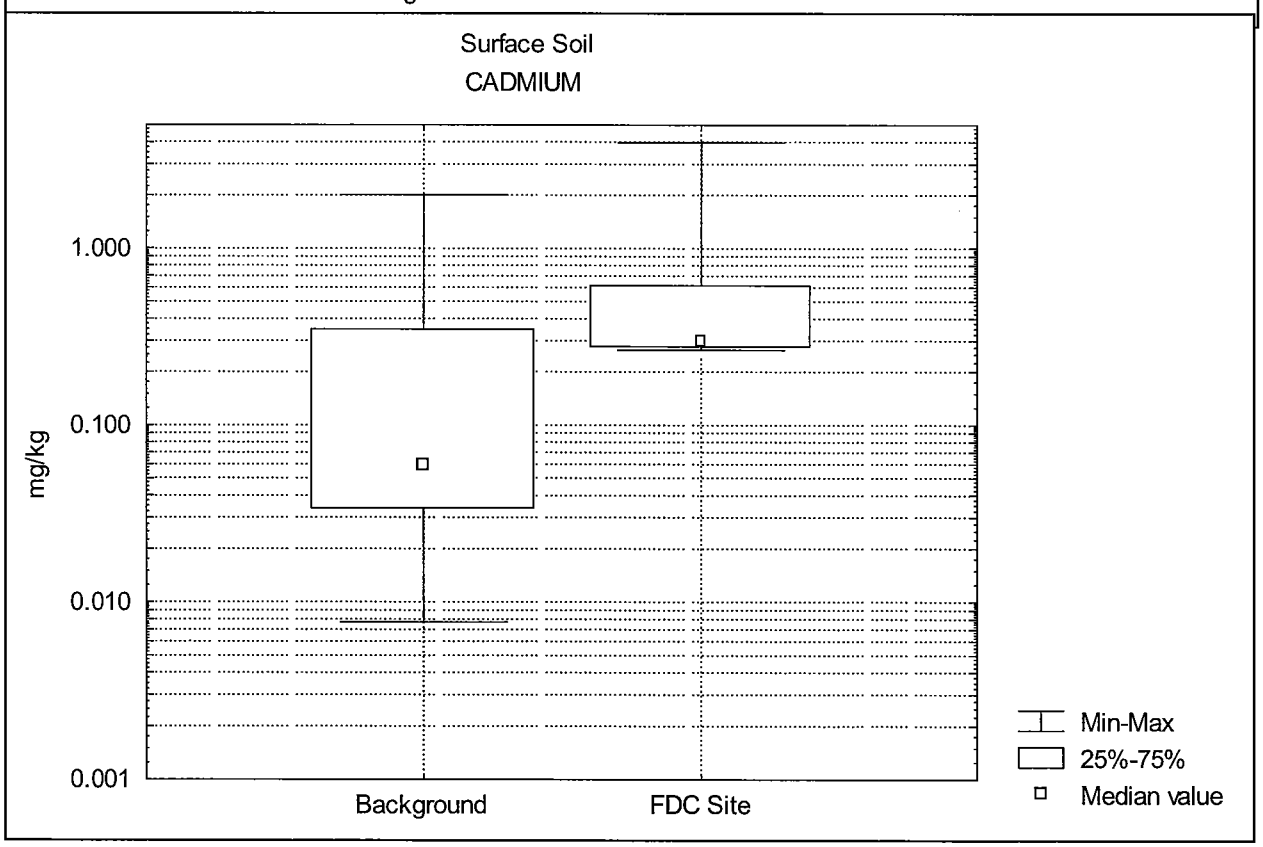
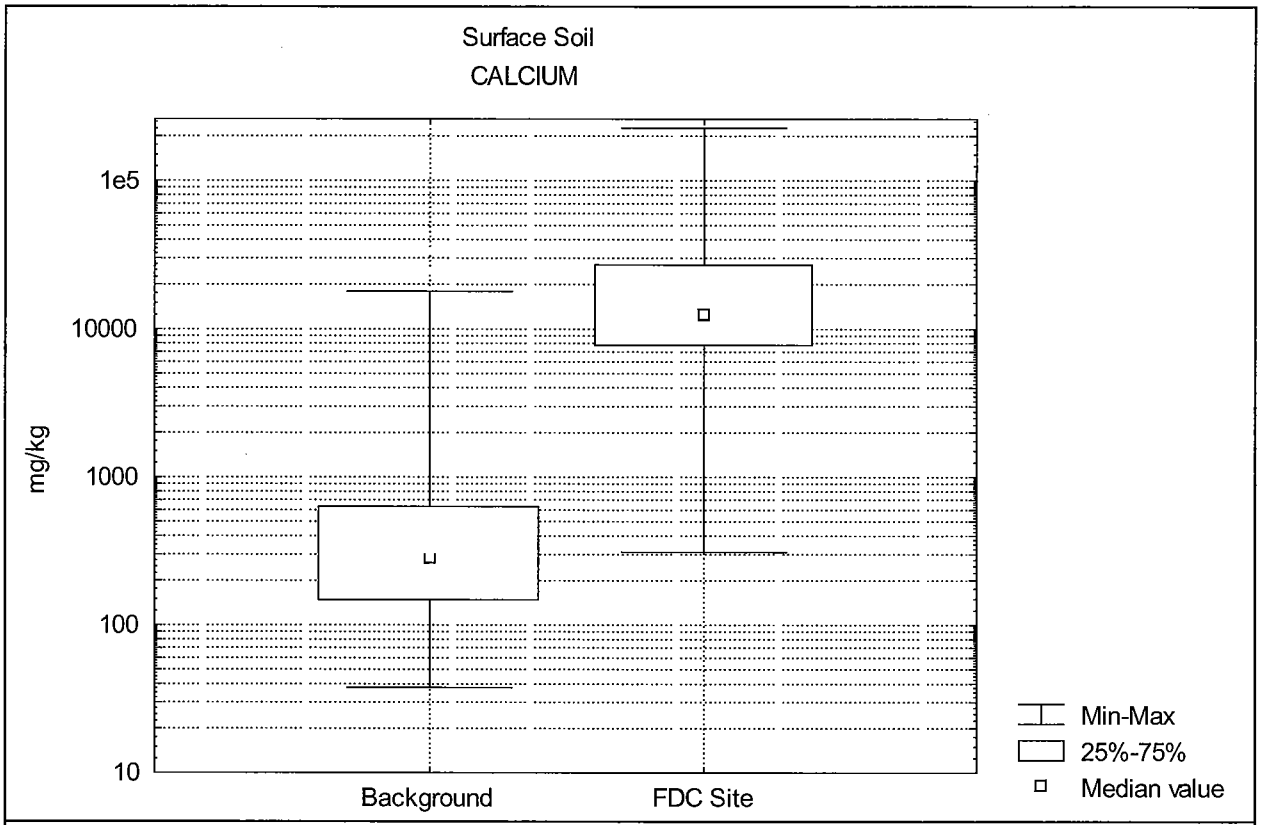

Surface Soil
CADMIUM
1.000
0.100
0.010
0.001
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-4


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

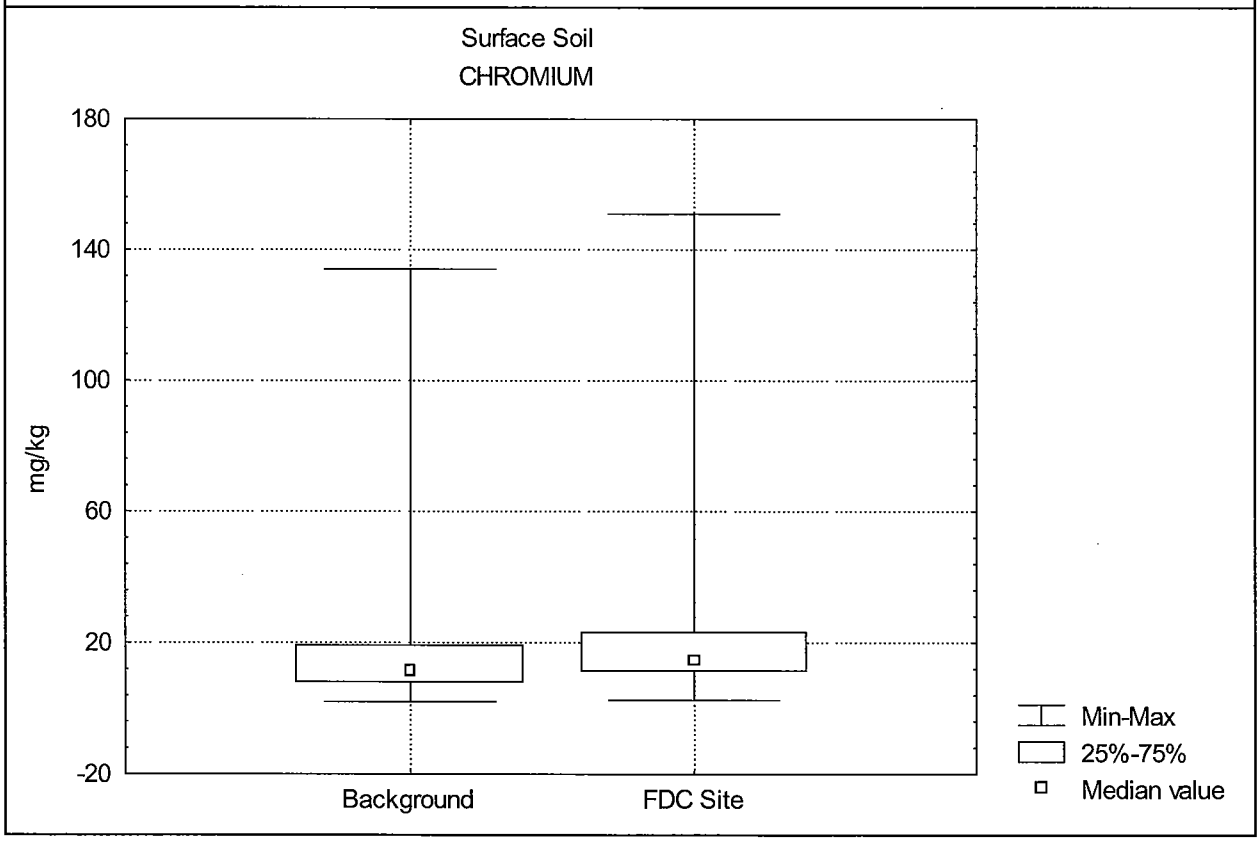
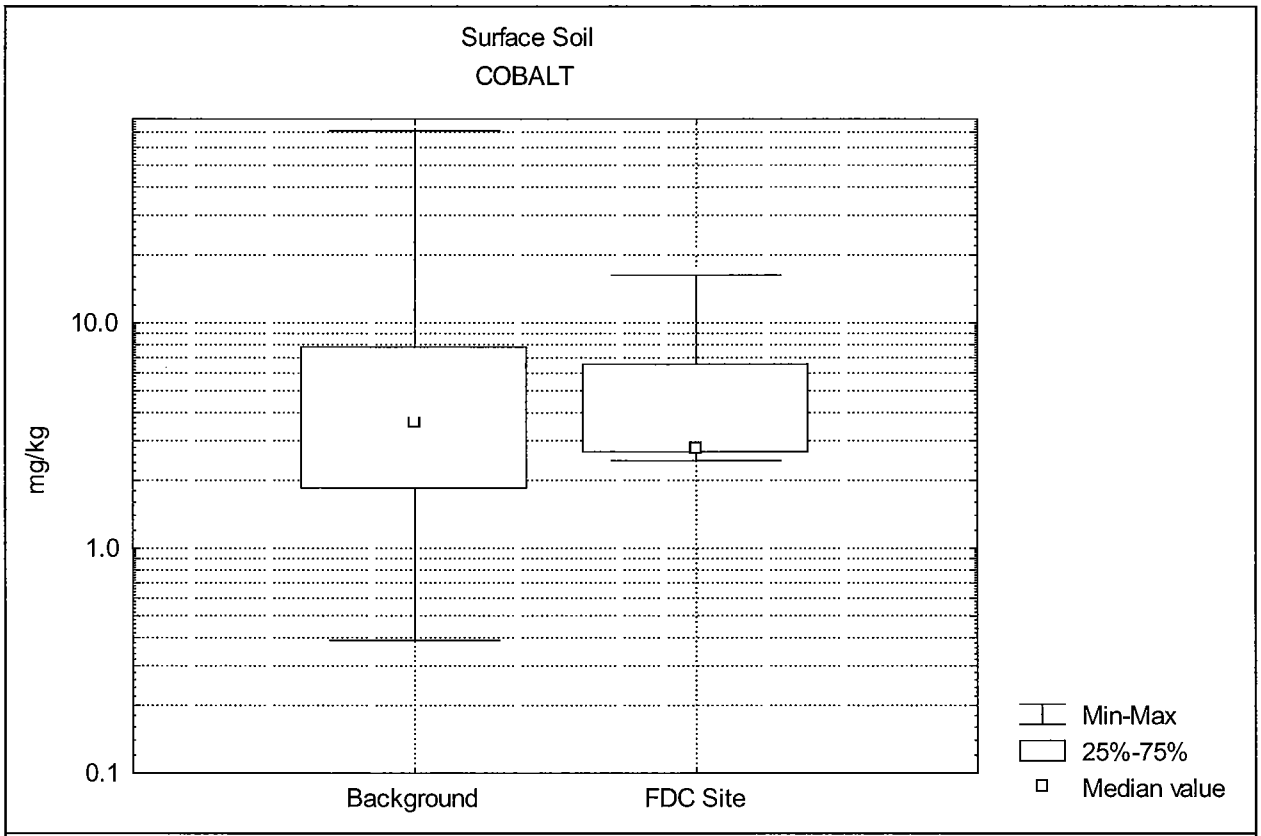

Surface Soil
CHROMIUM
180
140
100
60
20
-20
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-5


Surface Soil
COBALT
mg/kg
10.0
1.0
0.1
Background
FDC Site
Min-Max
25%-75%
Median value

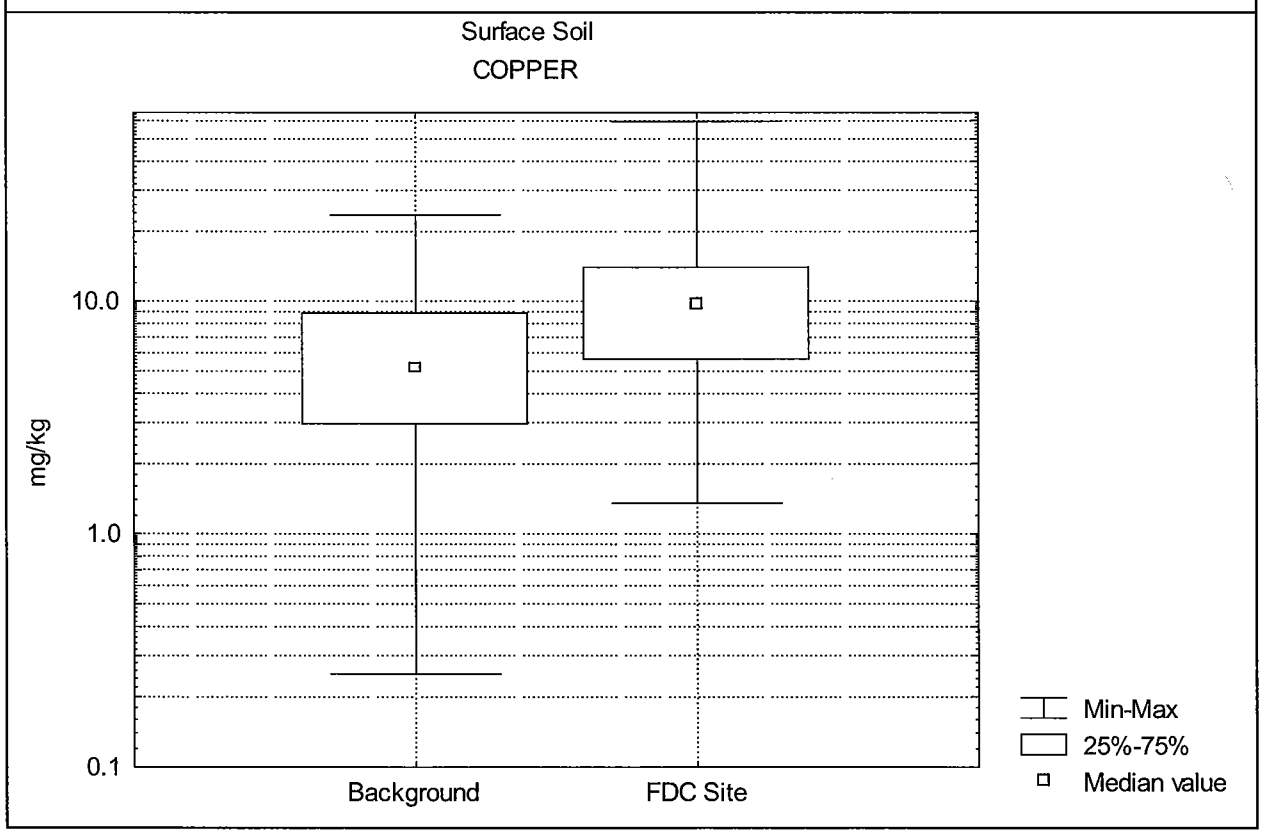

Surface Soil
COPPER
mg/kg
10.0
1.0
0.1
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-6

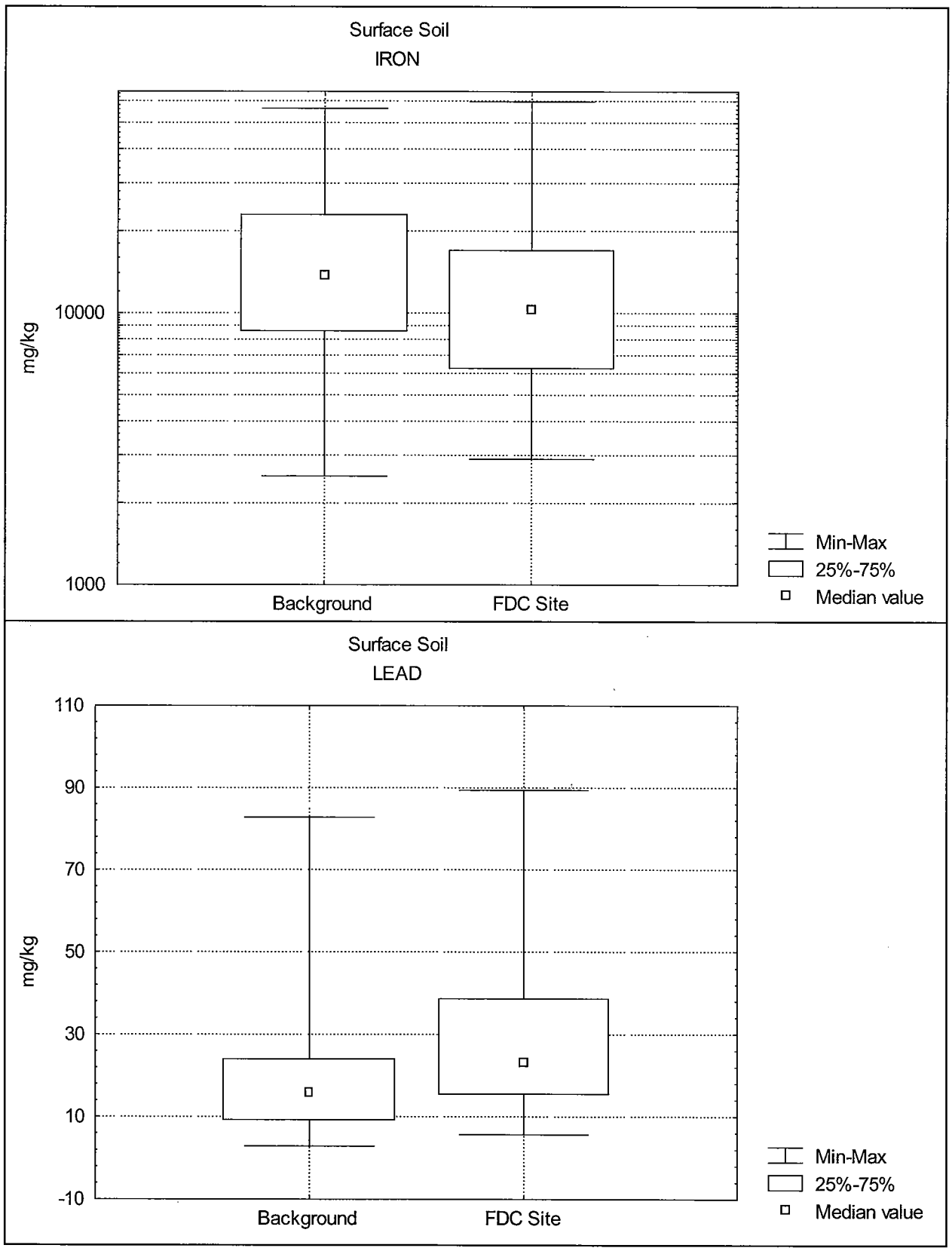
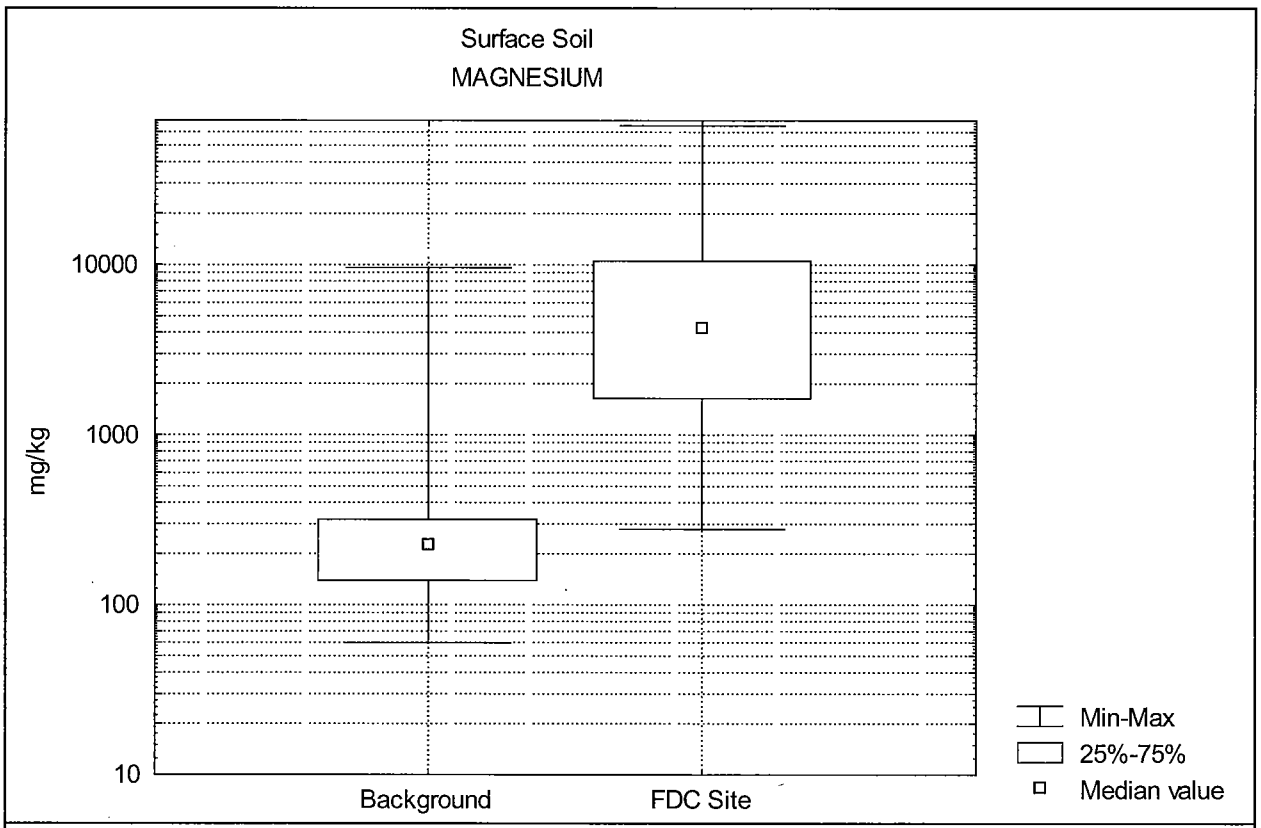

Surface Soil
IRON
mg/kg
10000
1000
Background
FDC Site
Min-Max
25%-75%
Median value
Surface Soil
LEAD
mg/kg
110
90
70
50
30
10
-10
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-7


Surface Soil
MAGNESIUM
mg/kg
10000
1000
100
10
Background
FDC Site
Min-Max
25%-75%
Median value

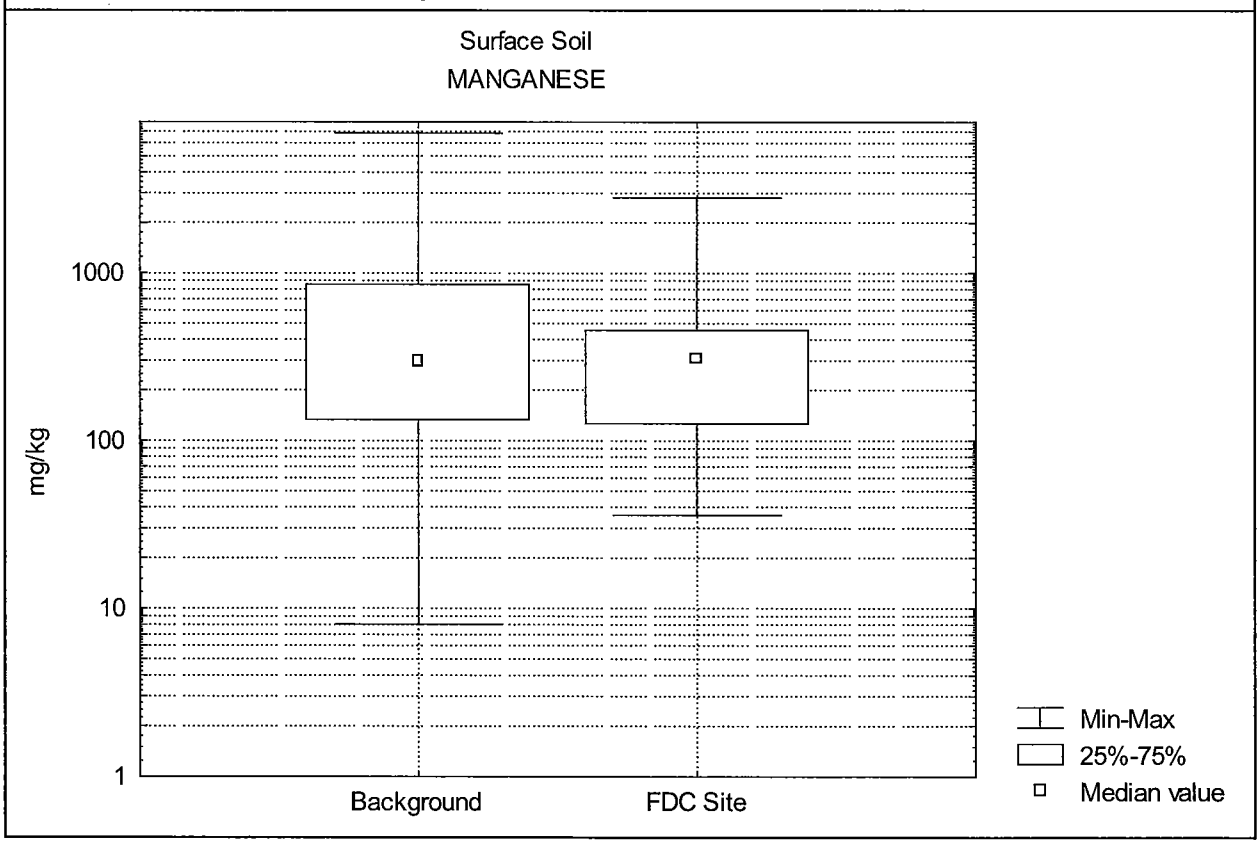
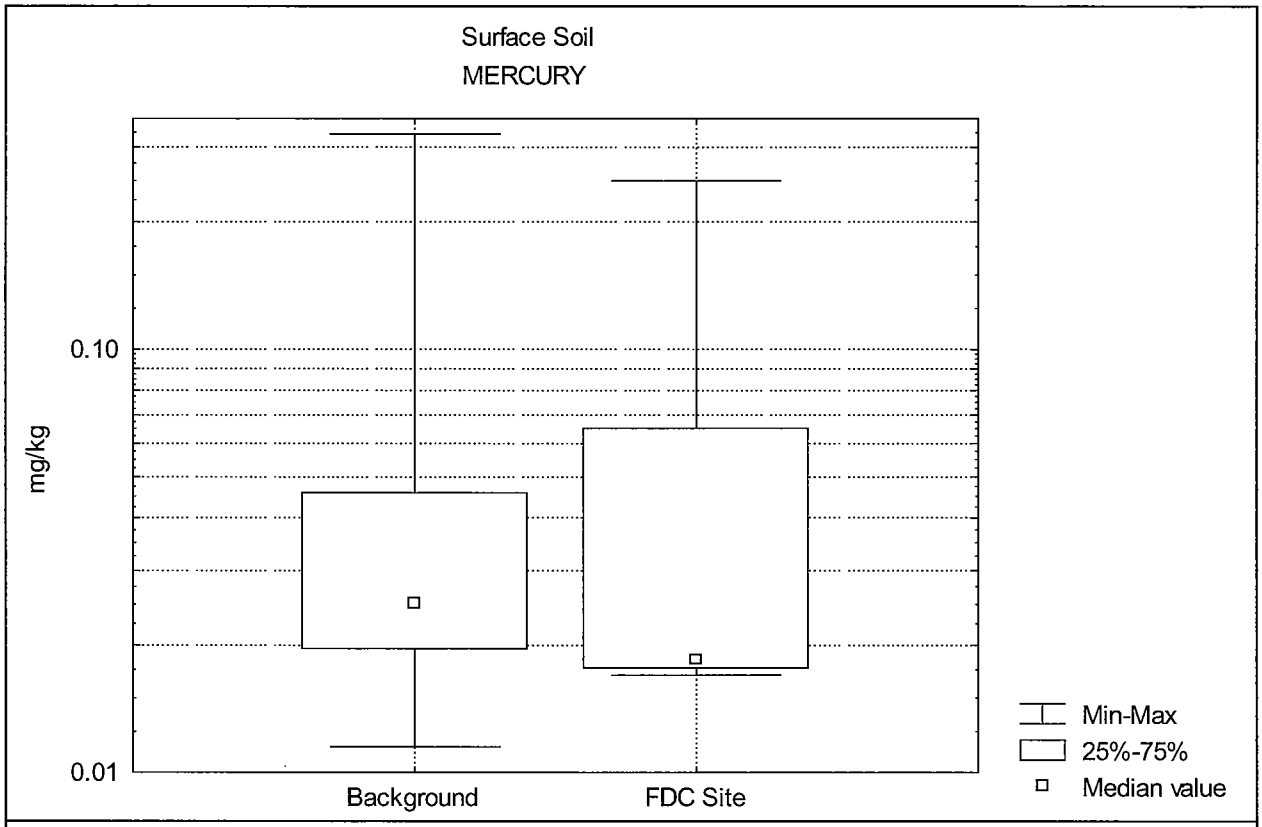

Surface Soil
MANGANESE
mg/kg
1000
100
10
1
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-8


Surface Soil
MERCURY
mg/kg
0.10
0.01
Background
FDC Site
Min-Max
25%-75%
Median value

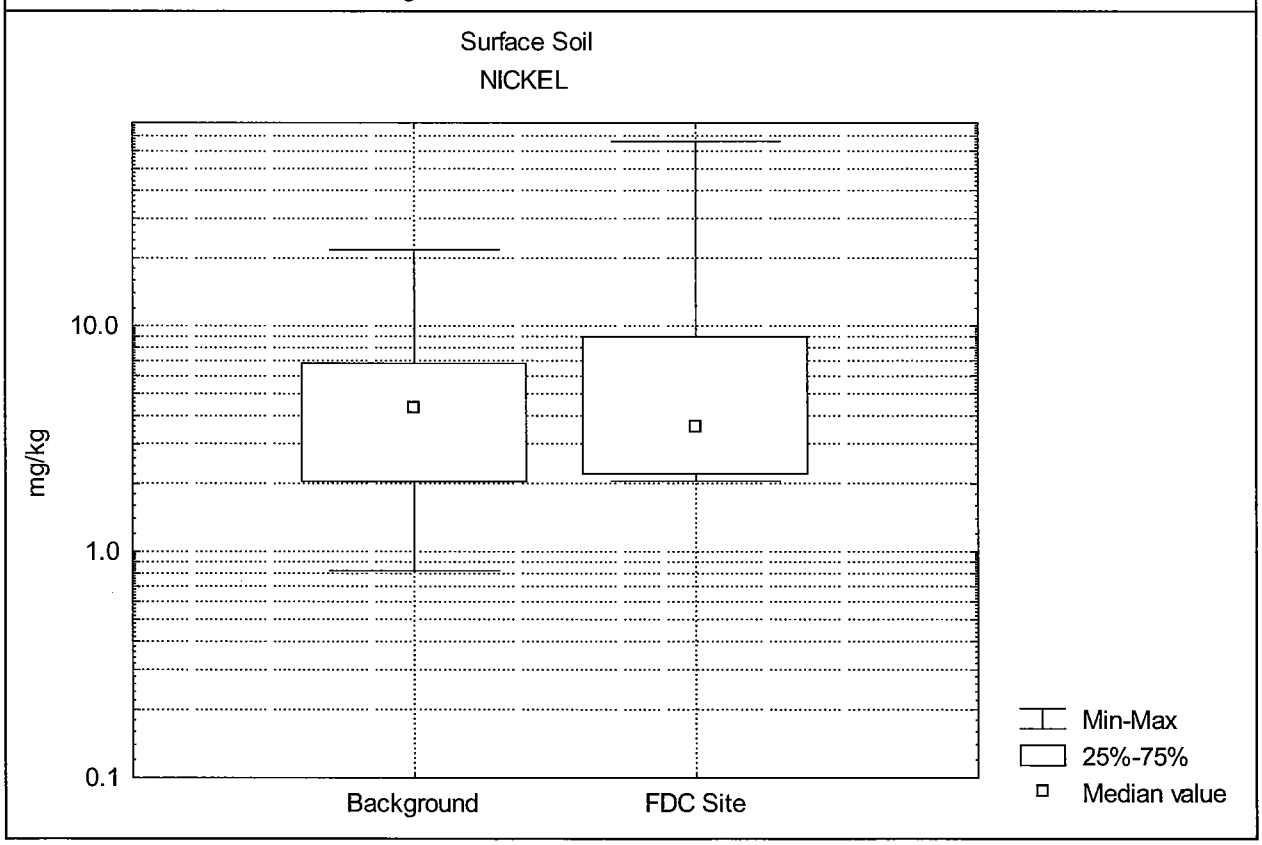

Surface Soil
NICKEL
mg/kg
10.0
1.0
0.1
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-9

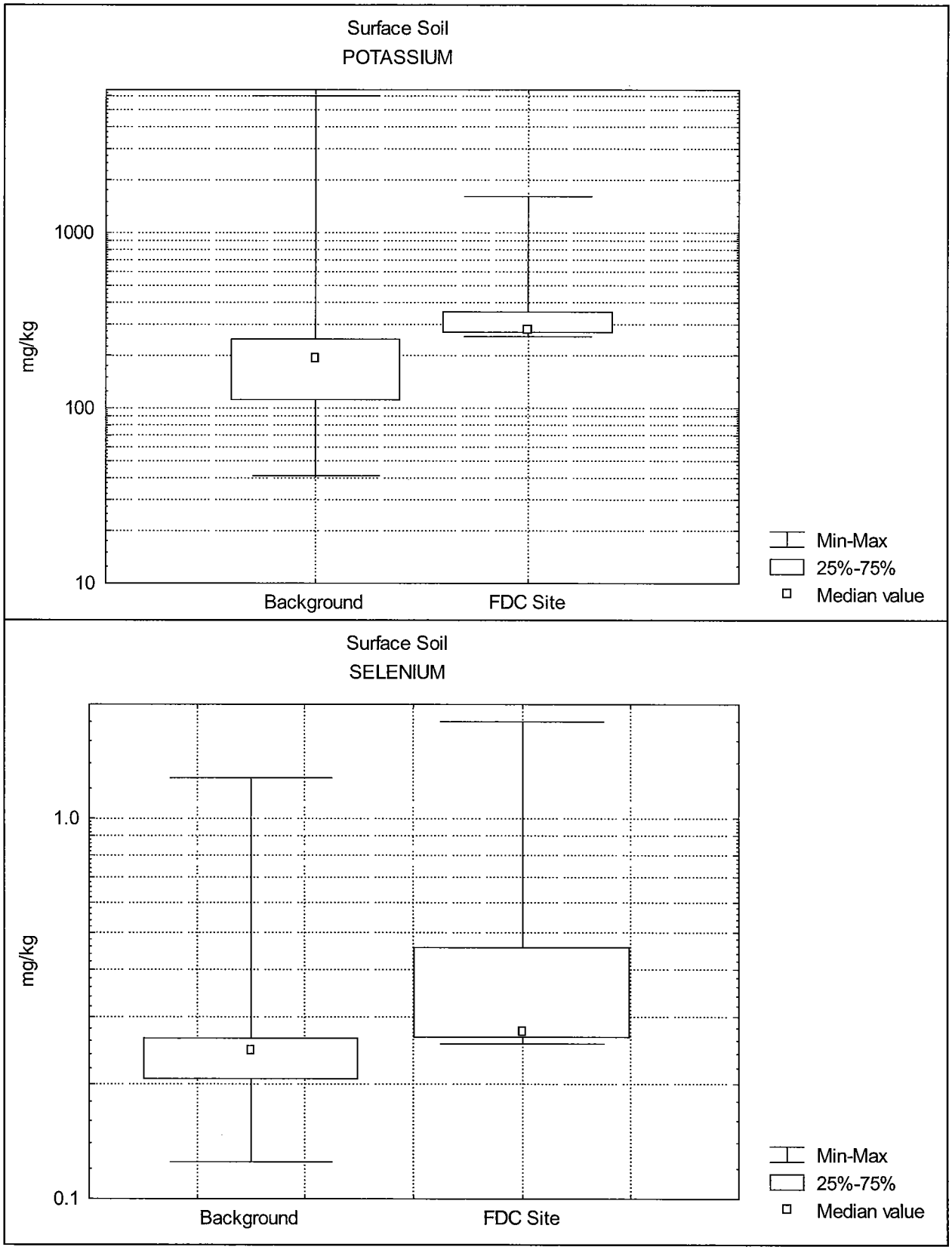

Surface Soil
POTASSIUM
mg/kg
1000
100
10
Background
FDC Site
Min-Max
25%-75%
Median value
Surface Soil
SELENIUM
mg/kg
1.0
0.1
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-10

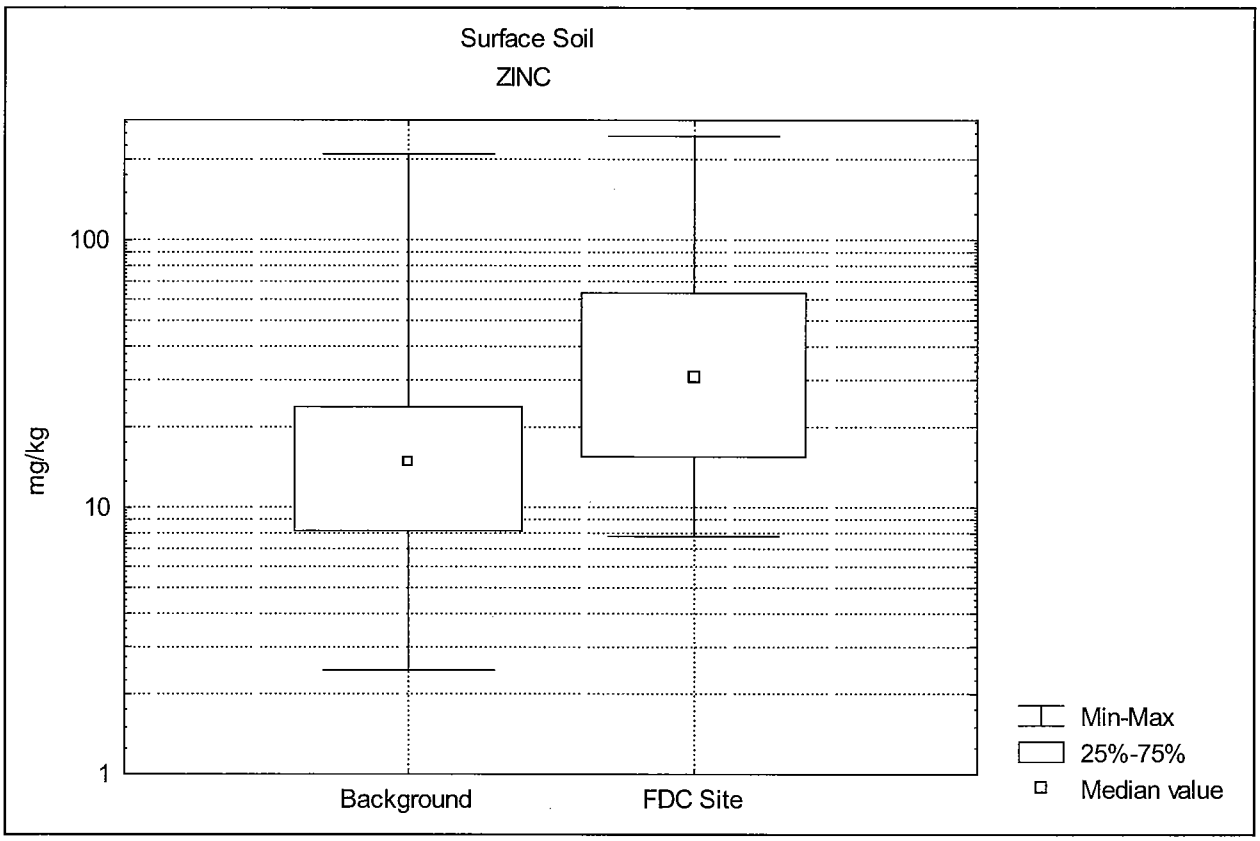
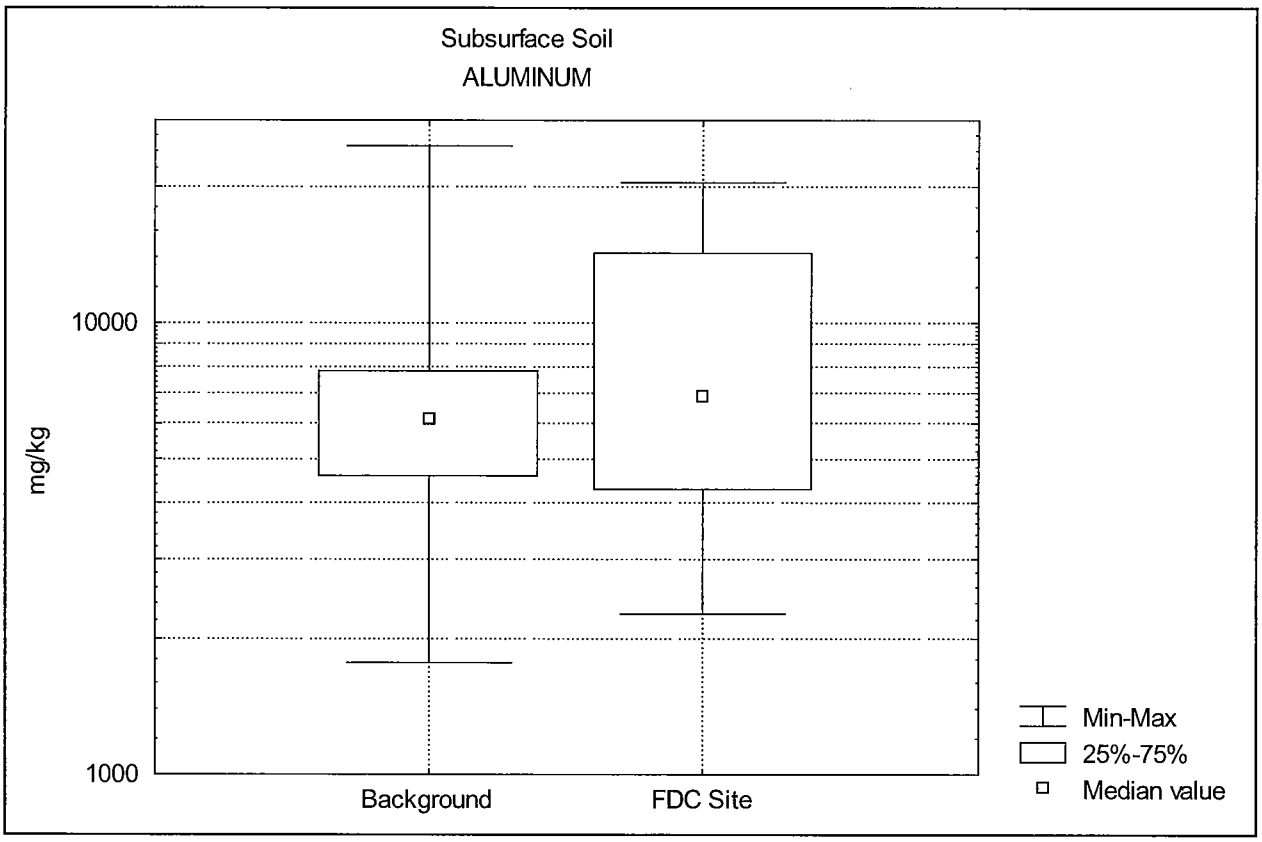

Surface Soil
ZINC
mg/kg
100
10
1
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-11


Subsurface Soil
ALUMINUM
mg/kg
10000
1000
Background
FDC Site
Min-Max
25%-75%
Median value

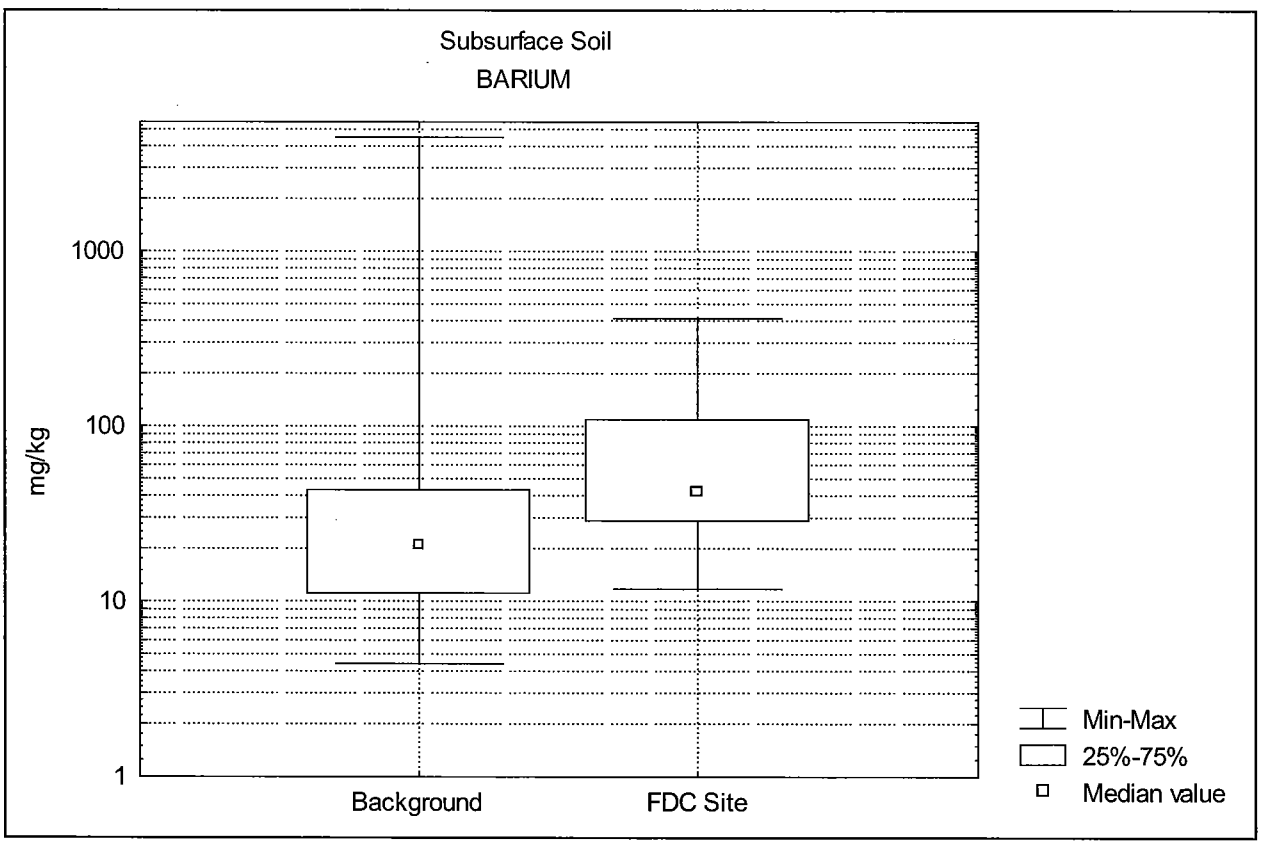

Subsurface Soil
BARIUM
mg/kg
1000
100
10
1
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-12

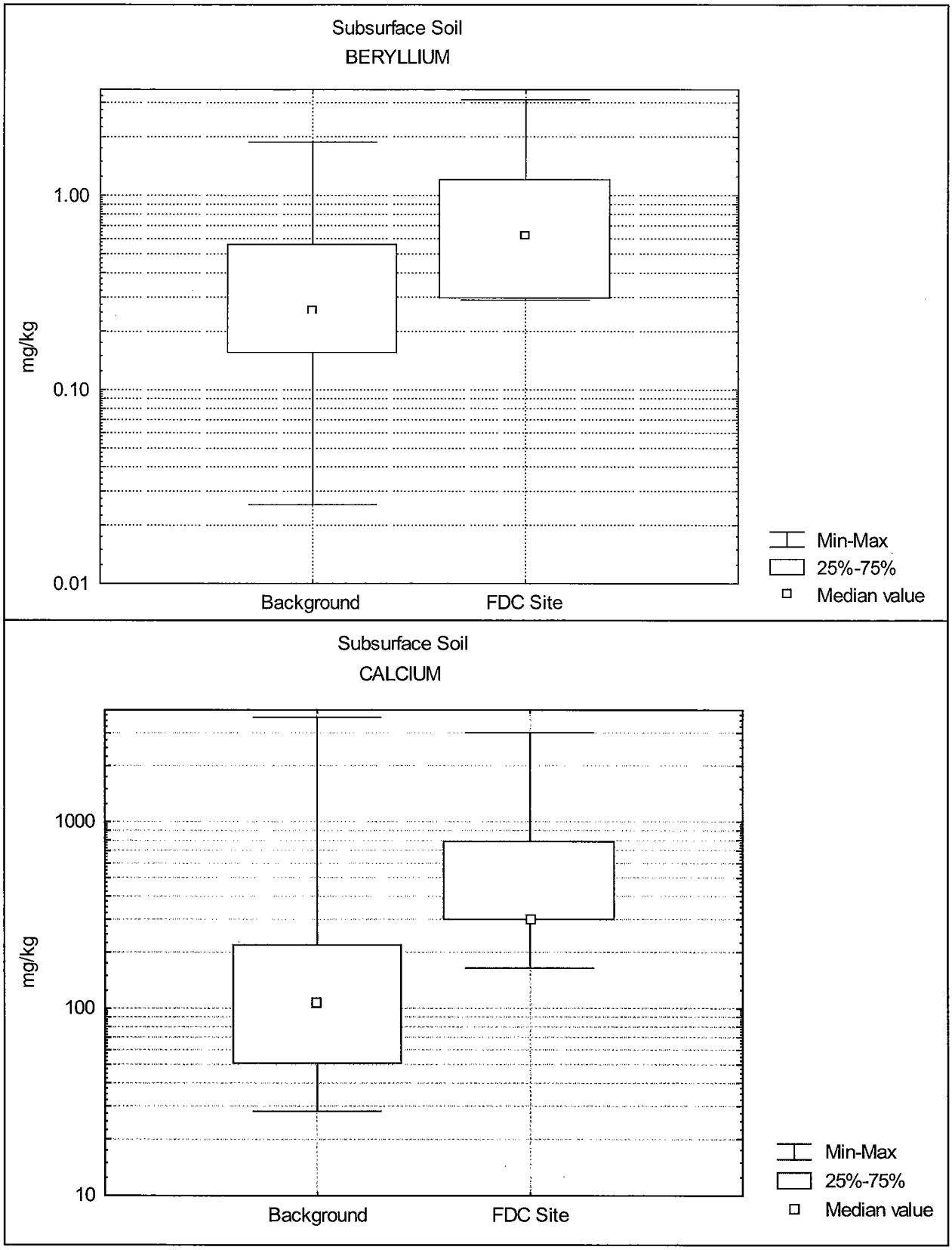

Subsurface Soil
BERYLLIUM
mg/kg
1.00
0.10
0.01
Background
FDC Site
Min-Max
25%-75%
Median value
Subsurface Soil
CALCIUM
mg/kg
1000
100
10
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-13

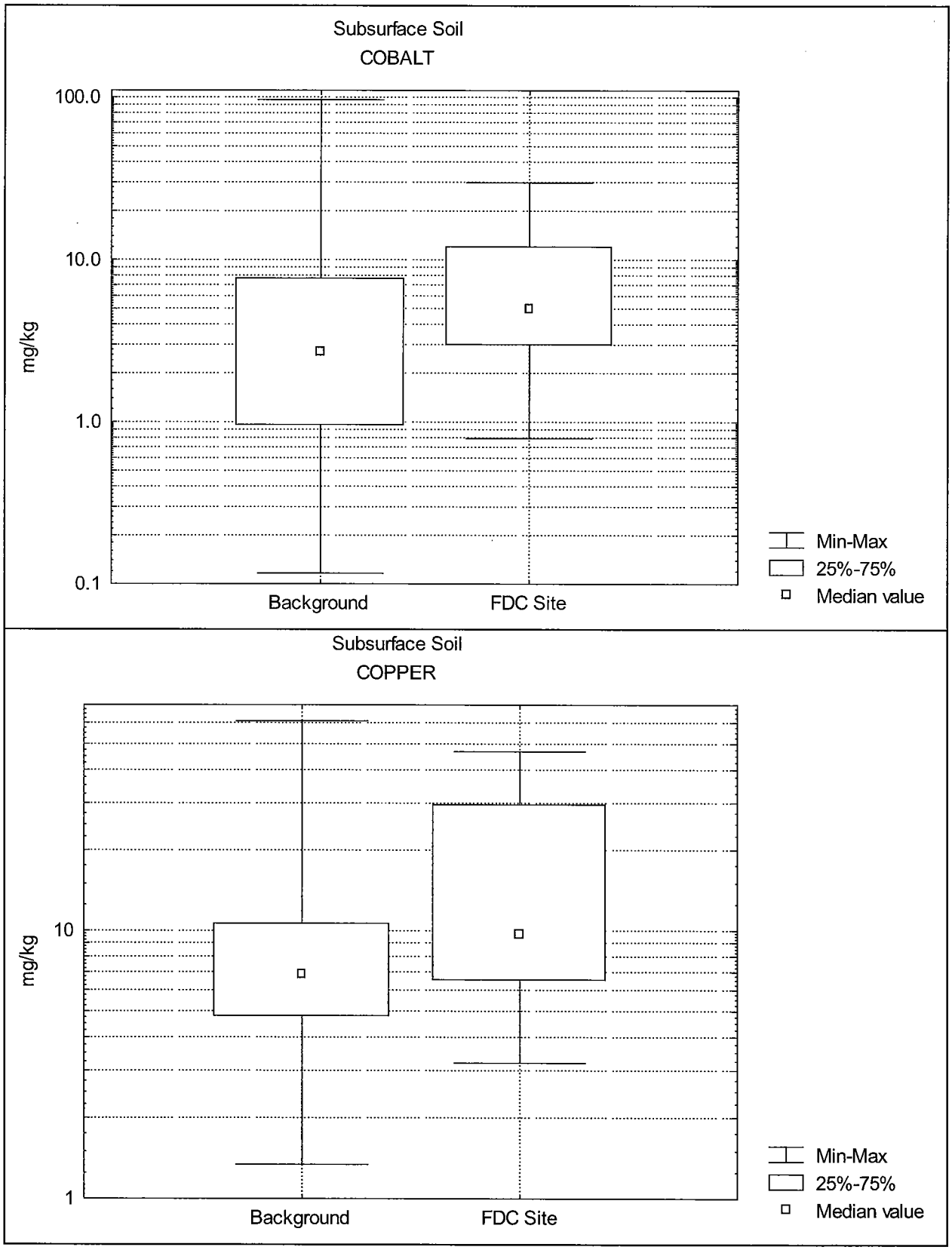

Subsurface Soil
COBALT
100.0
10.0
1.0
0.1
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value
Subsurface Soil
COPPER
10
1
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-14

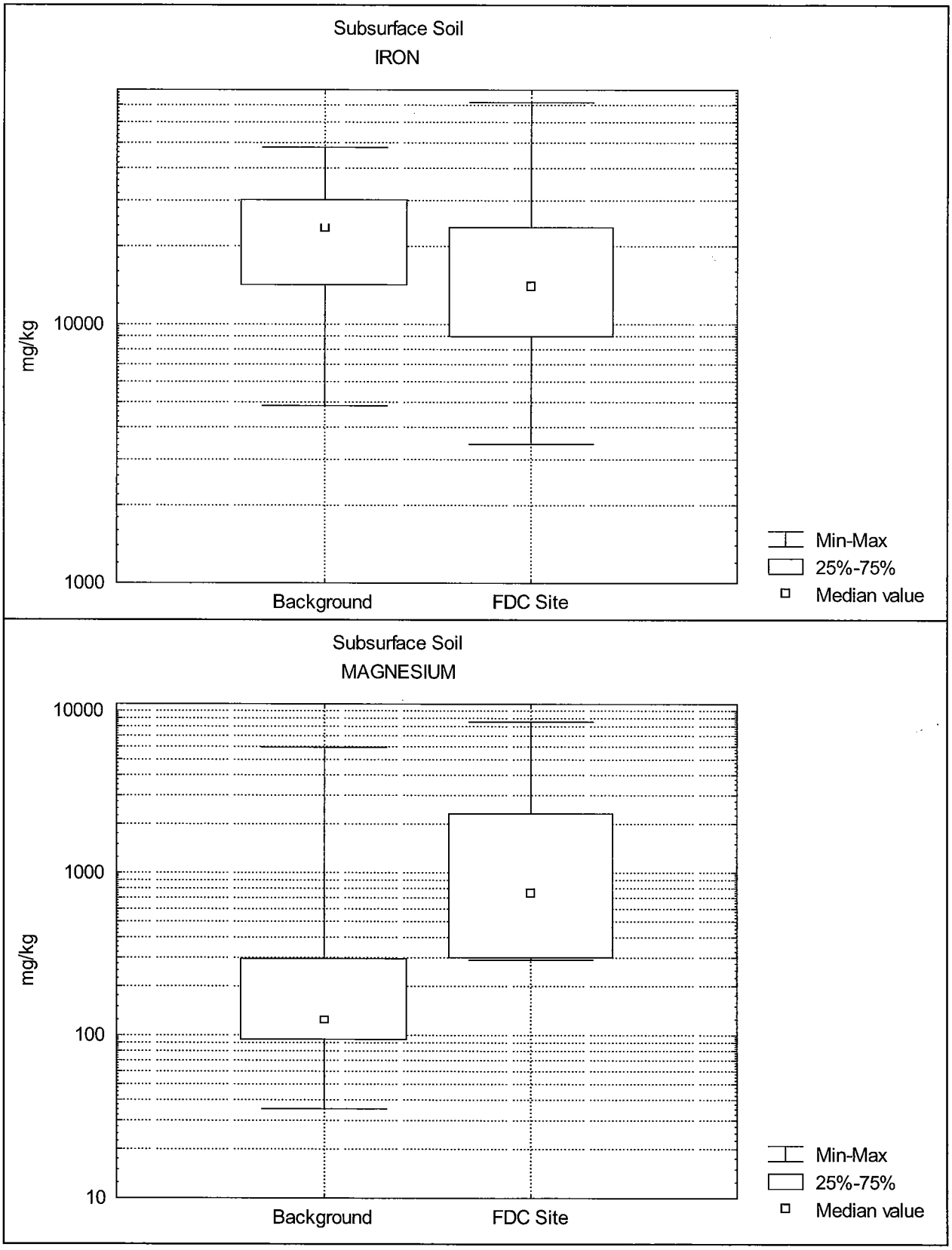

Subsurface Soil
IRON
mg/kg
10000
1000
Background
FDC Site
Min-Max
25%-75%
Median value
Subsurface Soil
MAGNESIUM
mg/kg
10000
1000
100
10
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-15

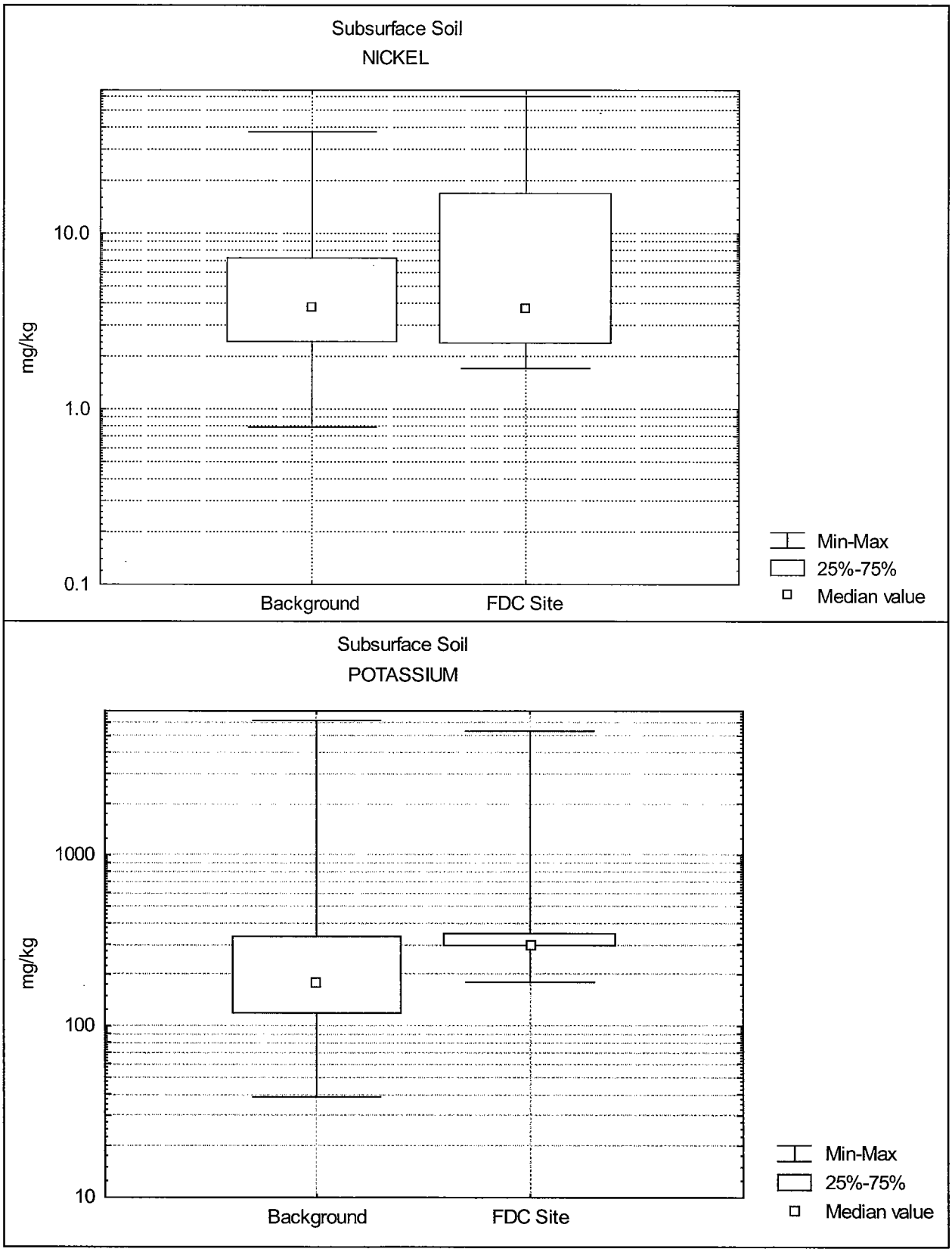

Subsurface Soil
NICKEL
mg/kg
10.0
1.0
0.1
Background
FDC Site
Min-Max
25%-75%
Median value
Subsurface Soil
POTASSIUM
mg/kg
1000
100
10
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-16

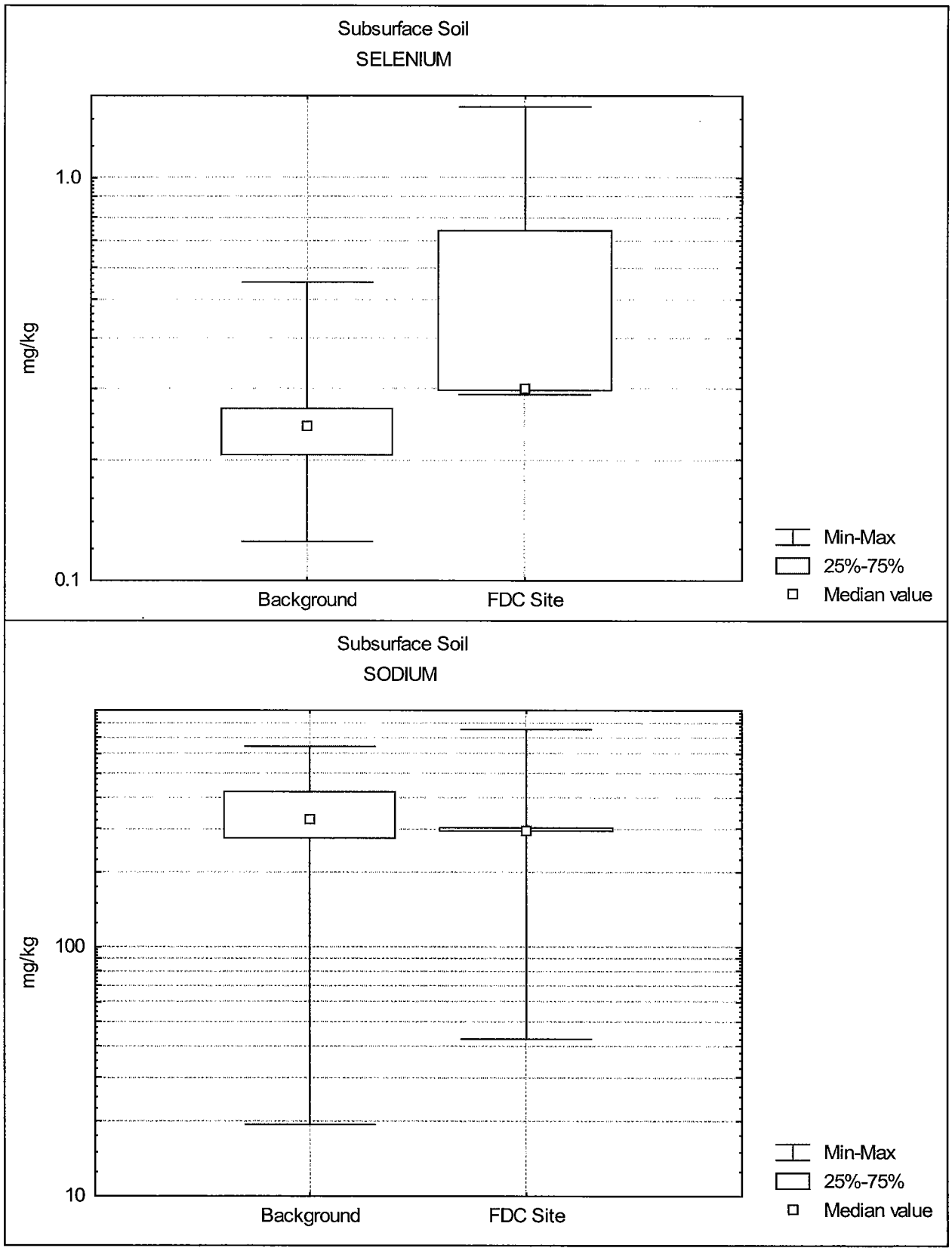

Subsurface Soil
SELENIUM
mg/kg
1.0
0.1
Background
FDC Site
Min-Max
25%-75%
Median value
Subsurface Soil
SODIUM
mg/kg
100
10
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-17

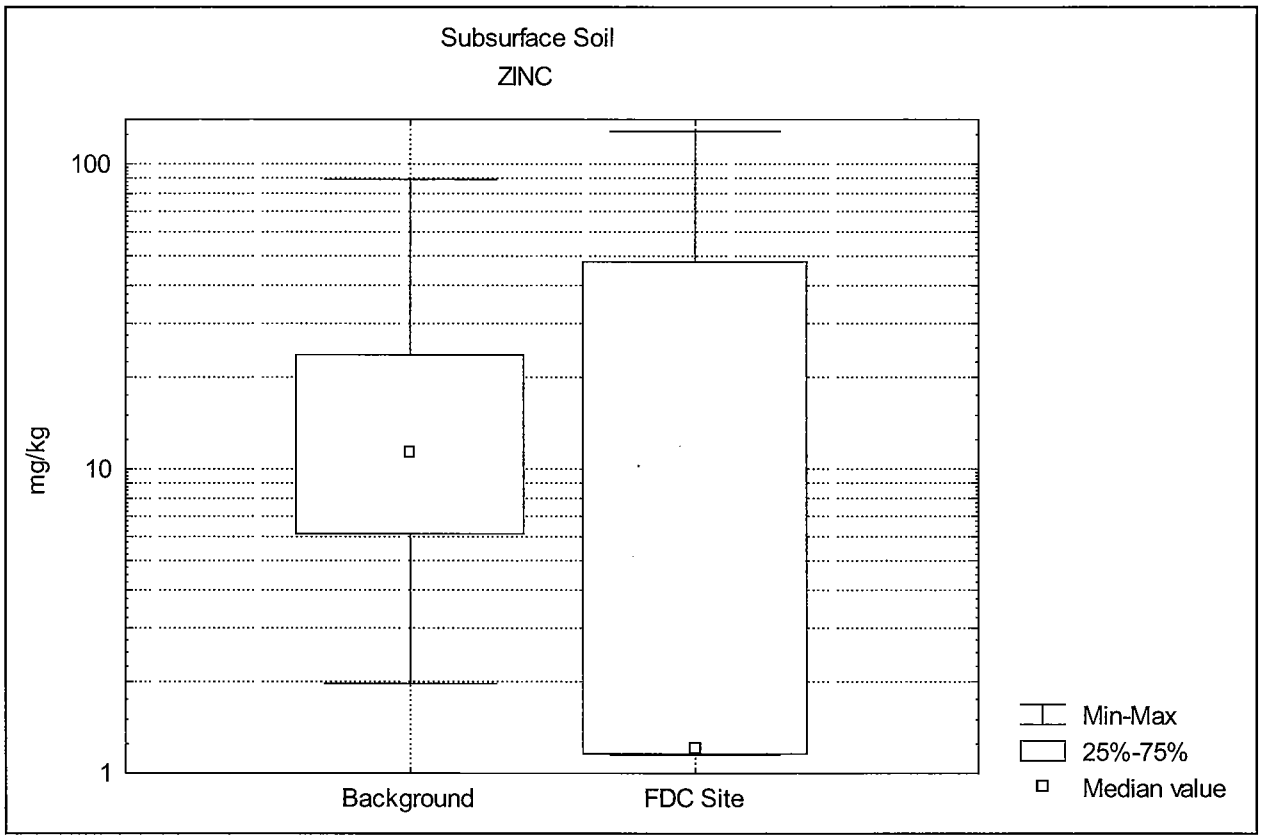

Subsurface Soil
ZINC
100
10
1
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-18

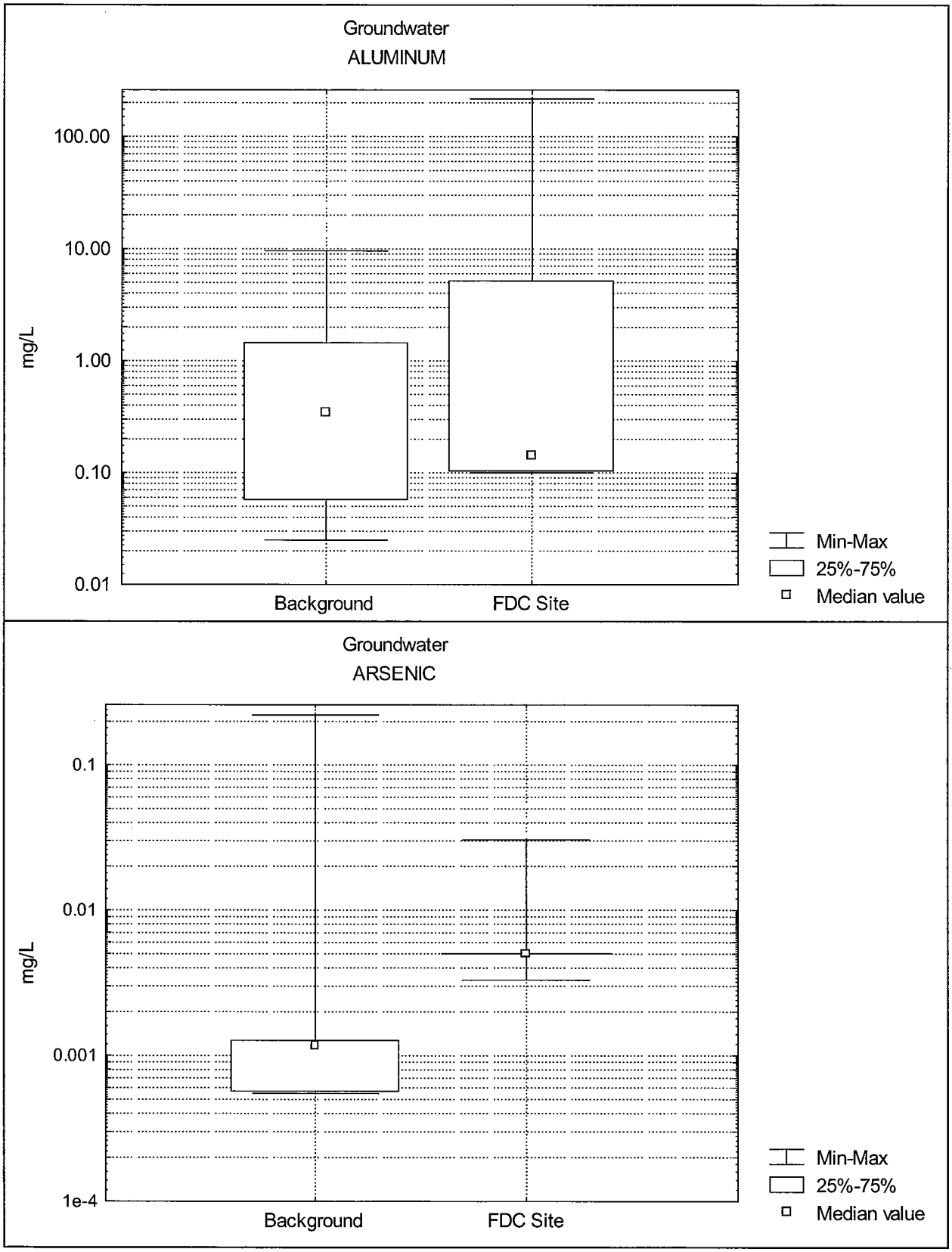
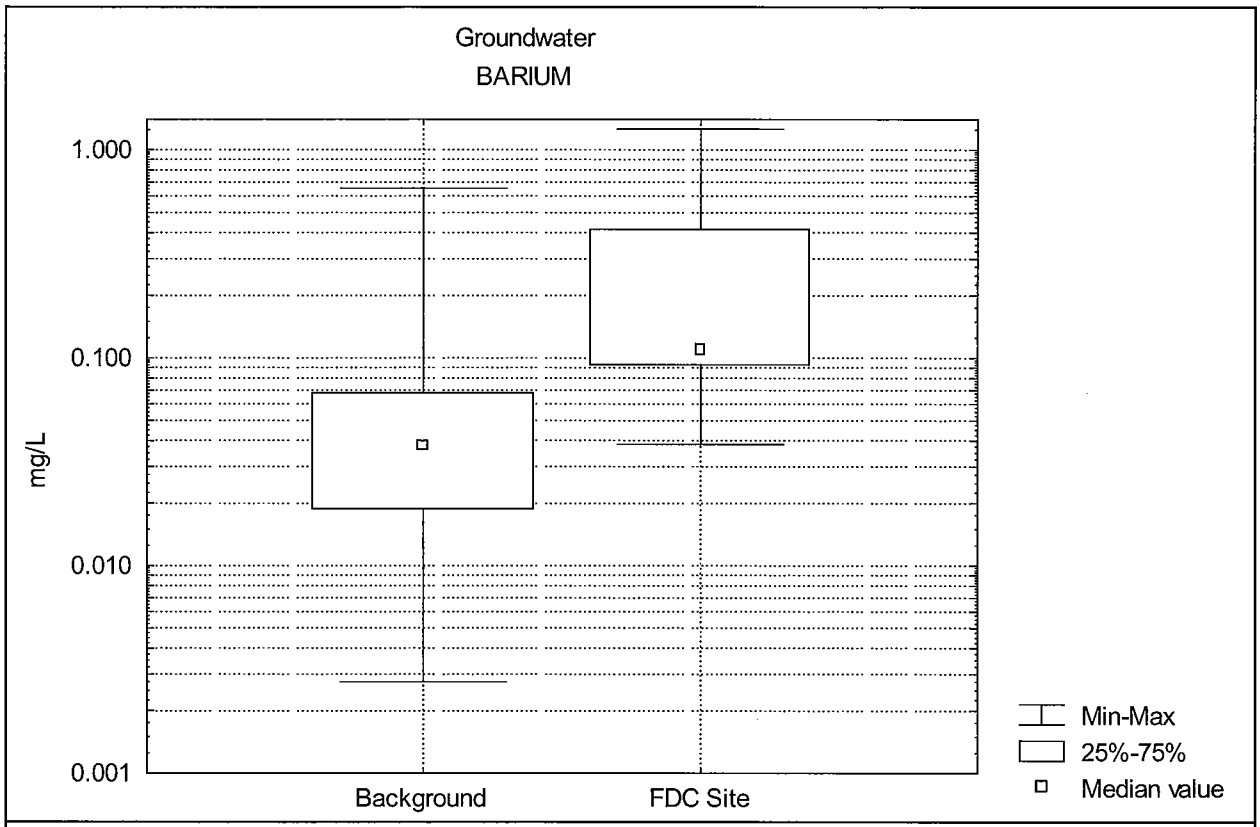

Groundwater
ALUMINUM
mg/L
100.00
10.00
1.00
0.10
0.01
Background
FDC Site
Min-Max
25%-75%
Median value
Groundwater
ARSENIC
mg/L
0.1
0.01
0.001
1e-4
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-19


Groundwater
BARIUM
1.000
0.100
0.010
0.001
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value

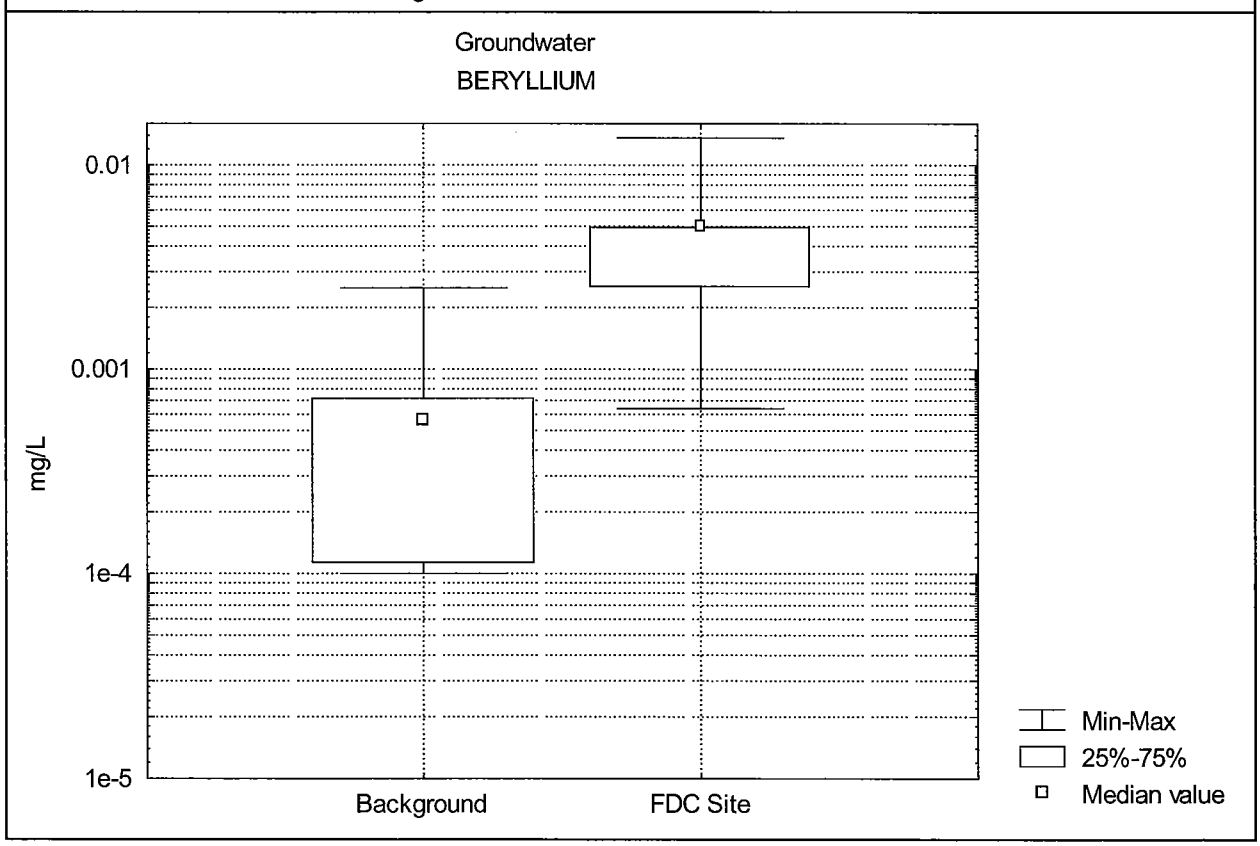
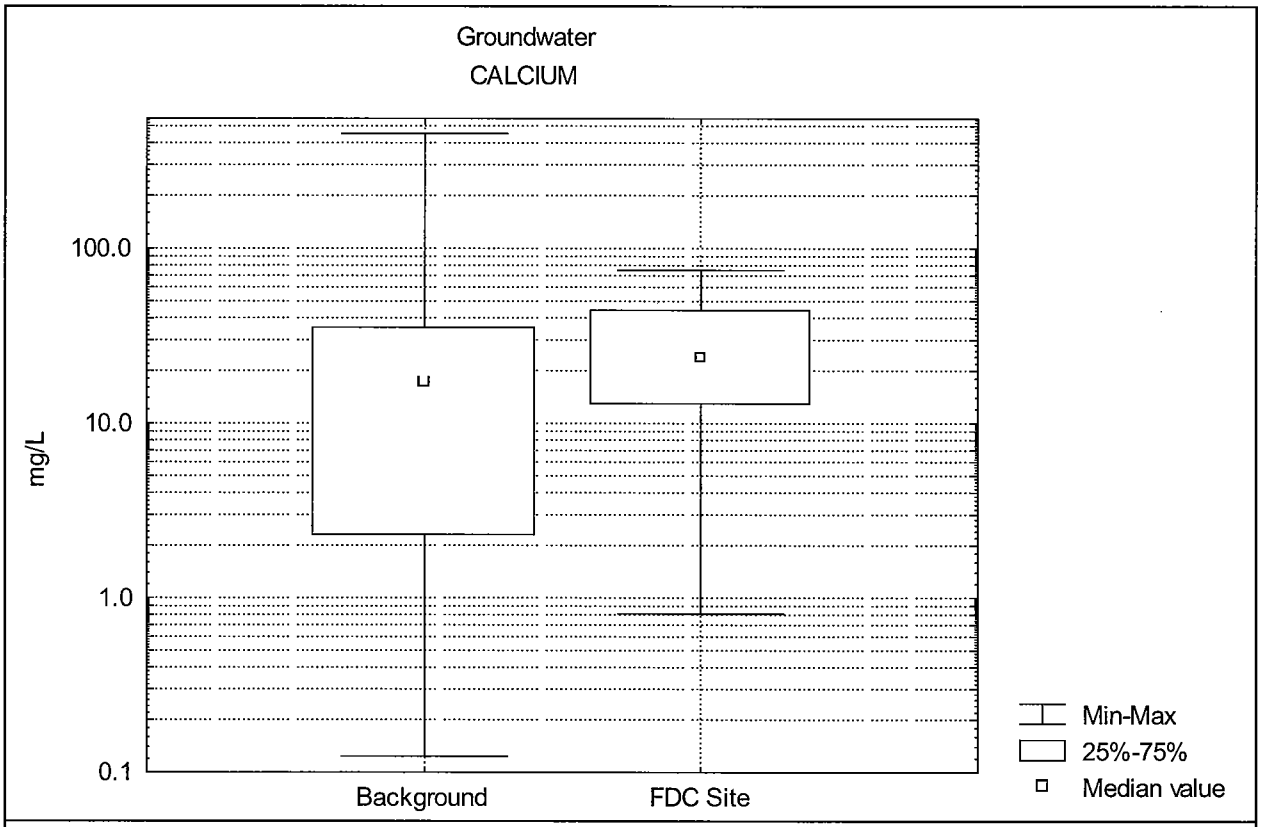

Groundwater
BERYLLIUM
0.01
0.001
1e-4
1e-5
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-20


Groundwater
CALCIUM
mg/L
100.0
10.0
1.0
0.1
Background
FDC Site
Min-Max
25%-75%
Median value

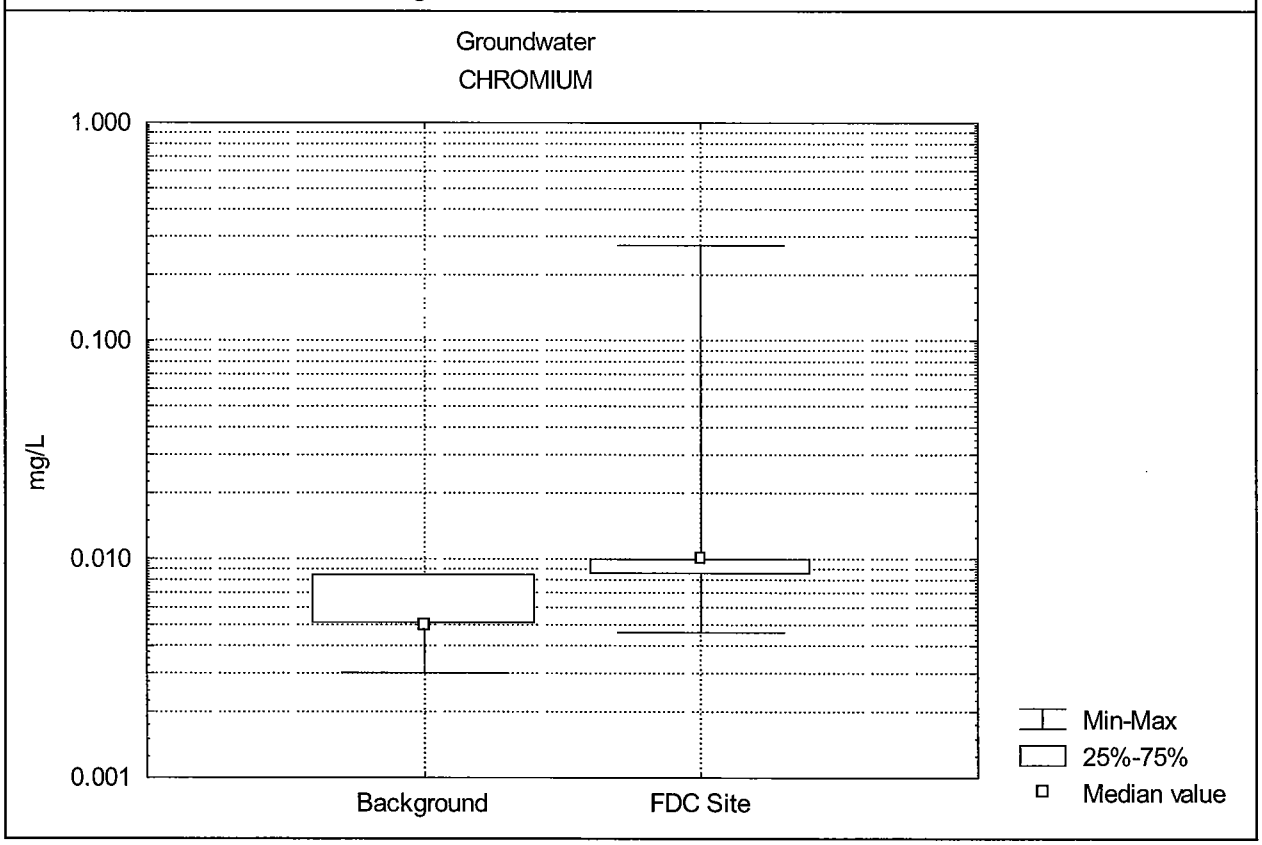

Groundwater
CHROMIUM
mg/L
1.000
0.100
0.010
0.001
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-21

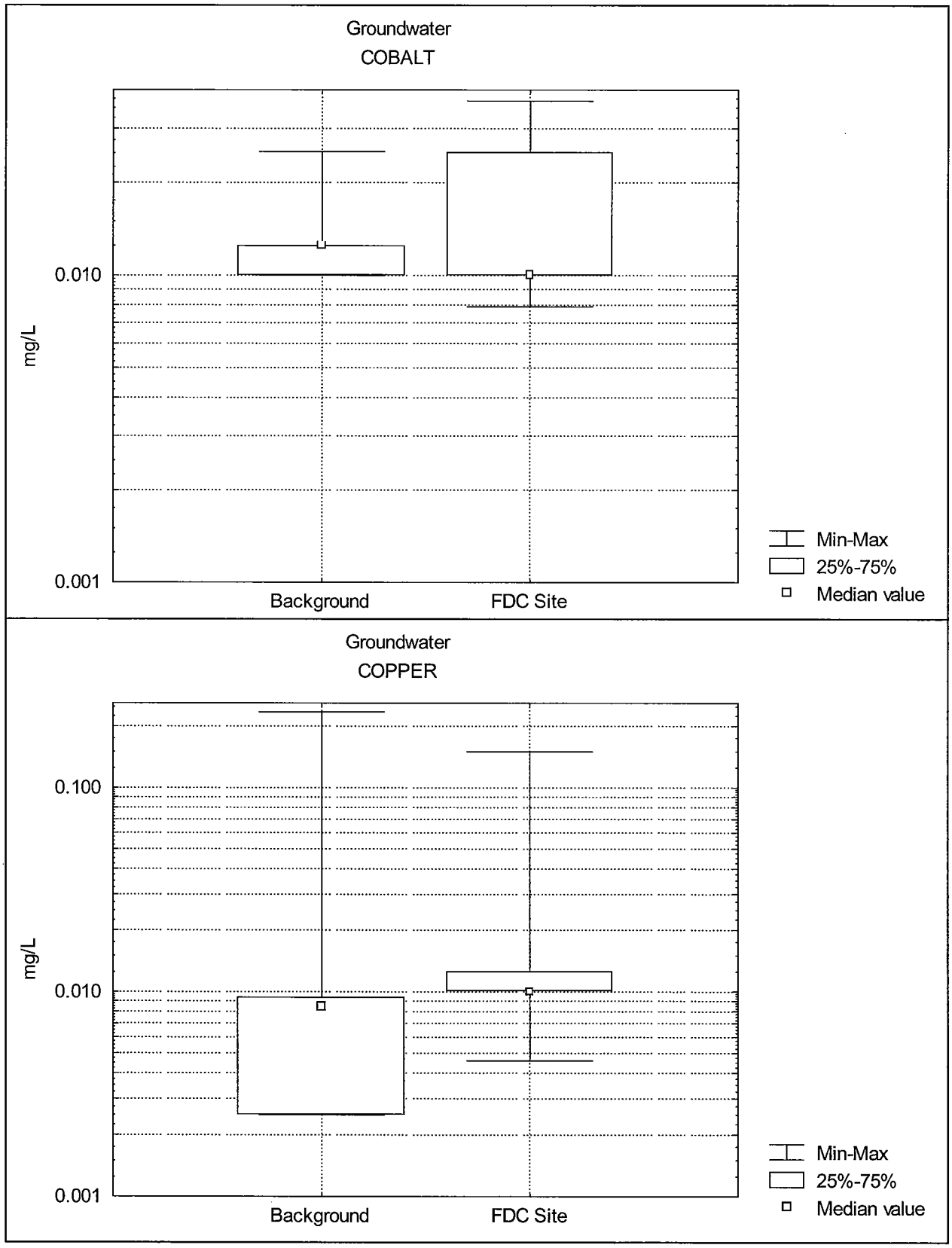
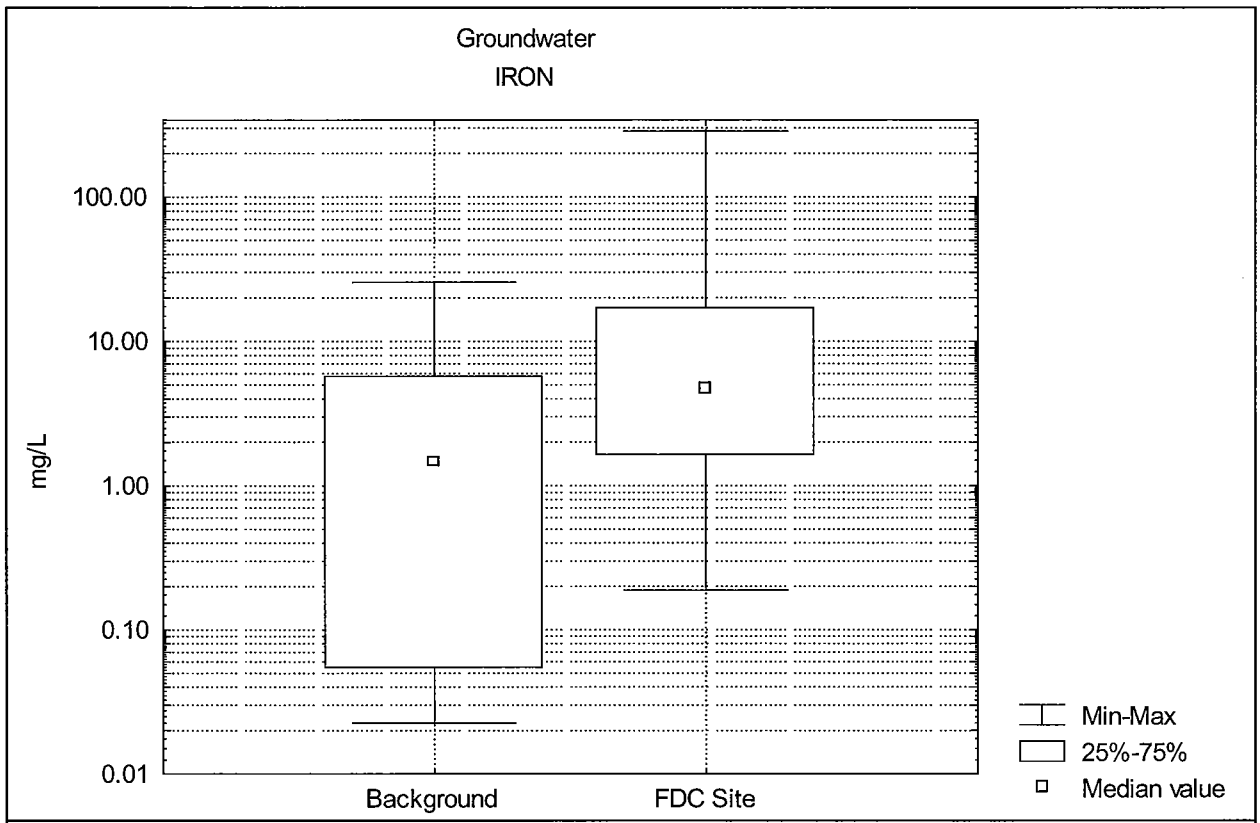

Groundwater
COBALT
0.010
0.001
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value
Groundwater
COPPER
0.100
0.010
0.001
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-22


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

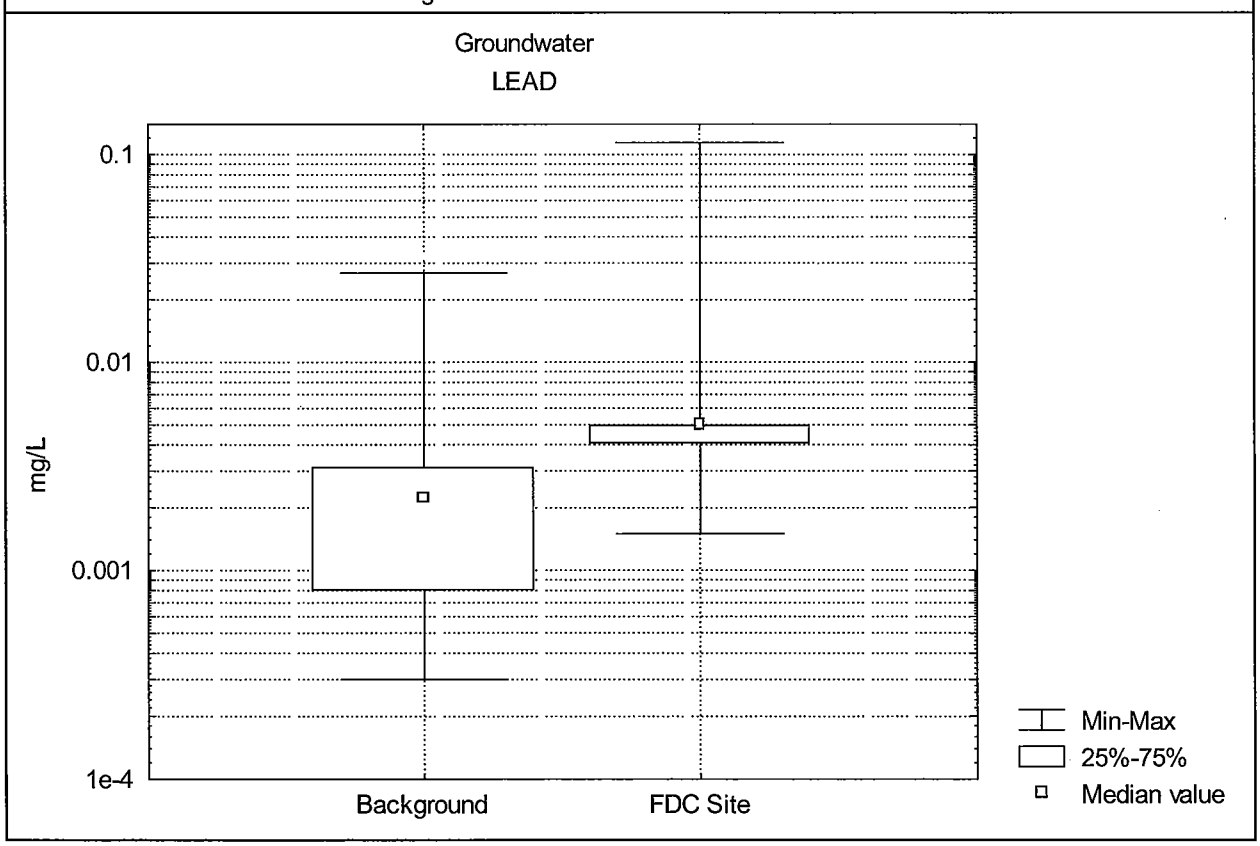
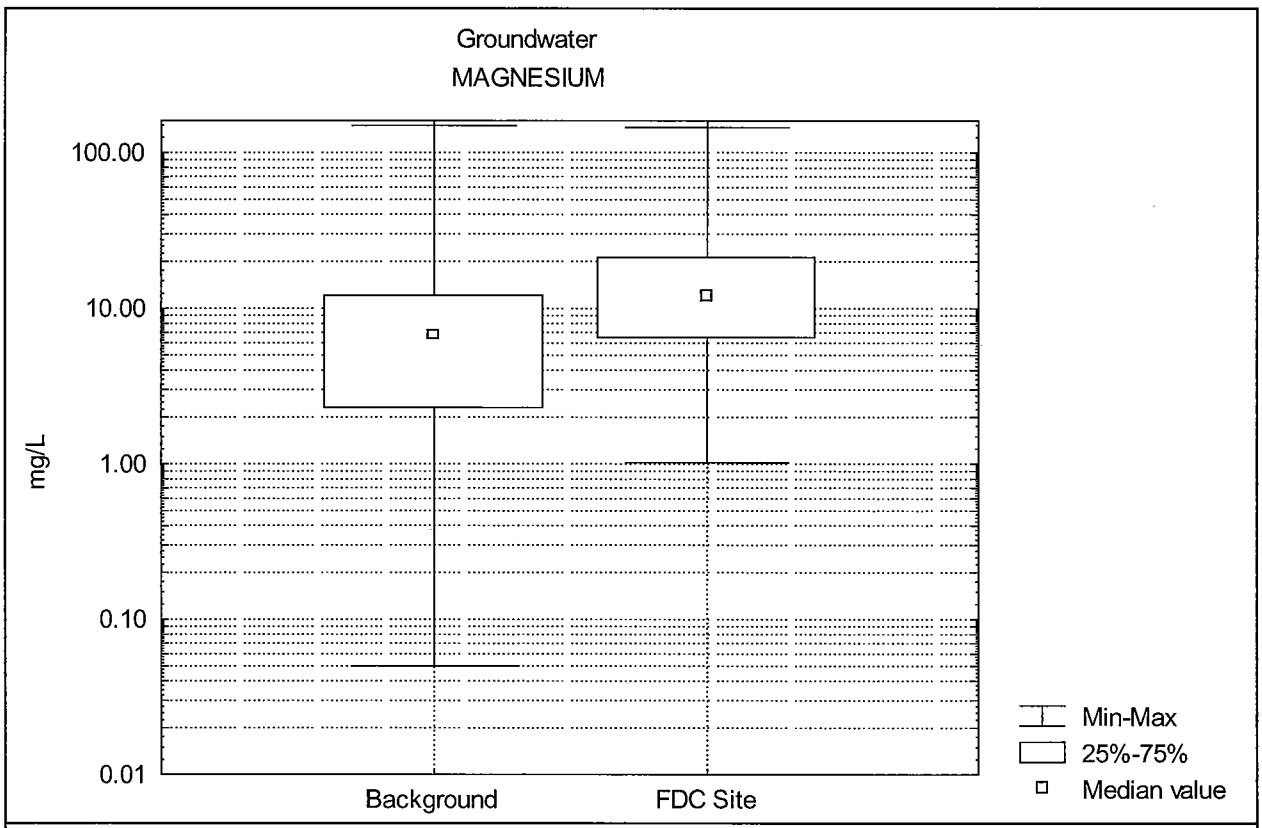

Groundwater
LEAD
0.1
0.01
0.001
1e-4
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-23


Groundwater
MAGNESIUM
100.00
10.00
1.00
0.10
0.01
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value

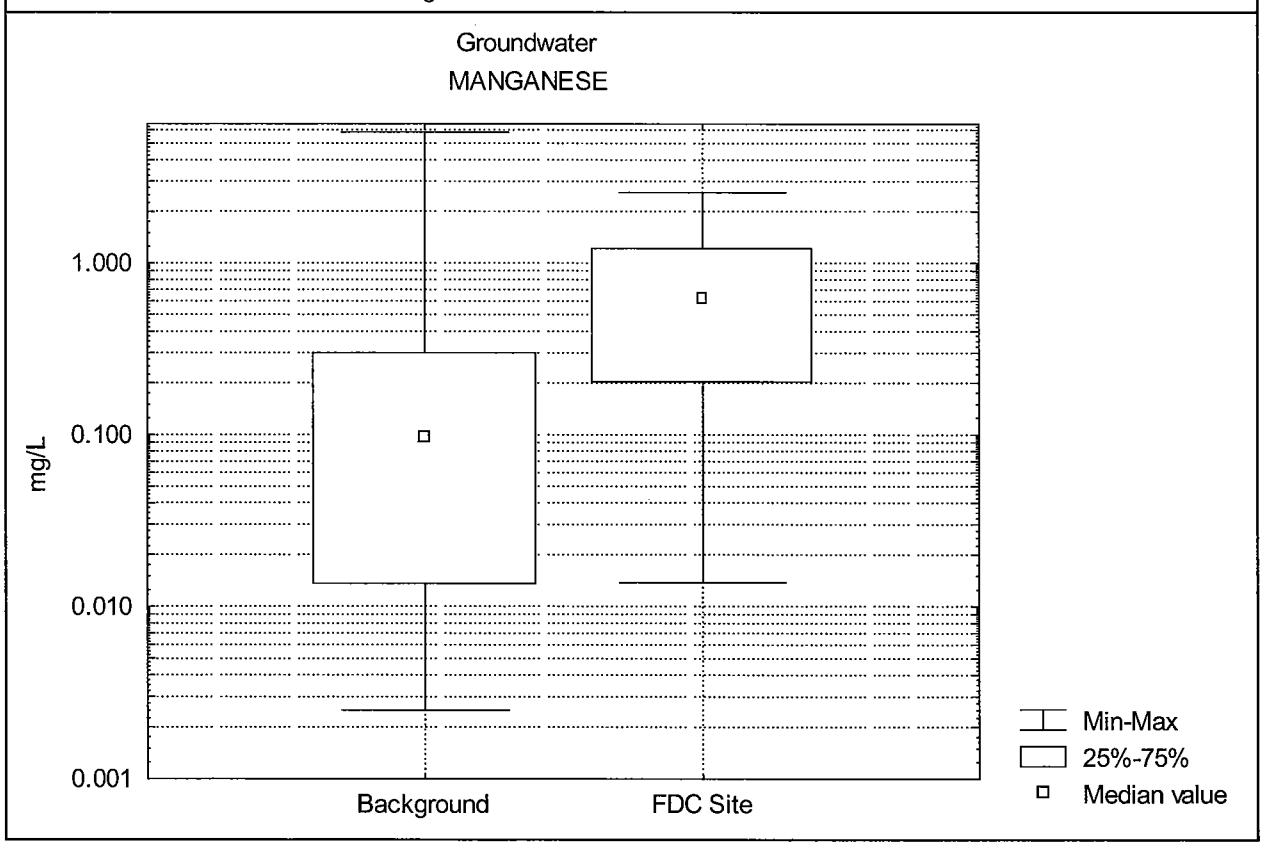
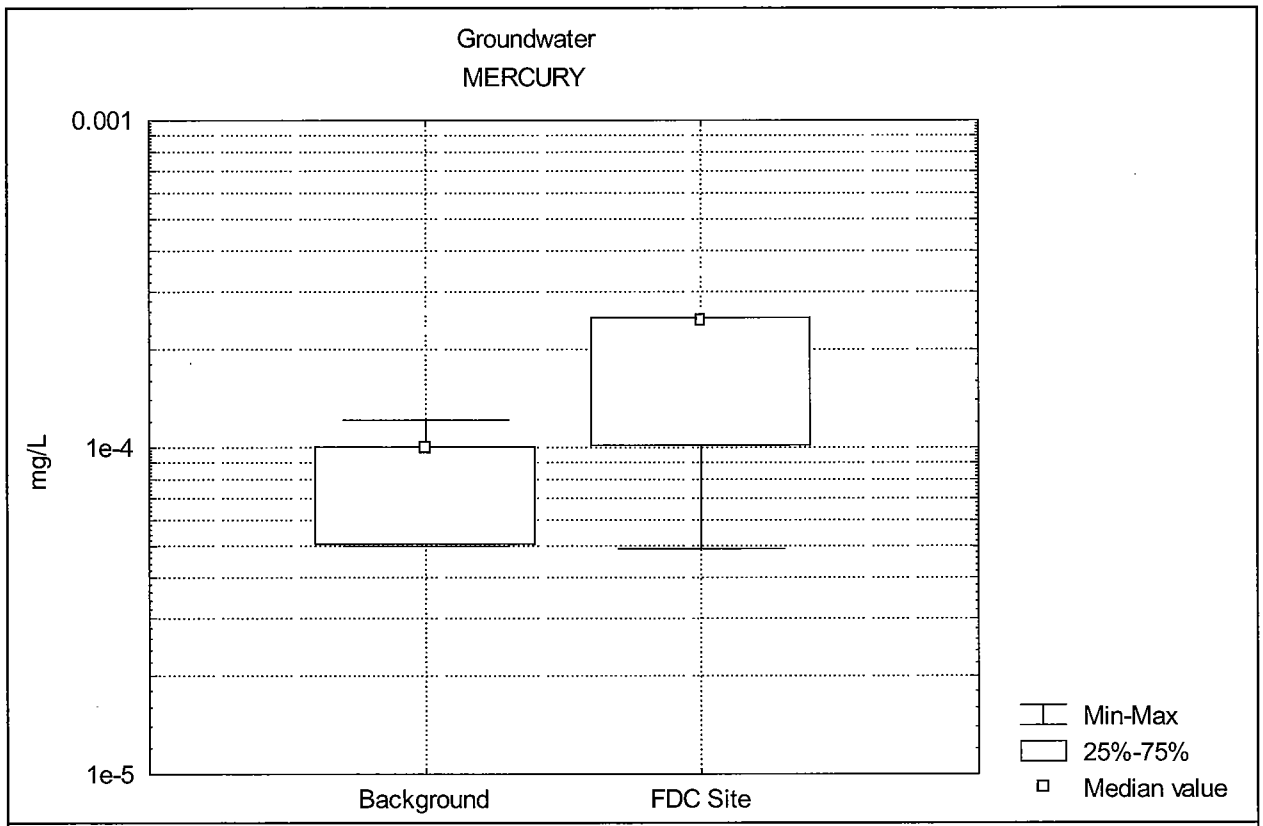

Groundwater
MANGANESE
1.000
0.100
0.010
0.001
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-24


Groundwater
MERCURY
0.001
1e-4
1e-5
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value

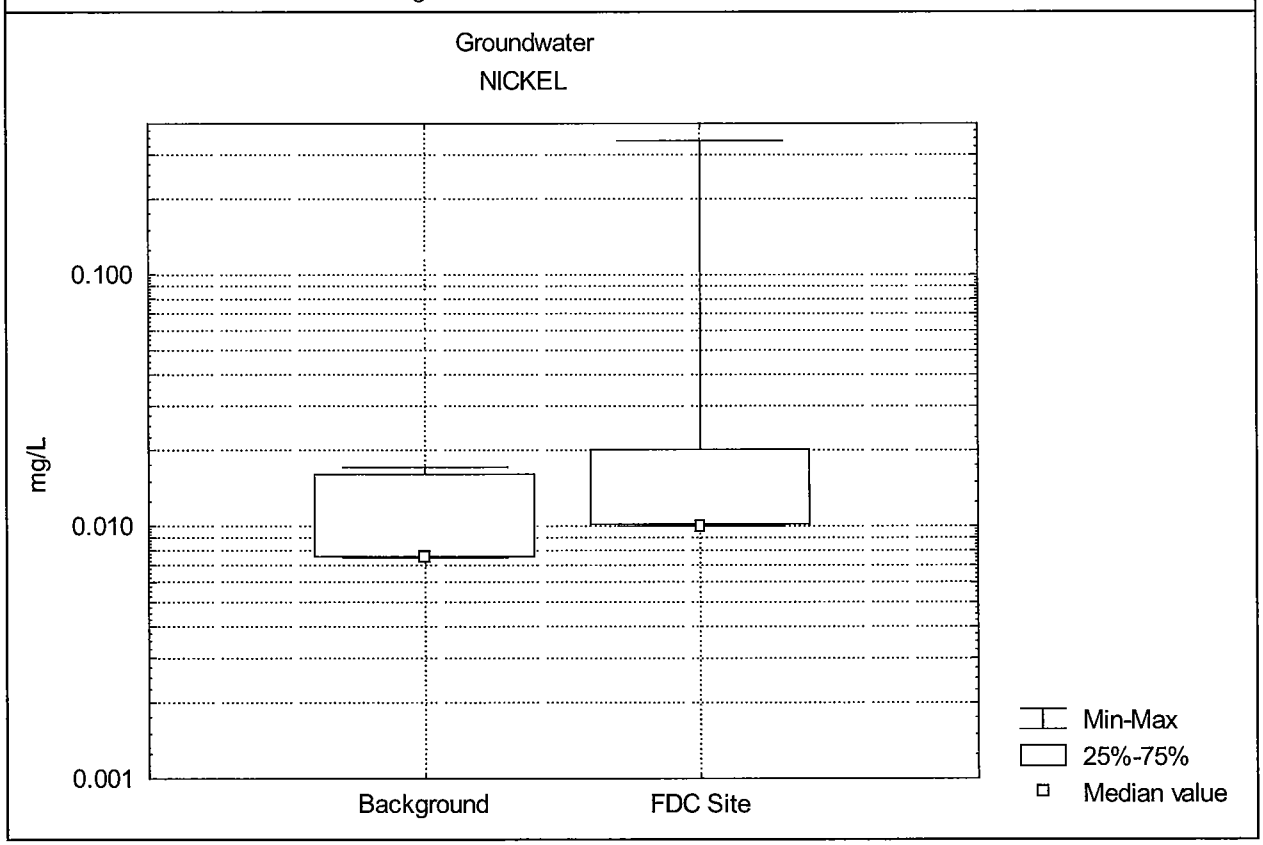
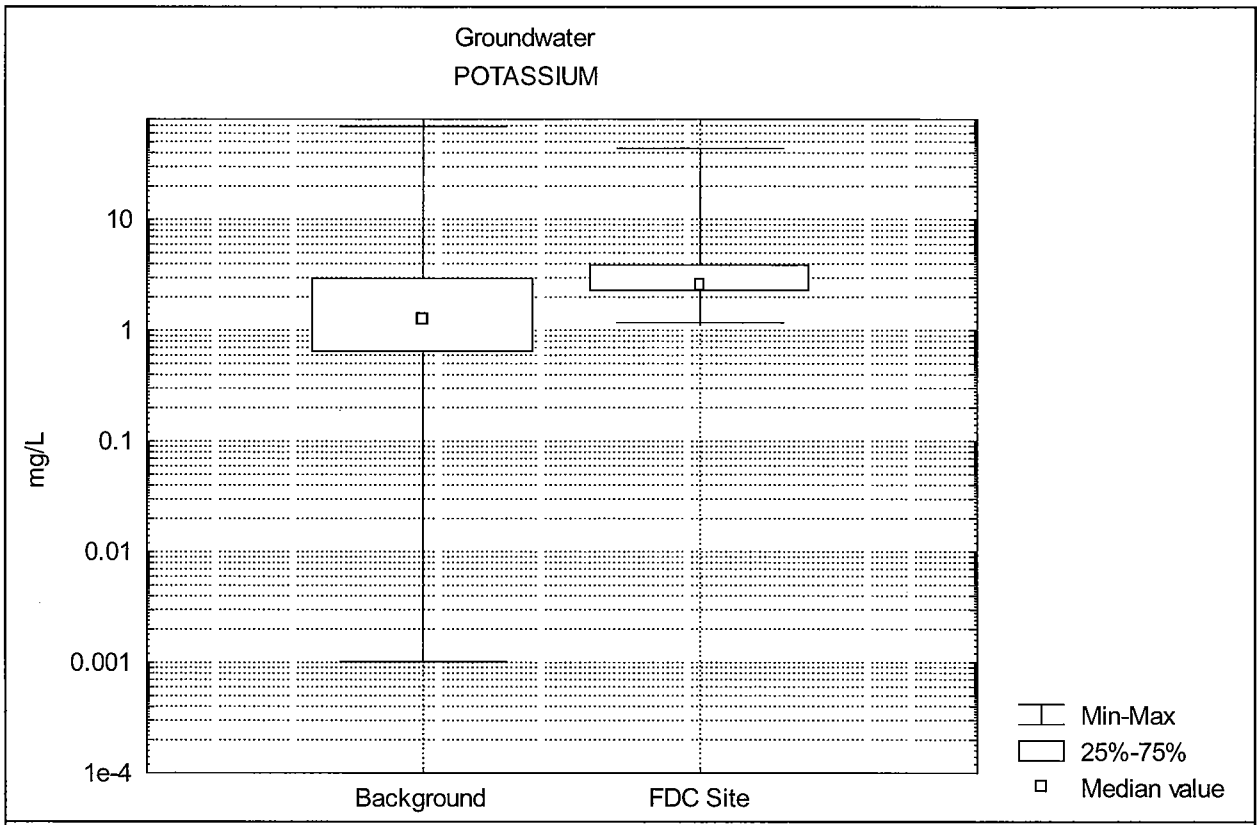

Groundwater
NICKEL
0.100
0.010
0.001
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-25


Groundwater
POTASSIUM
mg/L
10
1
0.1
0.01
0.001
1e-4
Background
FDC Site
Min-Max
25%-75%
Median value

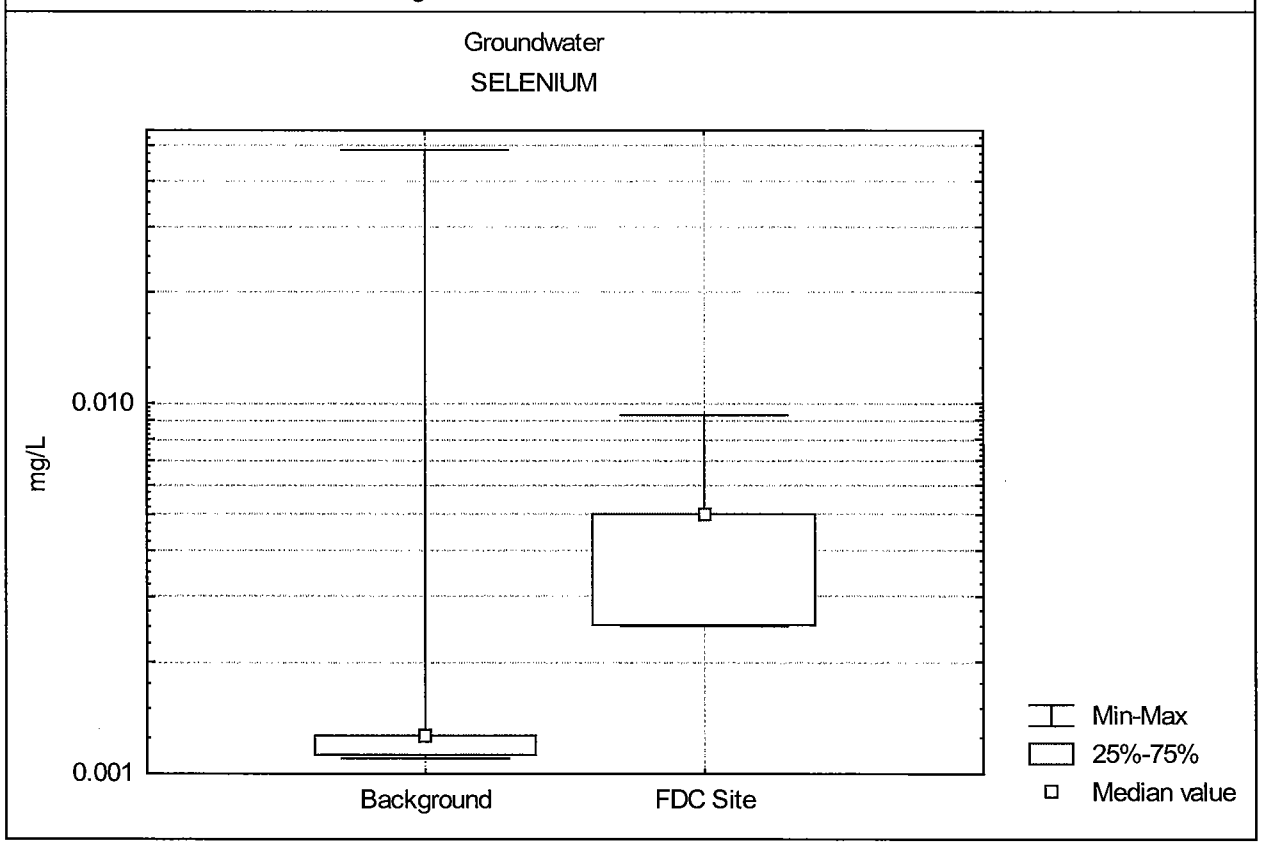

Groundwater
SELENIUM
mg/L
0.010
0.001
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-26

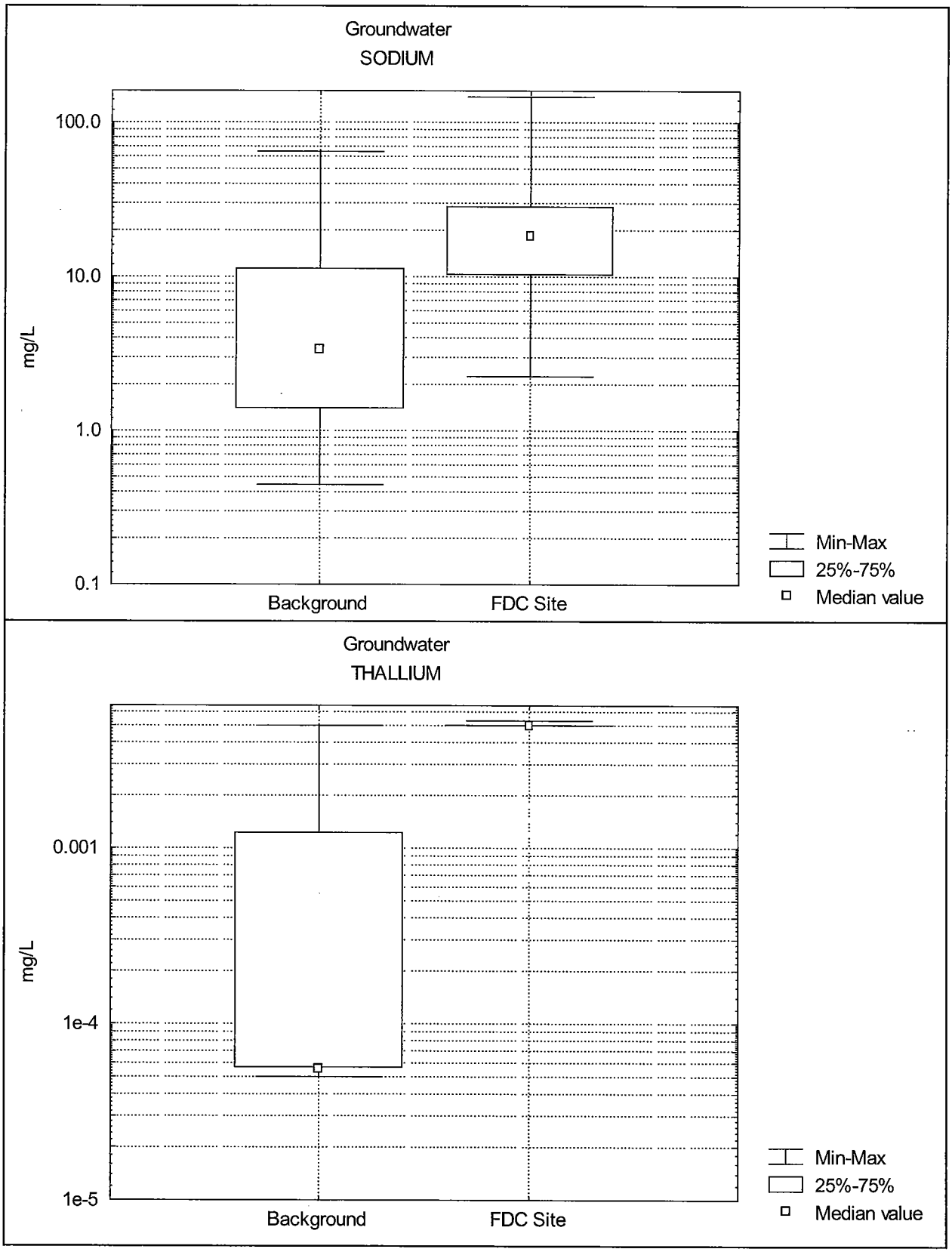

Groundwater
SODIUM
100.0
10.0
1.0
0.1
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value
Groundwater
THALLIUM
0.001
1e-4
1e-5
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-27

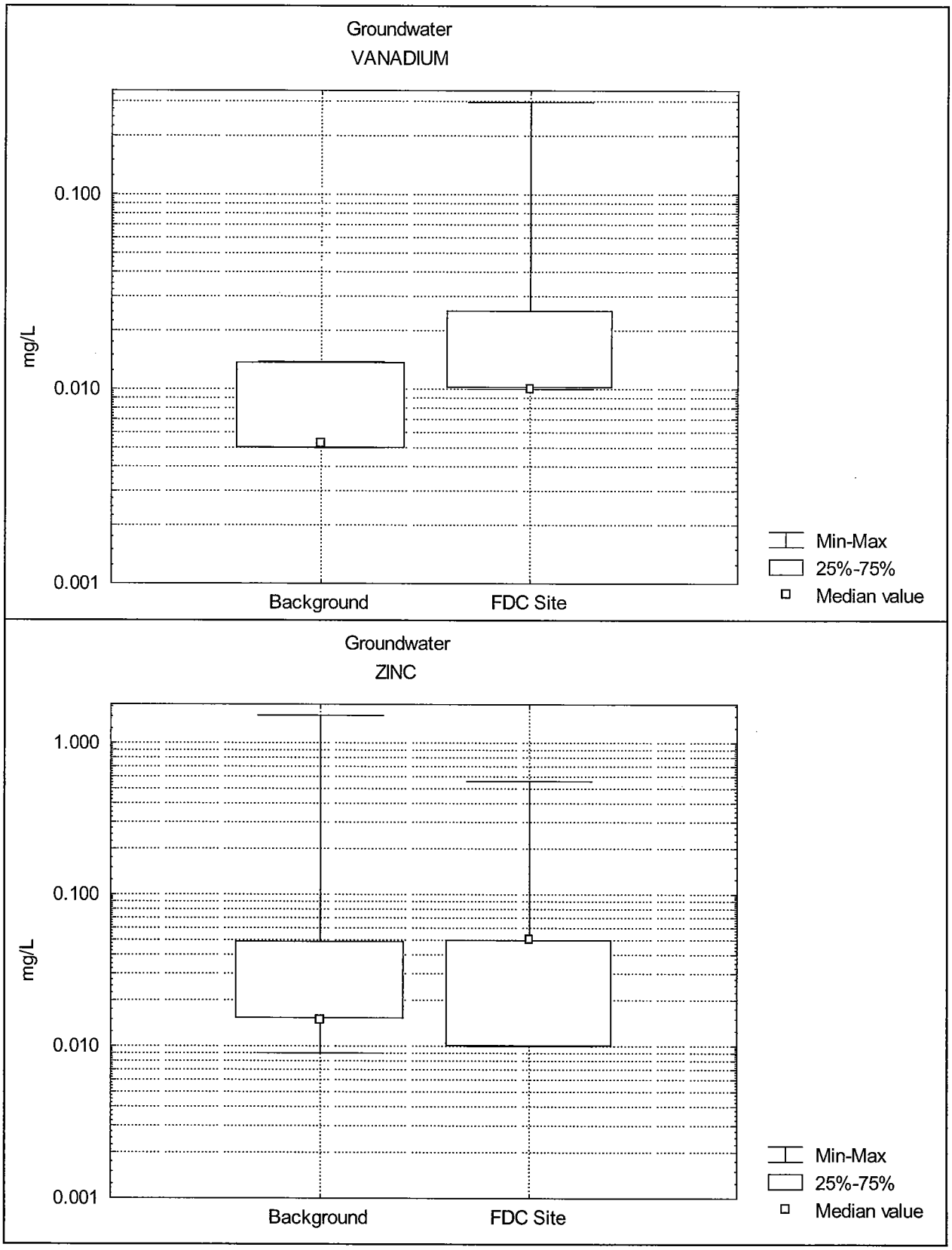

Groundwater
VANADIUM
mg/L
0.100
0.010
0.001
Background
FDC Site
Min-Max
25%-75%
Median value
Groundwater
ZINC
mg/L
1.000
0.100
0.010
0.001
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-28

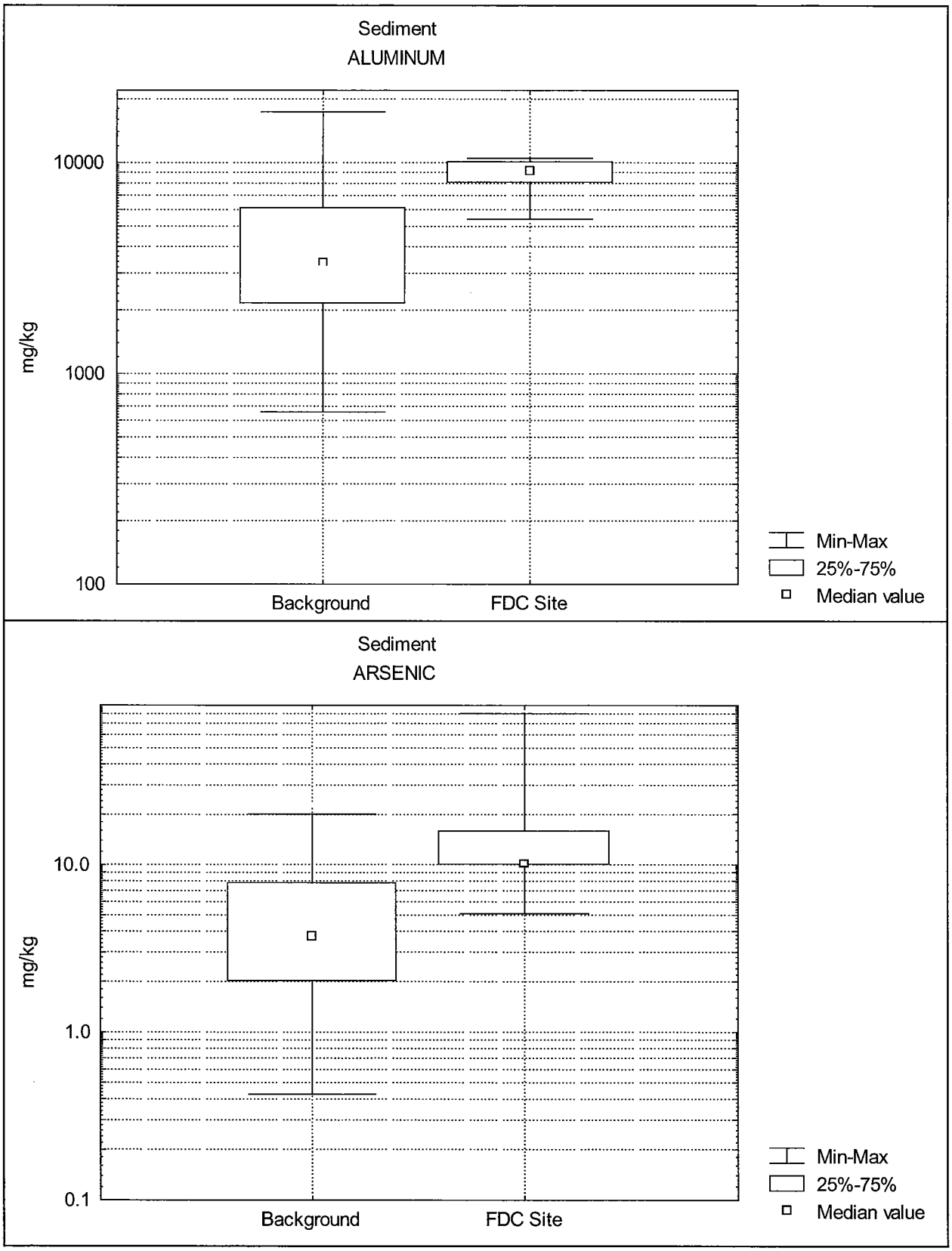
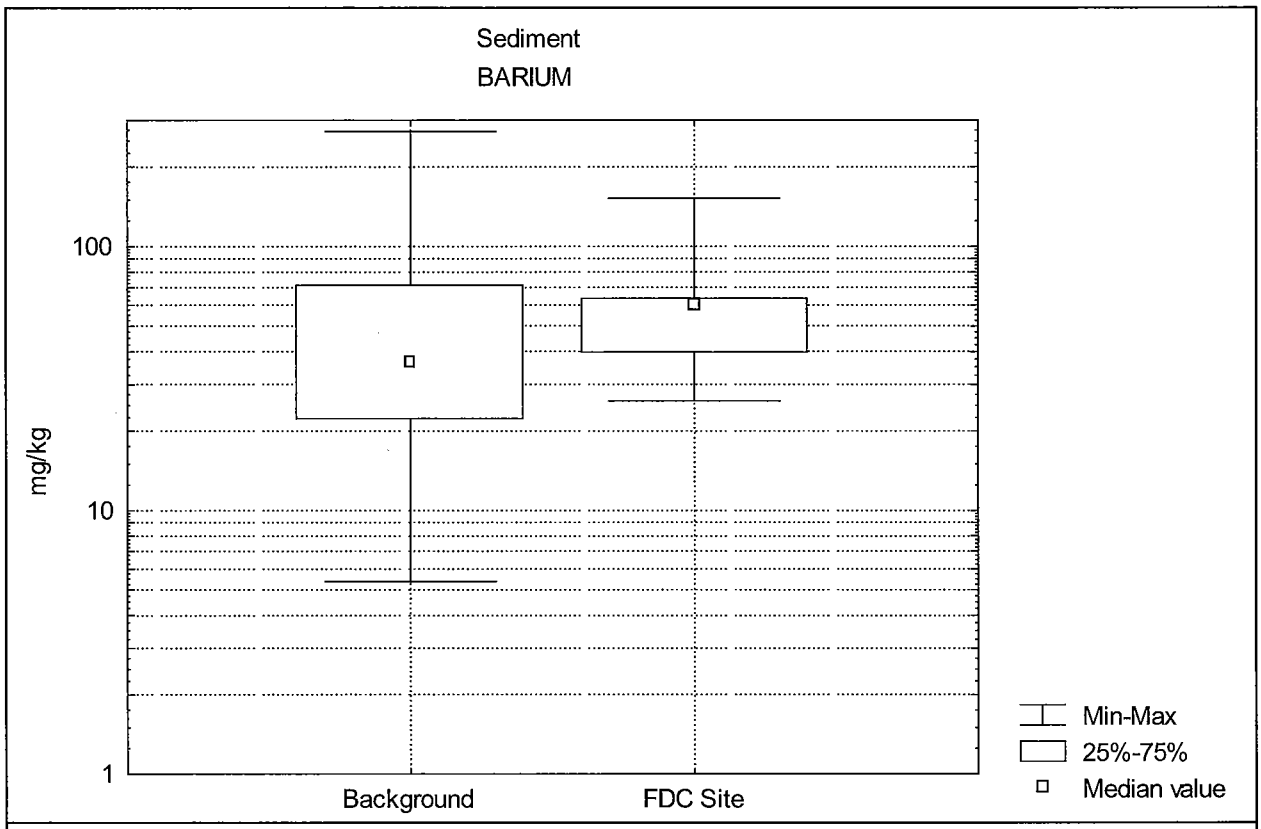

Sediment
ALUMINUM
mg/kg
10000
1000
100
Background
FDC Site
Min-Max
25%-75%
Median value
Sediment
ARSENIC
mg/kg
10.0
1.0
0.1
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-29


Sediment
BARIUM
100
10
1
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

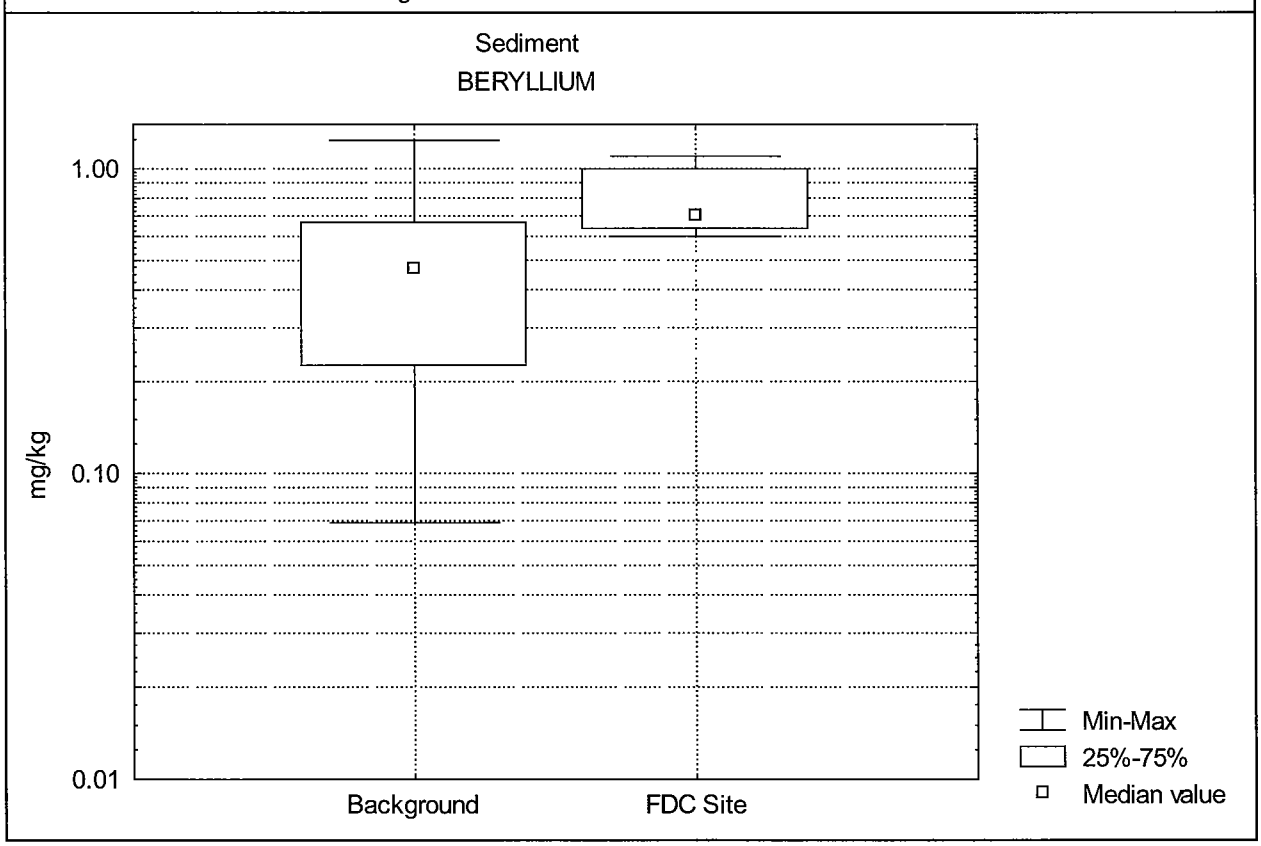

Sediment
BERYLLIUM
1.00
0.10
0.01
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-30

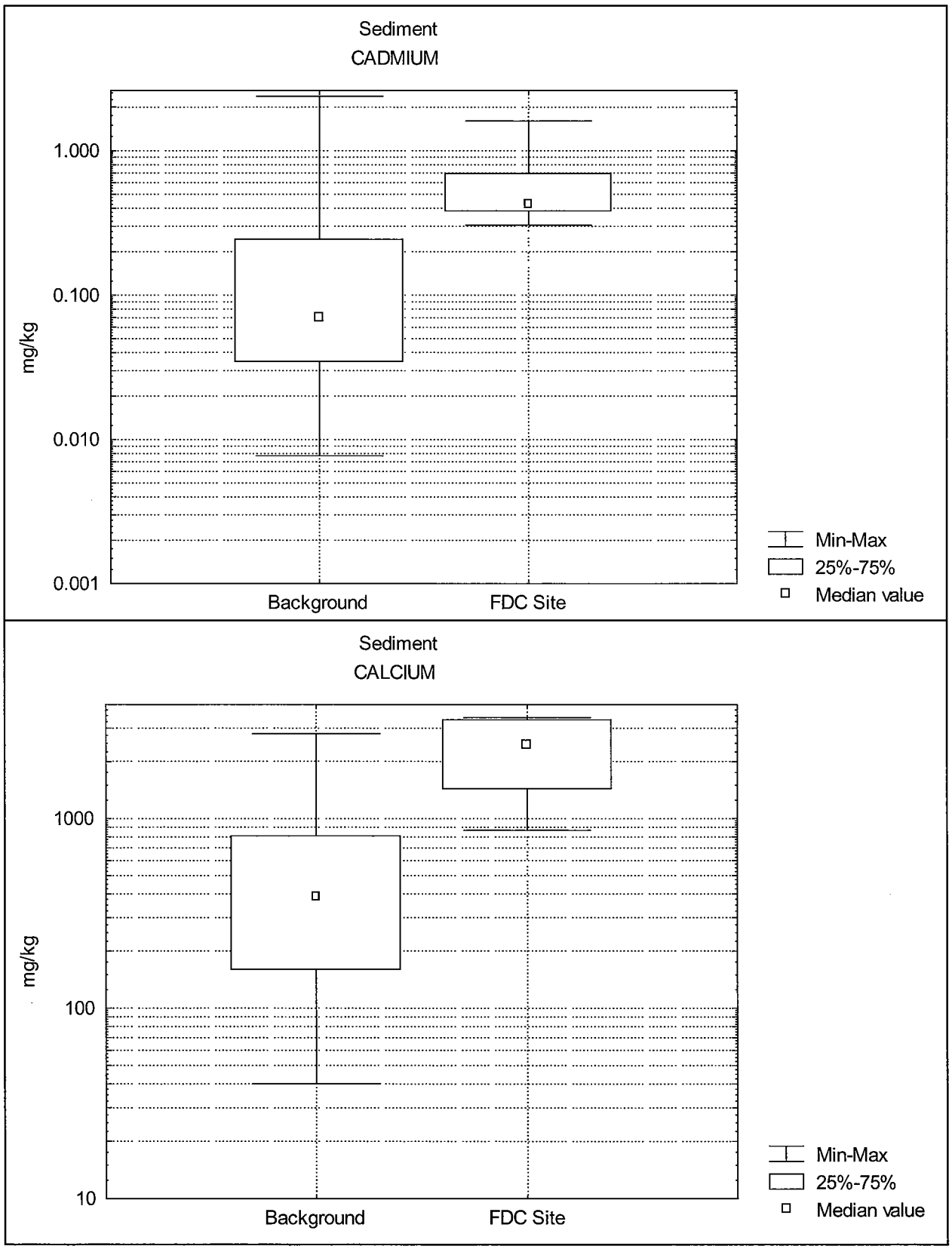
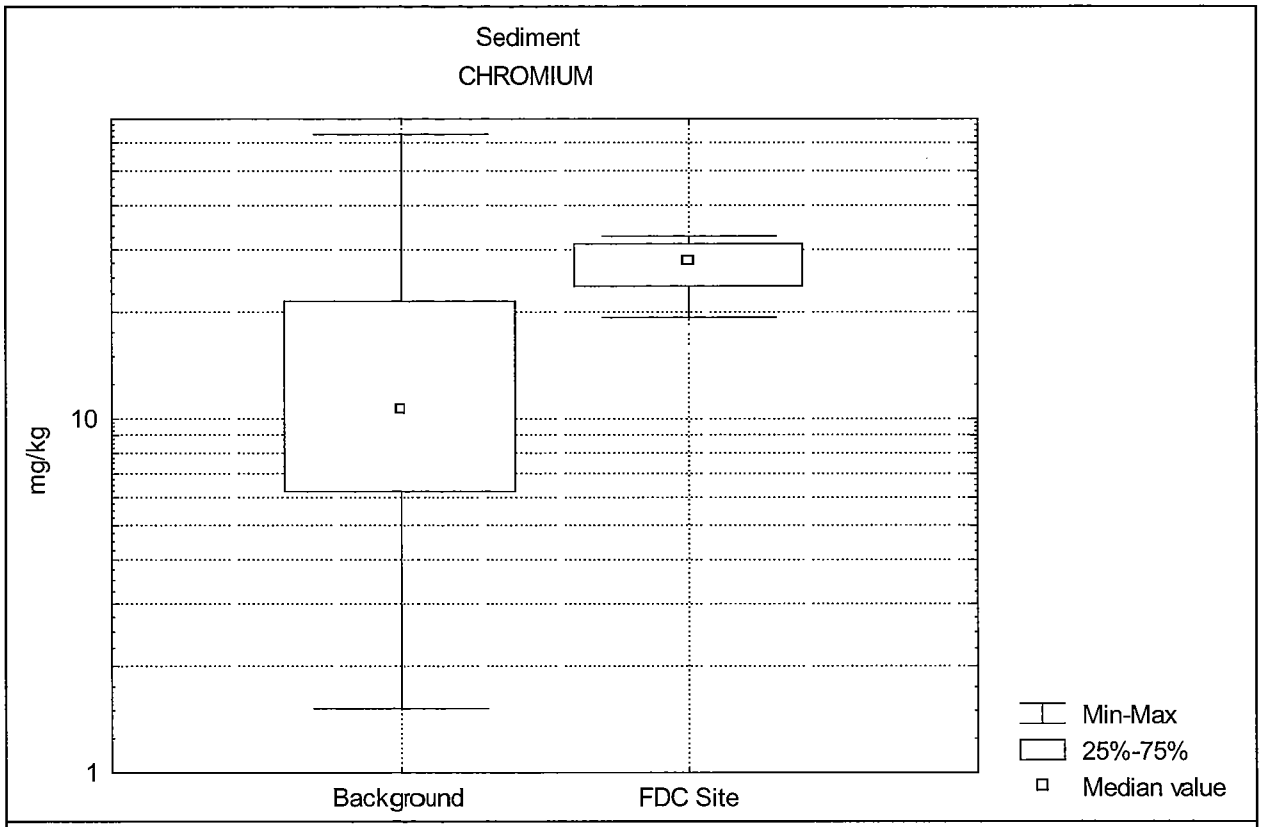

Sediment
CADMIUM
1.000
0.100
0.010
0.001
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value
Sediment
CALCIUM
1000
100
10
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-31


Sediment
CHROMIUM
mg/kg
10
1
Background
FDC Site
Min-Max
25%-75%
Median value

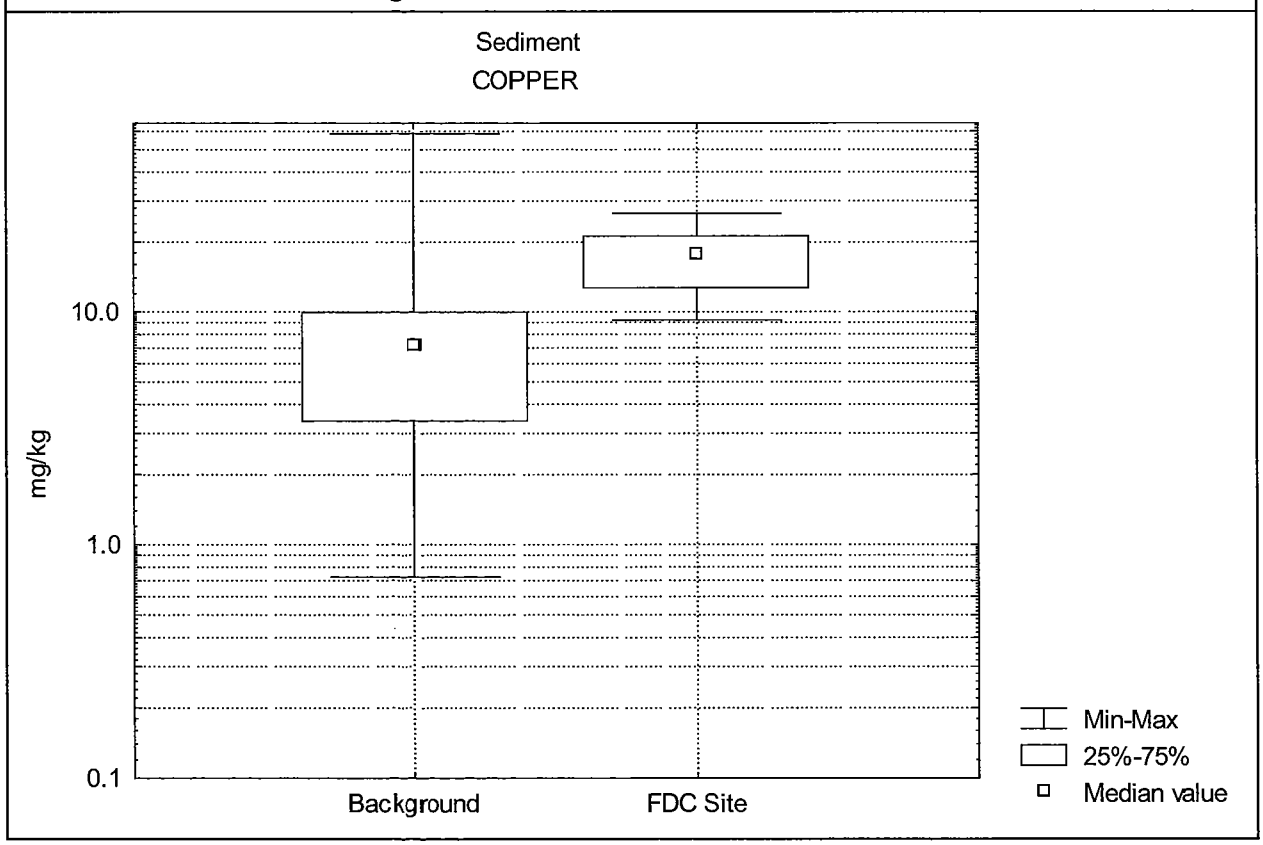

Sediment
COPPER
mg/kg
10.0
1.0
0.1
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-32

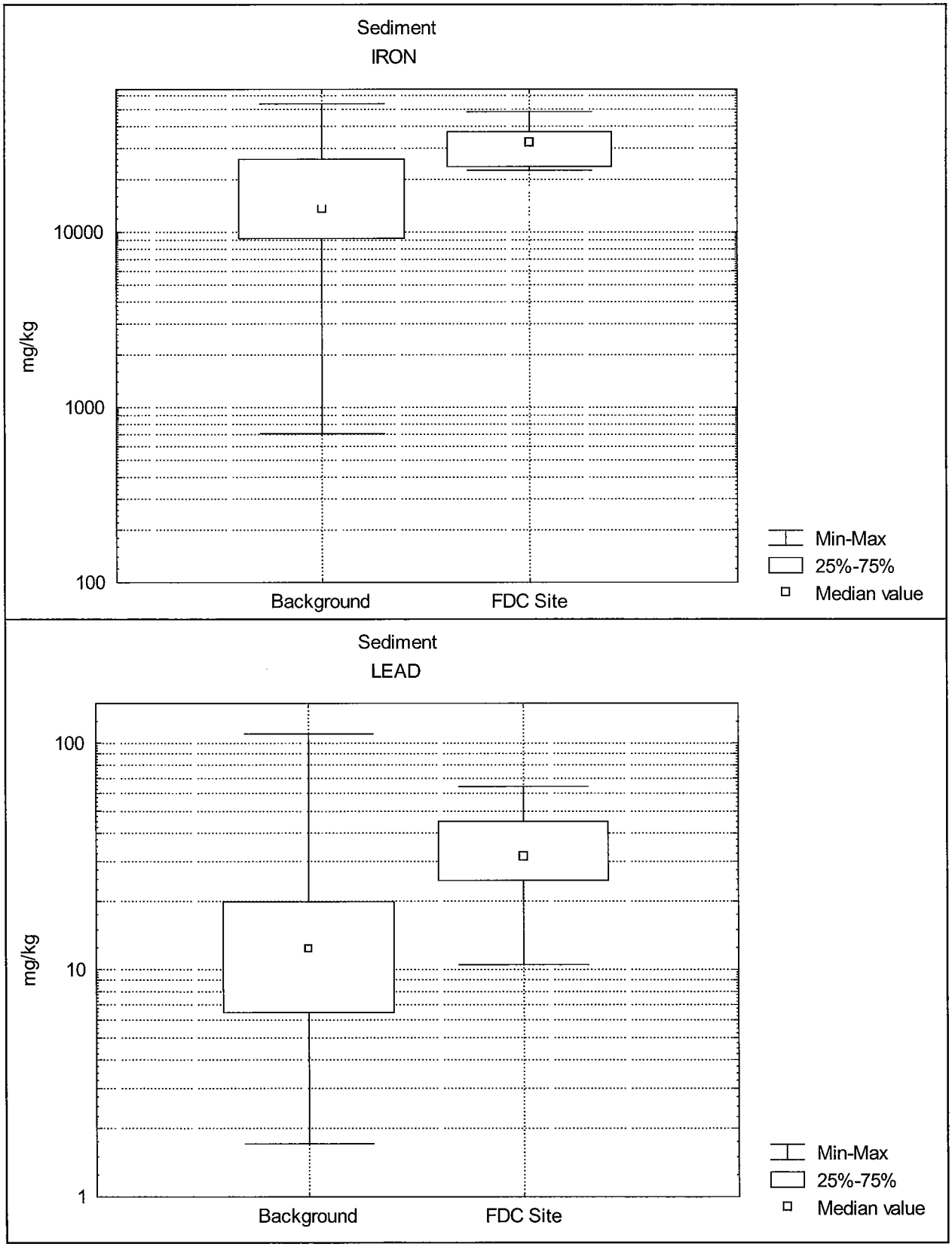
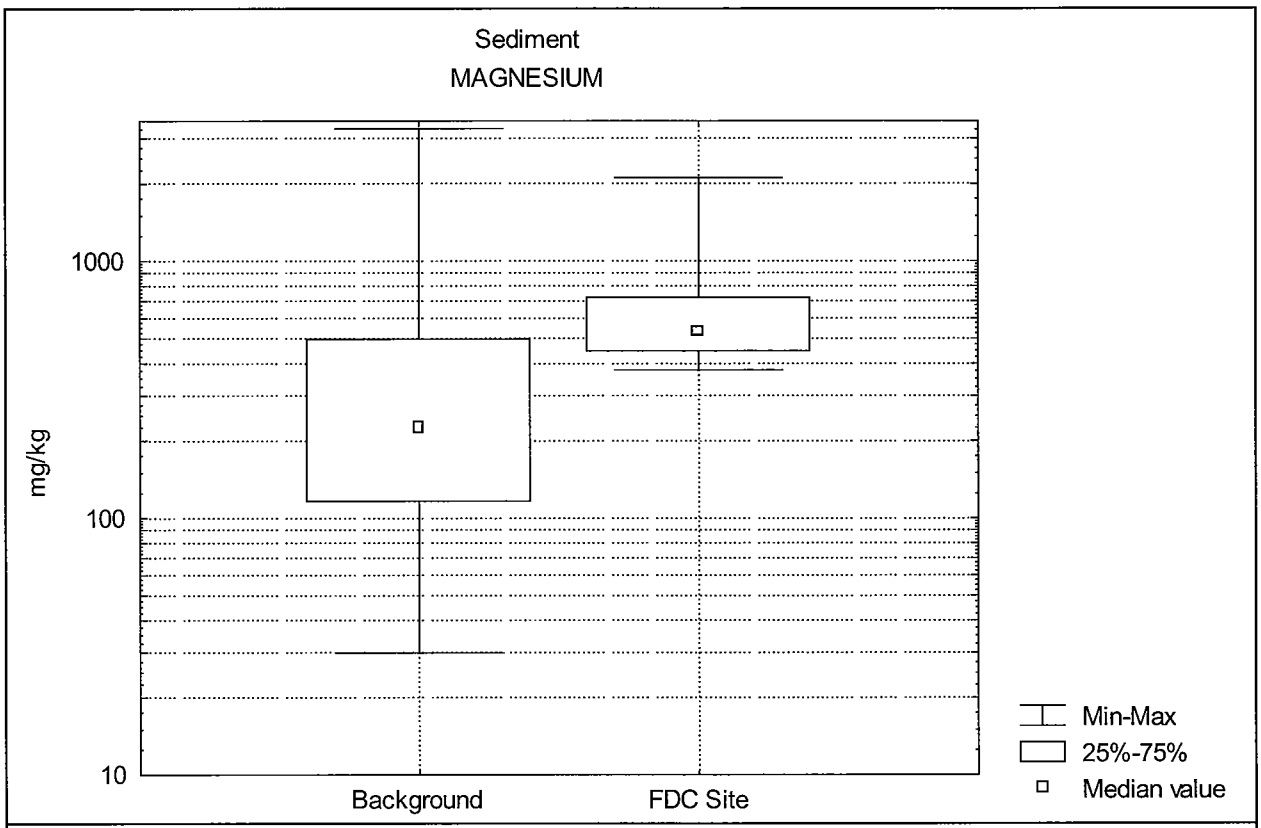

Sediment
IRON
mg/kg
10000
1000
100
Background
FDC Site
Min-Max
25%-75%
Median value
Sediment
LEAD
mg/kg
100
10
1
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-33


Sediment
MAGNESIUM
1000
100
10
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

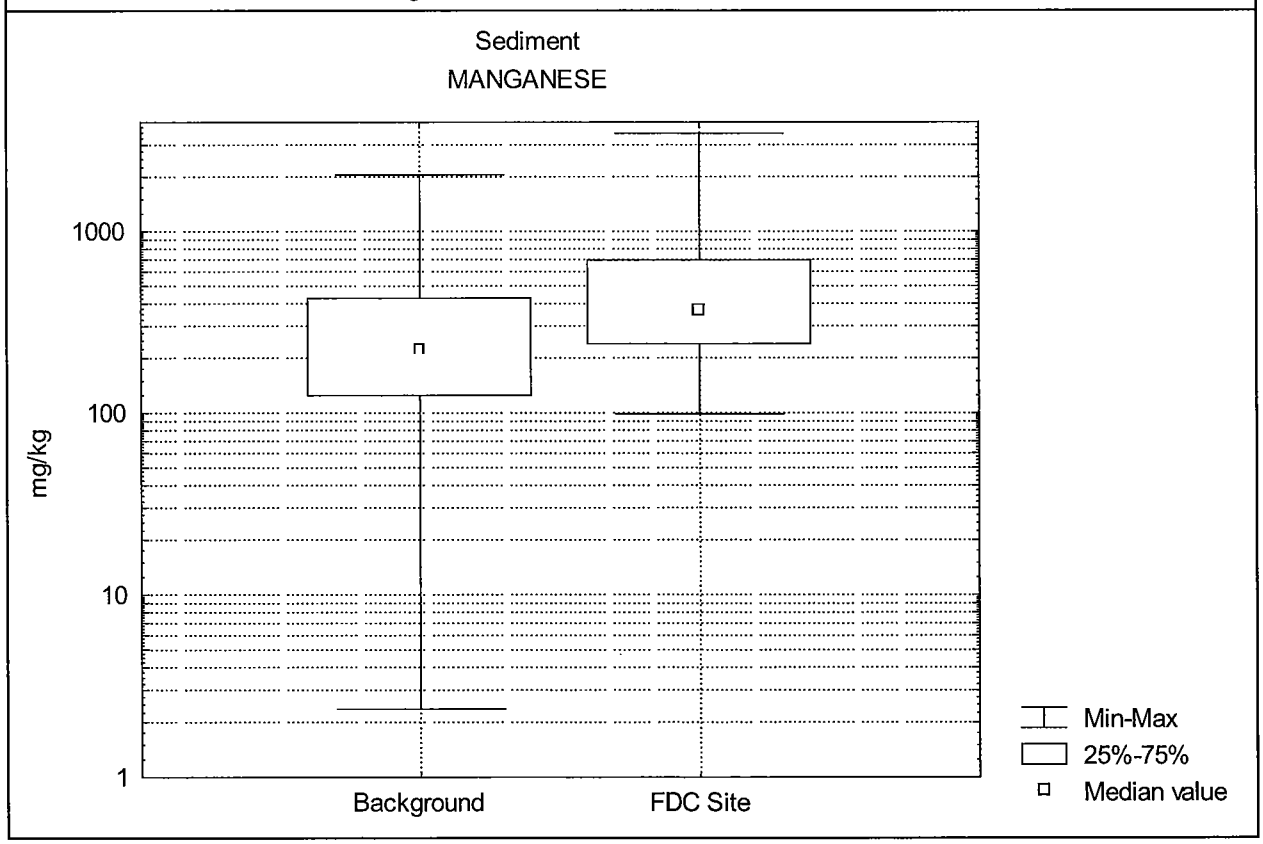

Sediment
MANGANESE
1000
100
10
1
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-34

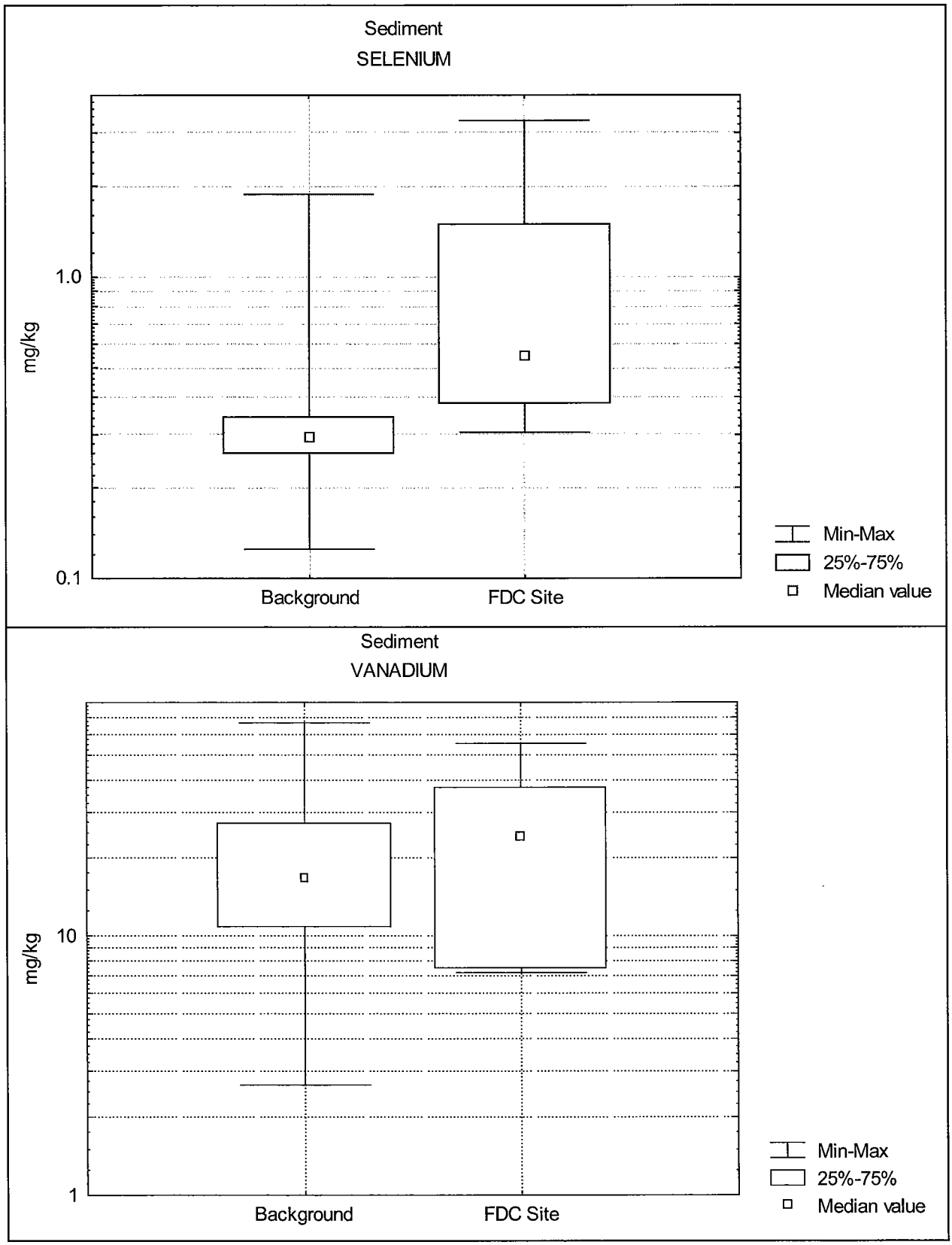

Sediment
SELENIUM
mg/kg
1.0
0.1
Background
FDC Site
Min-Max
25%-75%
Median value
Sediment
VANADIUM
mg/kg
10
1
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-35

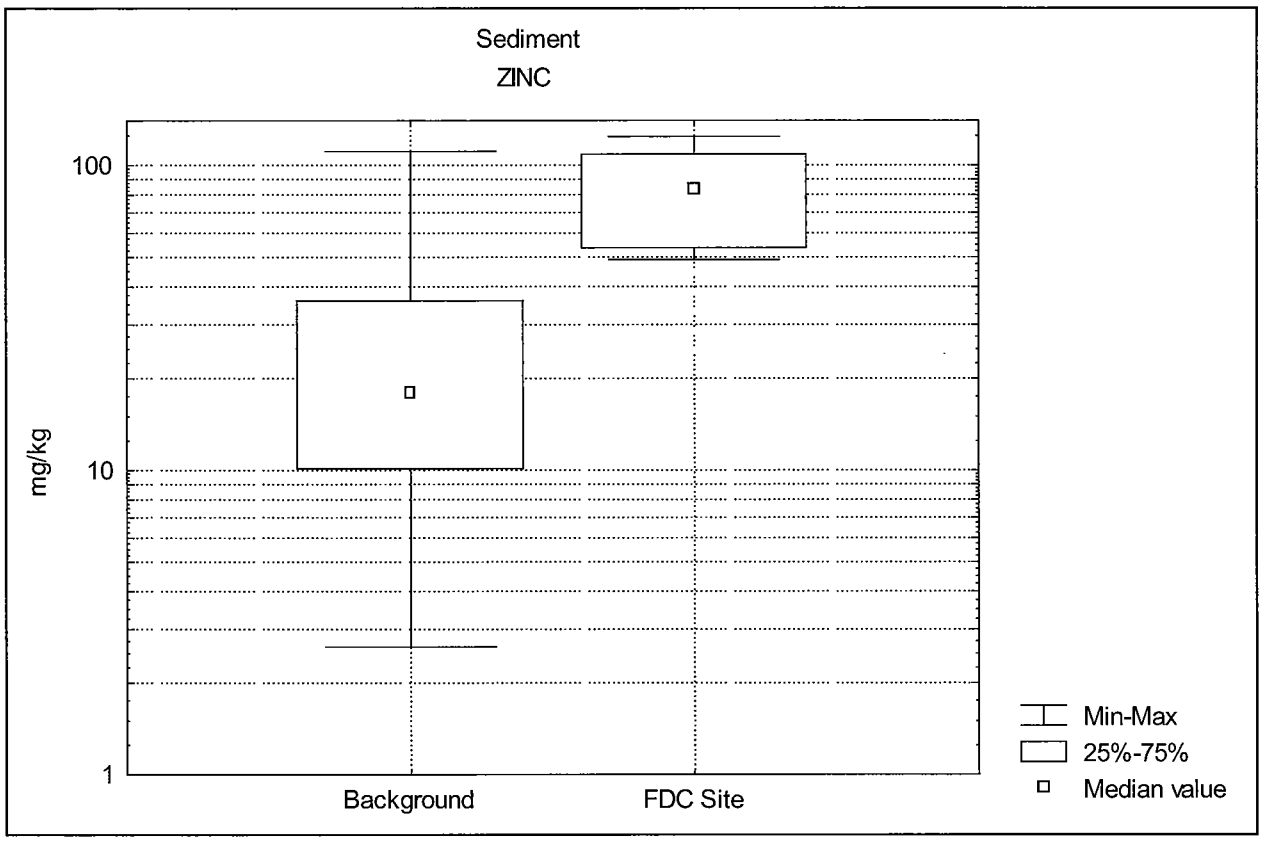

Sediment
ZINC
100
10
1
mg/kg
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-36

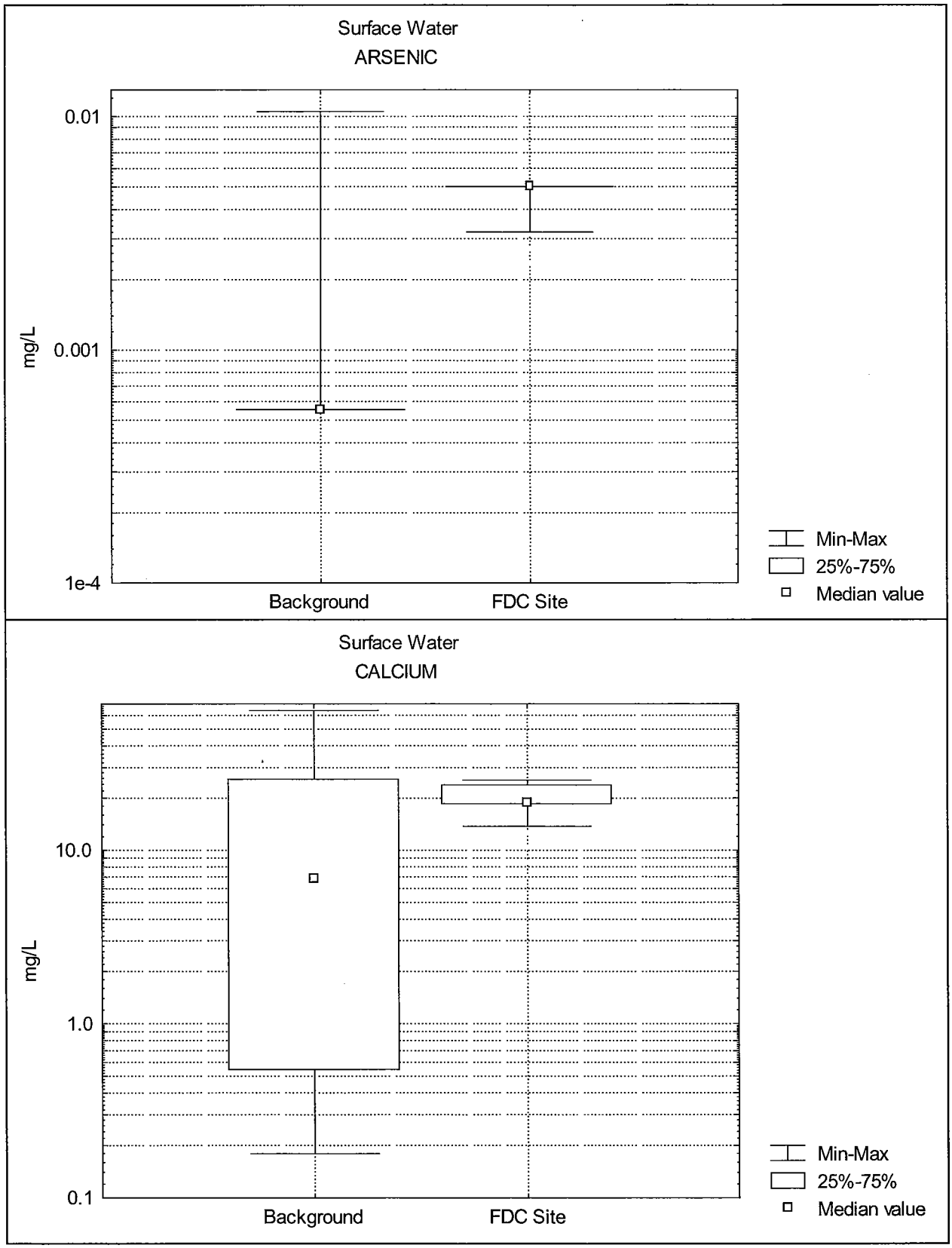
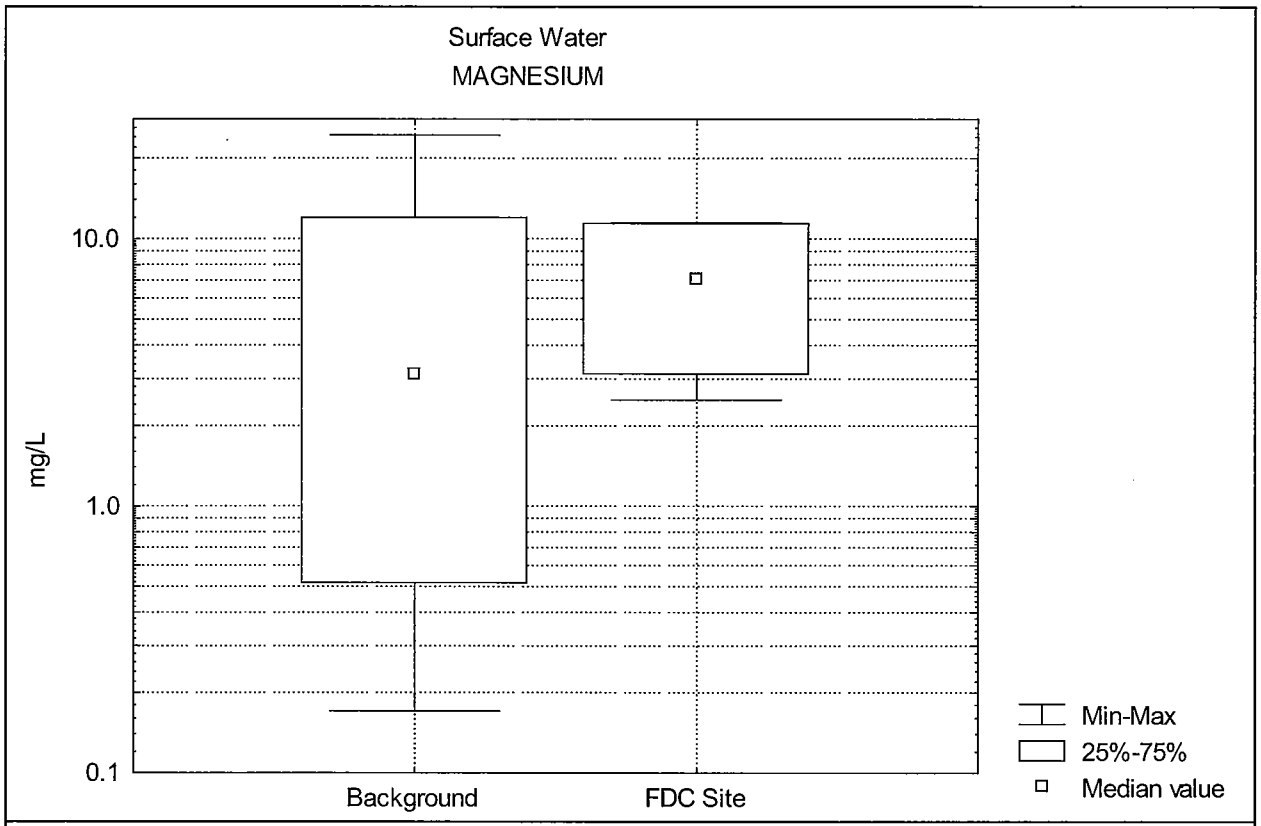

Surface Water
ARSENIC
0.01
0.001
1e-4
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value
Surface Water
CALCIUM
10.0
1.0
0.1
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-37


Surface Water
MAGNESIUM
mg/L
10.0
1.0
0.1
Background
FDC Site
Min-Max
25%-75%
Median value

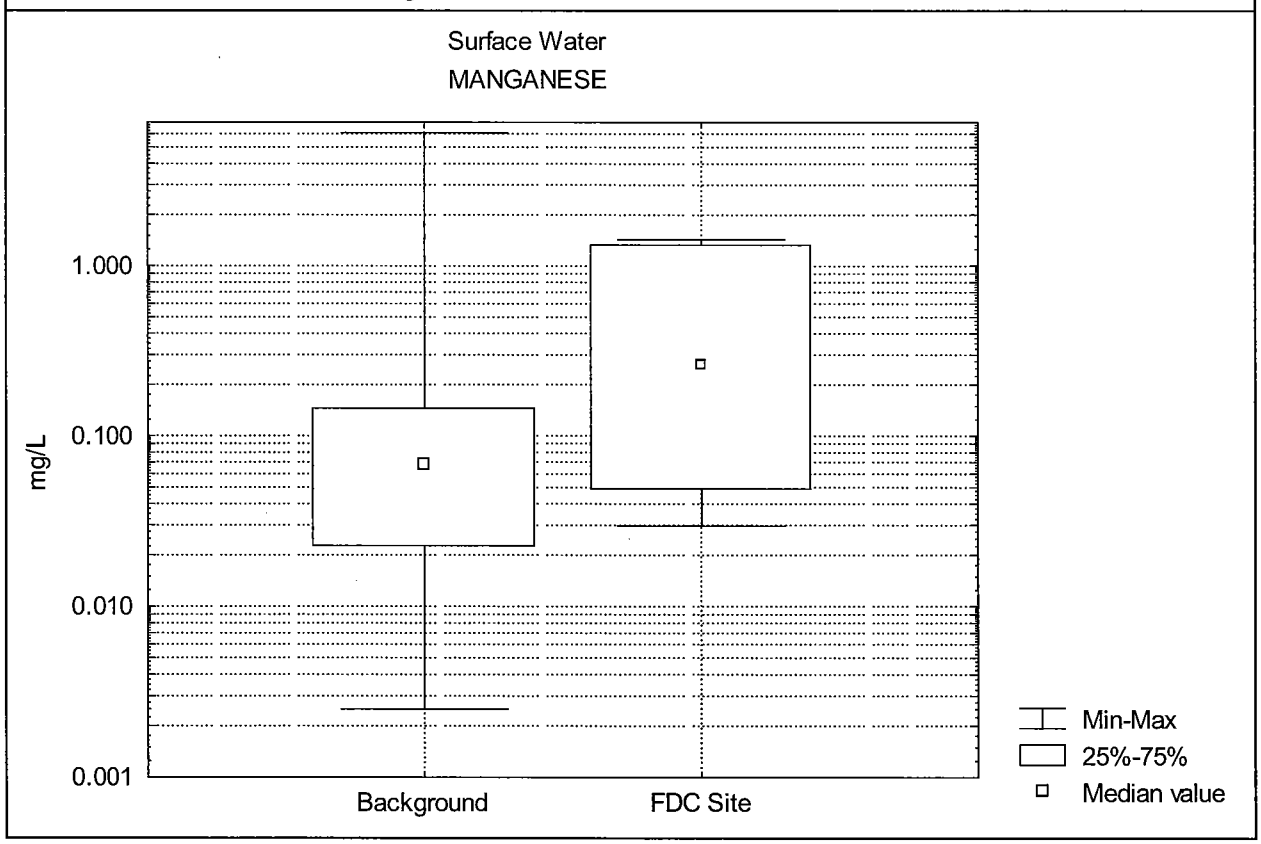
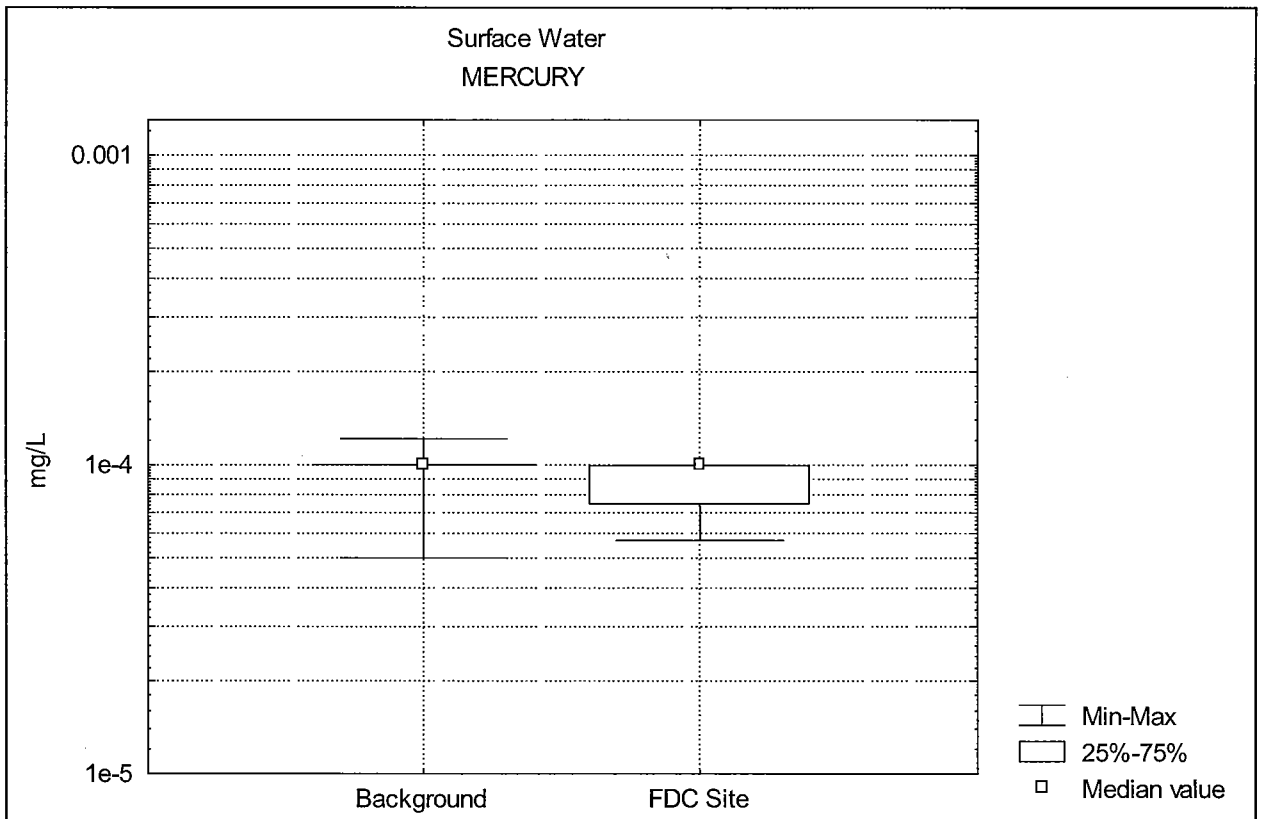
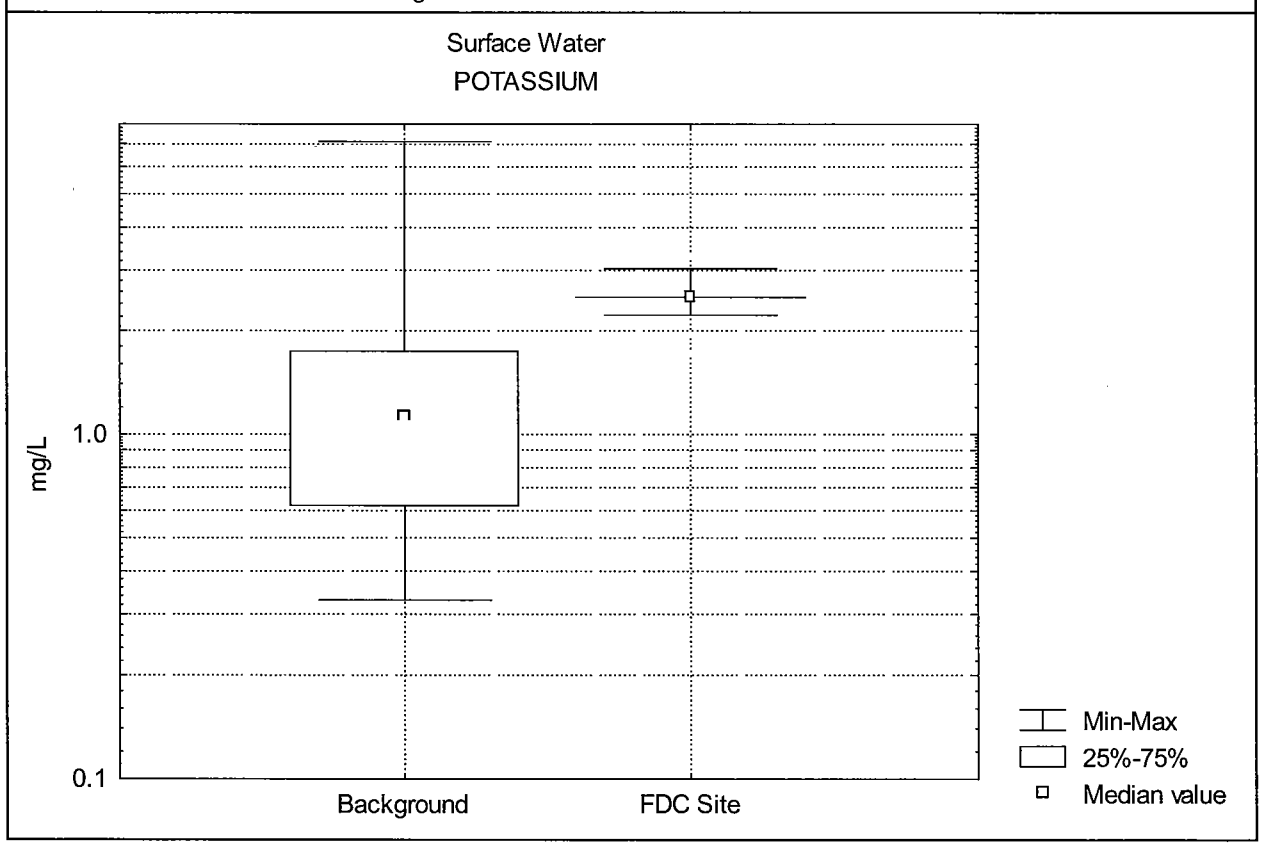

Surface Water
MANGANESE
mg/L
1.000
0.100
0.010
0.001
Background
FDC Site
Min-Max
25%-75%
Median value

Figure 1-38


Surface Water
MERCURY
0.001
1e-4
1e-5
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value


Surface Water
POTASSIUM
1.0
0.1
mg/L
Background
FDC Site
Min-Max
25%-75%
Median value

GEOCHEMICAL
(TIER 3)

Geochemical Evaluation of Metals in Soil, Sediment, Groundwater, and Surface Water Former Decon Complex, Parcel 93(7) Fort McClellan, Alabama

1.0 Introduction

This report provides the results of a geochemical evaluation of surface soil, sediment, groundwater, and surface water samples from the Former Decon Complex (Parcel 93[7]), Fort McClellan, Calhoun County, Alabama. Seventeen elements in soil, thirteen elements in sediment, fourteen elements in groundwater, and one element in surface water 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 evaluations consist of 31 surface soil samples (0 to 0.5 foot below ground surface [bgs] or 0 to 1 foot bgs) collected from October 1998 to November 2001; 26 subsurface soil samples (various depths ranging from 5 to 16 feet bgs) collected in October 1998 and February 1999; 6 sediment samples collected in October 1998 and February 1999; 20 unfiltered groundwater samples collected from October 1998 to December 2001; and 6 unfiltered surface water samples collected in October 1998 and January 1999. All of the site samples were analyzed for the full list of 23 target analyte list (TAL) metals. Installation-wide background data for TAL metals in soil, sediment, groundwater, and surface water are provided in the background study report (Science Applications International Corporation, 1998) and are used in the following evaluations.

2.0 Geochemical Evaluation Methodology

If an analyte fails statistical comparison to background as described in the "Statistical Comparison of Site and Background Data for the Former Decon Complex," 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 (EPA, 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 Former Decon Complex site-to-background comparisons.

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-to-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 oxides also have an affinity to adsorb divalent cations such as barium, cobalt, and lead (Kabata-Pendias, 2001). These trace elements would be evaluated against manganese.

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), 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, maintaining 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 (Bowell, 1994; Hem, 1985; Pourbaix, 1974; Brookins, 1988).

Chromium can be present in groundwater as a mixture of aqueous species with different charges, 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.

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.

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.

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 or tetrachloroethene under anaerobic conditions.

3.0 Results of the Geochemical Evaluation for Multiple Elements in Soil

This section presents the results of the geochemical evaluation of aluminum, barium, beryllium, cadmium, calcium, chromium, cobalt, copper, iron, lead, magnesium, mercury, nickel, potassium, selenium, sodium, and vanadium in soil samples from the Former Decon Complex. Correlation plots are provided in Attachment 1, and a list of samples containing anomalously high element concentrations is provided in Table 1.

Aluminum

The Former Decon Complex soil boring logs note the presence of clays in many of the sampled intervals. Aluminum is a primary component of common soil-forming minerals such as clays, feldspars, and micas. Iron oxides are minerals that are also common in soil. 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 can be used to

Table 1

Samples With Anomalous Element Concentrations
Former Decon Complex, Parcel 93(7)
Fort McClellan, Alabama

Medium	Sample Location	Sample Number	Element(s)
Surface Soil	FTA-93-GP05	DA0005	Chromium, Copper
Surface Soil	FTA-93-GP06	DA0006	Chromium, Zinc
Surface Soil	FTA-93-GP09	DA0009	Chromium, Nickel
Surface Soil	FTA-93-GP17	DA0019	Chromium
Surface Soil	FTA-93-GP18	DA0020	Zinc
Surface Soil	FTA-93-GP23	DA0027	Cadmium, Nickel
Surface Soil	FTA-93-GP24	DA0028	Chromium, Mercury, Nickel
Surface Soil	FTA-93-DEP01	DA0031	Zinc
Surface Soil	FTA-93-DEP02	DA0032	Zinc
Surface Soil	FTA-93-DEP03	DA0033	Chromium
Surface Soil	FTA-93-GP28	DA0038	Cadmium
Sediment	FTA-93-SW/SD04	DA1004	Arsenic, Selenium

qualitatively assess the relative abundance of these 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. The site samples exhibit a similar range of concentrations as the background samples, and they lie on the general background trend. This indicates that aluminum in the site samples is naturally occurring. It is worth noting that iron oxide and clay minerals 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
Aluminum detected in the site soil samples is naturally occurring.

Barium

As discussed in Section 2.1, divalent metals such as barium tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. If a soil sample contains a high proportion of clays, then it is expected to contain high concentrations of aluminum and associated trace elements. The site and background samples form a collinear trend in a plot of barium versus aluminum (Figure 2). Most of the site samples with high barium concentrations also contain proportionally higher aluminum, and lie on the trend established by the other samples. This indicates that barium in these site samples is associated with clays at a relatively constant ratio, and is natural. The two surface soil samples with 132 and 175 mg/kg barium (samples DA0017 and -09) exhibit slightly elevated Ba/Al ratios relative to the other samples and lie slightly above the background trend in Figure 2. Manganese oxides have a strong affinity to adsorb divalent cations such as barium (Kabata-Pendias, 2001). Samples DA0017 and -09 contain elevated barium but also proportionally higher manganese concentrations, indicating a natural source for the elevated barium in these two samples.

Conclusion
Barium concentrations detected in the site soil samples are naturally occurring.

Beryllium

Beryllium can substitute for aluminum in soil-forming minerals (Kabata-Pendias, 2001), so a positive correlation between beryllium and aluminum would be expected for uncontaminated samples. A plot of beryllium versus aluminum is provided in Figure 3. The site samples form a common linear trend with the background samples, and the samples that have the highest beryllium concentrations also have high aluminum. These observations indicate a natural source for beryllium in the site samples.

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

Cadmium

Cadmium is commonly present in soils as a divalent cation, and has an affinity to adsorb on manganese oxides (Kabata-Pendias, 2001). A positive correlation is expected between cadmium and manganese in uncontaminated soils. A plot of cadmium versus manganese is provided in Figure 4. The background samples form a generally linear trend with a positive slope, and two

of the four site surface soil samples with detectable cadmium lie on the background trend (cadmium was not detected in the subsurface soil samples). Samples DA0027 (from sample location FTA-93-GP23) and DA0038 (FTA-93-GP28) have the highest cadmium concentrations (2.7 and 3.98 mg/kg, respectively) of the site and background data sets but only moderate manganese, and lie above the trend formed by the other samples. Elevated cadmium in these samples is unexpected, and should be considered suspect.

Conclusion

The cadmium concentrations in surface soil samples DA0027 and -38 are anomalously high and may contain a component of contamination.

Calcium

Calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. A plot of magnesium versus calcium is provided in Figure 5. The background samples exhibit a generally linear trend with a positive slope. The site samples lie on this trend, and the site samples with the highest calcium concentrations also have the highest magnesium content. These observations indicate that calcium in the site samples has a natural source.

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). A plot of chromium versus iron reveals a strong collinear trend for the background samples and most of the site samples ($R^2 = 0.50$ and 0.82 for the background samples and site subsurface samples, respectively) (Figure 6). Most of 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. There are six surface soil samples (DA0005, -06, -09, -19, -28, and -33) that have elevated chromium (10.9, 24.5, 151, 19.1, 69.6, and 12.4 mg/kg, respectively) but only moderate iron, and which lie above the background trend. The chromium concentrations in these samples should be considered suspect. It is important to note that most of these anomalous surface soil samples were obtained from paved and unpaved parking areas, and that the soil boring logs for these locations note the presence of gravel, including chert and tar, in the sampled intervals. These samples likely represent nonnative materials used for surfacing the parking areas, which would explain the difference between their Cr/Fe ratios and those of the background and site subsurface soil samples. If this is the case, then the six anomalous surface soil samples might not reflect site-related contamination.

Conclusion

The chromium concentrations in surface soil samples DA0005, -06, -09, -19, -28, and -33 are anomalously high and should be considered suspect (Table 1). Chromium concentrations detected in the other site soil samples are 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 7). The site samples with high cobalt also contain high manganese, and lie on the trend established by the other samples. These observations suggest that cobalt in the soil samples is associated with manganese oxides at a relatively constant ratio, 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 oxide minerals (Kabata-Pendias, 2001). The background samples and most of the site samples form a linear trend in a plot of copper versus iron (Figure 8). The site samples with the highest copper concentrations also exhibit high iron and lie on the background trend. This indicates a natural source for the copper detected in these samples. The exception is surface soil sample DA0005 (sample location FTA-93-GP05; 15.3 mg/kg Cu). This sample has relatively high copper but low iron, and lies above the trend formed by the other samples. The elevated copper in this sample should be considered suspect.

Conclusion

The copper concentration in sample DA0005 is anomalously high and should be considered suspect. Copper concentrations detected in the other site soil samples are naturally occurring.

Iron

As discussed in the Aluminum evaluation, iron oxides and clays are common soil-forming minerals and tend to concentrate specific trace elements. The plot of aluminum versus iron concentrations provides a qualitative indicator of the relative abundance of these minerals in site soil (Figure 1). The site samples exhibit a similar range of iron concentrations as the background samples, and they lie on the general background trend. Iron in the site samples is naturally occurring. It is important to note that iron oxides and clays 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.

Lead

Manganese oxides in soil have a strong affinity to adsorb divalent cations such as barium and lead (Kabata-Pendias, 2001). Samples that contain a high percentage of manganese oxides will contain elevated manganese concentrations and proportionally higher lead. A common linear trend with a positive slope is observed for the site and background samples in a plot of lead versus manganese (Figure 9). The site samples with high lead also have high manganese, and lie

on the linear trend. This indicates that lead in the site samples is associated with manganese oxides at ratios consistent with those of the background samples, and is natural.

Conclusion
Lead concentrations detected in the site soil samples are naturally occurring.

Magnesium

As discussed in the Calcium evaluation, calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. A plot of magnesium versus calcium reveals a generally linear trend with a positive slope for the background samples (Figure 5). The site samples all lie on this trend, and the site samples with the highest magnesium concentrations also contain the highest calcium. Magnesium in the site samples is naturally occurring.

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

Mercury

Mercury concentrations in soil are commonly controlled through organic complex formation (Kabata-Pendias, 2001), so poor correlations between mercury and iron or mercury and aluminum are often observed, even in uncontaminated soil samples. A plot of mercury versus aluminum is provided in Figure 10. Most of the site samples lie on the general background trend, and the mercury in these samples is most likely natural. Site surface soil sample DA0028 (location FTA-93-GP24), however, contains the highest mercury concentration of the site samples (0.25 mg/kg) but has low aluminum (and only moderate iron), and lies above the background trend. Elevated mercury in this sample should be considered suspect.

Conclusion
The mercury concentration in sample DA0028 is anomalously high relative to the reference elements, and should be considered suspect. Mercury concentrations in the other site soil samples are most likely naturally occurring.

Nickel

Nickel is commonly associated with clays in soils (Kabata-Pendias, 2001). A plot of nickel versus aluminum reveals a generally linear trend with a positive slope for the background samples, and most of the site samples lie on this trend (Figure 11). This indicates that nickel in these site samples is associated with clays at ratios consistent with those of the background samples, and is natural. The exceptions are surface soil samples DA0009, -27, and -28; these samples contain high nickel concentrations (66.2, 24.8, and 29.3 mg/kg, respectively) but only low aluminum, and lie above the background trend. Elevated nickel in these samples should be considered suspect.

Conclusion
The nickel concentrations in samples DA0009, -27, and -28 are anomalously high and should be considered suspect (Table 1). Nickel concentrations detected in the other soil samples are naturally occurring.

Potassium

Potassium is a major element that is a common constituent of minerals such as clays, which also contain aluminum. The background samples form a generally linear trend in a plot of potassium versus aluminum (Figure 12). The site samples with high potassium generally have high aluminum, indicating that these samples are preferentially enriched in clays (and other aluminum-bearing minerals) and that the potassium is natural. Two subsurface soil samples contain high potassium but only moderate aluminum, and lie above the trend formed by the other site samples. However, there are two background samples with similarly high K/Al ratios. These samples most likely reflect the natural variability in K/Al ratios in Ft. McClellan soils.

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 soil samples. Comparison to background is hindered because of the high percentage of nondetects in the background data set. However, a plot of selenium versus iron reveals a linear trend with a positive slope for the site samples, and the two background samples with detectable selenium lie on this trend (Figure 13). The site samples with high selenium also exhibit high iron, and lie on the linear trend. These observations indicate that selenium in the samples is associated with iron oxides at a relatively constant ratio, and is natural.

Conclusion

Selenium detected in the site soil samples is naturally occurring.

Sodium

Sodium is a constituent of soil-forming minerals such as clays, which also contain aluminum. A plot of sodium versus aluminum is provided in Figure 14. The site samples with the highest sodium also contain high aluminum, and lie on the general background trend. Sodium in these samples most likely has a natural source. The three surface soil samples with detectable sodium lie below the background trend. The sodium concentrations in these samples are all estimated ("J"-qualified) quantitations that are below the reporting limit. Such values are uncertain, which may explain the lack of correlation observed for these samples.

Conclusion

Elevated sodium in the site samples is naturally occurring.

Zinc

As discussed in Section 2.1, divalent metals such as zinc tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. A positive correlation between zinc and aluminum is thus expected for uncontaminated samples. Most of the site samples lie on the linear background trend in a plot of zinc versus aluminum, indicating the zinc in these samples is associated with clays at a relatively constant ratio (Figure 15). There are four surface soil samples with anomalously high Zn/Al ratios that lie above the linear trend.

Samples DA0006, -20, -31, and -32 contain elevated zinc concentrations (148, 244, 106, and 165 mg/kg, respectively) but only low to moderate aluminum content, and should be considered suspect.

Surface soil sample DA0027 also contains elevated zinc (150 mg/kg) but only moderate aluminum, and lies above the background trend in Figure 15. In addition to its affinity to adsorb on clays, zinc can also sorb on iron oxides and it commonly substitutes for magnesium in minerals (Kabata-Pendias, 2001). Sample DA0027 contains elevated zinc but proportionally higher iron and magnesium; this suggests a natural source for the zinc in the sample.

Conclusion
Zinc concentrations in samples DA006, -20, -31, and -32 are anomalously high and should be considered suspect. Zinc concentrations detected in the other site soil samples are most likely naturally occurring.

4.0 Results of the Geochemical Evaluation for Multiple Elements in Sediment

This section presents the results of the geochemical evaluation of aluminum, arsenic, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, selenium, and zinc in sediment samples from the Former Decon Complex. Correlation plots are provided in Attachment 1, and a list of samples containing anomalously high element concentrations is provided in Table 1.

Aluminum

Aluminum is a primary component of common minerals such as clays, feldspars, and micas. Iron oxides are minerals that are also common in sediment. 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 can be used to qualitatively assess the relative abundance of these minerals in site sediment (Figure 16). The site samples exhibit higher aluminum concentrations than many of the background samples, but they also contain proportionally higher iron and lie on the background trend. This suggests that the site samples are naturally enriched in clays and iron oxides relative to the background samples, and that the aluminum is natural. It is worth noting that iron oxide and clay minerals adsorb specific trace elements (as discussed in Section 2.2), so samples that plot on the upper end of the trend in Figure 16 are expected to contain proportionally higher concentrations of trace elements.

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

Arsenic

As discussed in Section 2.1, arsenic has an affinity to adsorb on the surfaces of iron oxides, so a positive correlation is expected between arsenic and iron in uncontaminated samples. A plot of arsenic versus iron reveals a common linear trend for the background samples and most of the

site samples (Figure 17). Most of the site samples with elevated arsenic also exhibit proportionally higher iron, and lie on the linear trend. Arsenic in these samples is associated with iron oxides at a relatively constant ratio, and is natural. The exception is site sample DA1004 (from sample location FTA-93-SW/SD04), which contains the highest arsenic concentration of the site and background samples (80.5 mg/kg), but only moderate iron. Elevated arsenic in this sample should be considered suspect.

Conclusion
The arsenic concentration in sample DA1004 is anomalously high relative to iron and may contain a component of contamination. Arsenic concentrations detected in the other site sediment samples are naturally occurring.

Barium
As discussed in Section 2.1, manganese oxides have an affinity to adsorb divalent metals such as barium. If a sediment 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 18). The site sample with the highest barium concentration also contains the highest manganese concentration, and lies on the trend established by the other samples. These observations indicate that barium in the site samples is associated with manganese oxides at a relatively constant ratio, and is natural.

Conclusion
Barium concentrations detected in the site sediment samples are naturally occurring.

Beryllium
A plot of beryllium versus aluminum reveals a common linear trend for the site and background samples (Figure 19). The site samples have higher beryllium concentrations than many of the background samples, but they also contain proportionally higher aluminum and lie on the background trend. This suggests that beryllium in the site samples is associated with clays at a relatively constant ratio, and is natural.

Conclusion
Beryllium concentrations detected in the site sediment samples are naturally occurring.

Cadmium
Cadmium has an affinity to adsorb on clays (Kabata-Pendias, 2001), so a positive correlation between cadmium and aluminum is expected for uncontaminated samples. The background samples form a weak linear trend with a positive slope in plot of cadmium versus aluminum (Figure 20). The single site sample with detectable cadmium has high cadmium relative to many of the background samples, but it also contains proportionally higher aluminum, and lies on the background trend. This suggests a natural source for cadmium in the sample.

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

Calcium

Calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. A plot of magnesium versus calcium is provided in Figure 21. The background samples exhibit a generally linear trend with a positive slope, and the site samples lie on this trend. This indicates a natural source for calcium in the samples.

Conclusion

Calcium detected in the site sediment samples is naturally occurring.

Chromium

Chromium has an affinity to adsorb on the surfaces of iron oxides (Cornell and Schwertmann, 1996), so a positive correlation between chromium and iron is expected in uncontaminated samples. A plot of chromium versus iron reveals a linear trend with a positive slope for the site and background samples (Figure 22). The site samples contain higher chromium concentrations than many of the background samples, but they also contain proportionally higher iron and lie on the background trend. These observations indicate that chromium in the site samples is associated with iron oxides at a relatively constant ratio, and is natural.

Conclusion

Chromium concentrations detected in the site sediment samples are naturally occurring.

Copper

Copper concentrations are commonly controlled through adsorption on the surfaces of clays and aluminum hydroxides (Kabata-Pendias, 2001). Most of the background samples form a linear trend in a plot of copper versus aluminum (Figure 23). The site samples have higher copper concentrations relative to many of the background samples, but they also contain proportionally higher aluminum and lie on the background trend. Copper in these samples is associated with clays (and other aluminum-bearing minerals) at a relatively constant ratio, and is natural.

Conclusion

Copper in the site sediment samples is naturally occurring.

Iron

As discussed in the Aluminum evaluation, iron oxide minerals are common in sediments and tend to concentrate specific trace elements. The positive correlation between chromium and iron, and the absence of outliers plotting off the linear trend on the correlation plot, indicate a natural source for these elements (Figure 22). Iron in the site samples is naturally occurring.

Conclusion

Iron detected in the site sediment samples is naturally occurring.

Lead

Manganese oxides have an affinity to adsorb divalent cations such as barium and lead (Kabata-Pendias, 2001). A plot of lead versus manganese is provided in Figure 24. The site and background samples form a common linear trend with a positive slope, and the site sample with the highest lead concentration also has the highest manganese. These observations indicate that

lead in the site samples is associated with manganese oxides at ratios consistent with those of the background samples, and is natural.

Conclusion
Lead concentrations in the site sediment samples are naturally occurring.

Magnesium
As discussed in the Calcium evaluation, calcium and magnesium have similar chemical properties, and magnesium often substitutes for calcium in minerals. A plot of magnesium versus calcium reveals a generally linear trend with a positive slope for the site and background samples (Figure 21). The site sample with the highest magnesium concentration also contains high calcium, and lies on the background trend. Magnesium in the site samples is naturally occurring.

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

Nickel
A plot of nickel versus iron reveals a generally linear trend with a positive slope for most of the background samples (Figure 28). The site samples with high nickel concentrations have proportionally higher iron, and lie on the general background trend. Nickel in the site samples is natural.

Conclusion
Nickel concentrations detected in the site sediment samples are naturally occurring.

Selenium
Evaluation is hindered because of the high percentage of nondetects in both the site and background data sets. However, a plot of selenium versus aluminum reveals a common linear trend with a positive slope for the background samples and one of the site samples (Figure 25). This indicates that selenium in these samples is associated with clay minerals at a relatively constant ratio, and is natural. Site sample DA1004 (location FTA-93-SW/SD04) contains the highest selenium concentration of the site and background samples (3.3 mg/kg) but only moderate aluminum (as well as low iron and manganese), and lies slightly above the linear background trend. Elevated selenium in this sample is unexpected, and should be considered suspect.

Conclusion
The selenium concentration in sample DA1004 is anomalously high relative to the reference elements, and should be considered suspect. This sample also contains an anomalously high concentration of arsenic.

Zinc
As discussed in Section 2.1, divalent metals such as zinc tend to form cationic species in solution and are attracted to clay mineral surfaces, which maintain a negative surface charge. A positive correlation between zinc and aluminum is thus expected for uncontaminated samples. All of the

site samples lie on the general background trend in a plot of zinc versus aluminum (Figure 26). The site samples have higher zinc concentrations than many of the background samples, but they also contain proportionally higher aluminum. Zinc in the site samples is associated with clay minerals at a ratios consistent with those of the background samples, and is natural.

Conclusion
Zinc detected in the site sediment samples is naturally occurring.

5.0 Results of the Geochemical Evaluation for Multiple Elements in Groundwater

This section presents the results of the geochemical evaluation of aluminum, barium, beryllium, calcium, chromium, cobalt, iron, lead, magnesium, manganese, nickel, potassium, sodium, and vanadium in unfiltered groundwater samples from the Former Decon Complex. Correlation plots are provided in Attachment 1.

Field-measured pH readings for the site groundwater samples range from 4.9 to 7.89 standard units, with a mean of 6.36. These observations indicate near-neutral pH to neutral pH conditions at most of the sample locations. Field-measured DO readings range from 0 to 6.95 mg/L, with a mean of 1.80 mg/L, and ORP readings range from –150 to +222 millivolts (mV), with a mean of +14 mV. These readings suggest that redox conditions at the sample locations ranged from oxidizing to reducing.

Aluminum

The detected concentrations of aluminum in the site samples range from 0.1 J mg/L to 216 mg/L. 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 the Former Decon Complex pH readings are higher than this and are generally in the neutral range. Thus, the detectable aluminum in the site samples is primarily associated with suspended particulates.

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 permits a qualitative assessment of the amount of suspended particulates in the groundwater samples (Figure 27a). A strong linear trend with a positive slope is typically observed when the aluminum and iron are both present in particulate form. Just such a trend is observed here for most of the site samples ($R^2 = 0.96$) and most of the background samples. The site samples with the highest aluminum concentrations exhibit proportionally higher iron, and lie on the linear trend formed by the other samples. This indicates that the elevated aluminum is due to the presence of suspended clay particulates, and is natural.

This conclusion is corroborated by the field-measured turbidity readings. Turbidity measurements for some of the samples are quite high, ranging from 0 to 1000 nephelometric turbidity units (NTU) (mean of 171 NTU). The samples with high aluminum concentrations also exhibit proportionally higher turbidity (Figure 27b).

Conclusion
Aluminum concentrations detected in the site groundwater samples are 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 28). The site samples all lie on the background trend, and the two site samples with the highest barium concentrations also have high aluminum. These observations suggest that barium in these site samples is associated with suspended clays at ratios consistent with those of the background samples, and is natural.

Nine samples are not depicted in Figure 28 because they lack detectable aluminum (DA3012, -13, -15, -18, -19, -20, -21, -22, and -23). This absence of detectable aluminum suggests that suspended particulates are not a primary mechanism controlling barium concentrations in these samples. 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. The establishment of local reducing conditions caused by fuel or solvent releases could cause the dissolution of barite within these areas. However, the nine samples in question are mostly nondetect for the VOCs (only a few of the samples contain estimated hits of VOCs); this suggests that the elevated barium is not due to reductive dissolution caused by VOC contamination, and that the low redox may be natural.

Conclusion
Barium concentrations detected in the site groundwater samples are naturally occurring.

Beryllium

Only 2 of the 20 site samples (DA3001 and -09) contain detectable beryllium. These samples also contain detectable aluminum and elevated turbidity (34.4 and 1000 NTUs, respectively). A plot of beryllium versus aluminum reveals a common linear trend for the site and background samples (Figure 29). Sample DA3009 contains the highest beryllium concentration of both the site and background data sets (0.0136 mg/L), but it also contains the highest aluminum concentration of both data sets (216 mg/L) and lies on the trend formed by the other samples. These observations indicate that the elevated beryllium in the site samples is primarily associated with suspended particulates such as clays, and is natural.

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

Calcium

Calcium and magnesium are both major dissolved constituents in groundwater, and are derived from the weathering of silicate and carbonate minerals. A plot of magnesium versus calcium reveals a linear trend with a positive slope for the background samples, and the site samples lie on this trend (Figure 30). Calcium in these samples is natural.

Conclusion

Calcium detected in the site groundwater samples is naturally occurring.

Chromium

As noted in Section 2.2, chromium can be present in groundwater as a mixture of aqueous species with different charges, depending on pH, and thus chromium can have an affinity for several different types of sorptive surfaces, including clay and iron oxide minerals. A plot of chromium versus aluminum is provided in Figure 31. Comparison to background is hindered by the high percentage of nondetects in the background data set. However, the site samples exhibit a strong linear trend positive slope in a plot of chromium versus aluminum ($R^2 = 0.99$). The site samples with the highest chromium concentrations exhibit proportionally higher aluminum, and lie on the trend formed by the other samples. These observations indicate that the chromium detected in the site samples is associated with suspended clay particulates at a nearly constant ratio, and is natural.

Conclusion

Chromium detected in the site groundwater samples is naturally occurring.

Cobalt

Cobalt was detected in only 3 of the 20 site groundwater samples. A plot of cobalt versus aluminum is provided in Figure 32. Comparison to background is hindered by the high percentage of nondetects in both data sets. However, the site sample with the highest cobalt concentration (DA3009; 0.0368 mg/L) also contains the highest aluminum concentration of the site and background data sets. This sample also contains the highest iron concentration of the site and background data sets (285 mg/L), as well as elevated turbidity (1000 NTUs). These observations indicate that the elevated cobalt in sample DA3009 is primarily associated with suspended particulates such as clays and iron oxides, and is natural.

Conclusion

Elevated cobalt observed in the site groundwater samples is naturally occurring.

Iron

As discussed in Section 2.2, iron concentrations greater than about 1 mg/L in neutral-pH, moderate to oxidizing redox conditions likely reflect the presence of suspended iron oxides. The field-measured pH readings for the site samples are generally in the neutral range, but several of the samples have low DO readings and negative ORP measurements, which indicate reducing conditions at some of the sample locations. Iron concentrations in the site samples are thus expected to be controlled to some degree by redox effects as well as the effects of suspended particulates.

Aluminum concentrations in excess of approximately 1 mg/L in neutral pH groundwater indicate the presence of suspended clays. As discussed in the Aluminum evaluation, a positive correlation is expected between aluminum and iron concentrations in neutral-pH, moderate to oxidizing groundwater. The strong positive correlation observed for the several of the site samples in the plot of aluminum versus iron indicates that both elements are present in particulate form, in those samples (Figure 27a). The two site samples with the highest iron concentrations (DA3009 and -11; 285 and 65.8 mg/L, respectively) exhibit proportionally higher aluminum, and lie on the linear trend formed by the other samples. The detectable DO (5.32 and 3.32 mg/L) and positive ORP readings (78 and 70 mV) indicate oxidizing conditions at the time of sample collection. The turbidity readings of 1000 NTUs indicate a high mass of suspended particulates in the samples. These observations indicate that the elevated iron in these two samples is due to the presence of suspended iron oxides, and is natural.

A plot of iron versus turbidity is provided in Figure 33. As seen in the plot, there is a positive correlation between iron concentrations and turbidity, with the samples containing higher iron also exhibiting higher turbidity measurements. This observation supports the contention that the presence of suspended particulates is a primary control on iron concentrations in the site samples.

There are nine samples that are not depicted in Figure 27a because they do not contain detectable aluminum (DA3012, -13, -15, -18, -19, -20, -21, -22, and -23). Iron is a redox-sensitive element, and its dissolved concentrations will increase under reducing conditions. The iron concentrations in these samples range from 0.188 J mg/L to 12.9 J mg/L; the DO readings are low or nondetect in most of these samples, and the ORP readings range from -150 to +157 mV. The lack of detectable aluminum and the low redox suggest that the elevated iron in these samples is primarily in solution and is not associated with suspended particulates. However, these iron concentrations are below the background maximum of 25.8 mg/L. Additionally, these samples are mostly nondetect for the VOCs (only a few of the samples contain estimated hits of VOCs); this suggests that the elevated iron is not due to reductive dissolution caused by VOC contamination, and that the low redox may be natural.

Conclusion

Iron detected in the site samples is naturally occurring.

Lead

Lead was detected in only 5 of the 20 site groundwater samples. A plot of lead versus aluminum reveals a common linear trend for the site and background samples (Figure 34). Samples DA3009 and -11 contain the highest lead concentrations of both the site and background data sets (0.114 and 0.0714 mg/L, respectively), but they also contain the highest aluminum concentration of both data sets (216 and 89.6 mg/L, respectively) and lie on the trend formed by the other samples. These samples also contain the highest iron concentrations of the site and background data sets (285 and 65.8 mg/L respectively), as well as elevated turbidity (1000 NTUs). These observations indicate that lead in the site samples is primarily associated with suspended particulates such as clays, and is natural.

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

Magnesium

As discussed in the Calcium evaluation, calcium and magnesium are both major dissolved constituents in groundwater, and are derived from the weathering of silicate and carbonate minerals. A plot of magnesium versus calcium reveals a linear trend with a positive slope for the background samples, and the site samples lie on this trend (Figure 30). Magnesium in these samples is natural.

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

Manganese

There is weak correlation between manganese and aluminum in the site and background data sets – and 9 of the site samples are nondetect for aluminum – which suggests that suspended particulates (manganese oxides) are not a primary control on manganese concentrations in most of the samples. Manganese behaves similarly to iron in that it is redox-sensitive and soluble only under reducing conditions. Field readings for the site samples indicate reducing conditions at several of the sample locations. A plot of manganese versus iron is provided in Figure 35. The site samples with high manganese also contain high iron, and lie on the background trend. None of the samples contain excess manganese relative to background, suggesting a natural source for the manganese in the site samples.

Conclusion
Manganese in the site samples is naturally occurring.

Nickel

Nickel was detected in only 4 of the 20 site groundwater samples. Comparison to background is hindered by the high percentage of nondetects in the background data set. A plot of nickel versus iron reveals a linear trend with a positive slope for the site samples (Figure 36). Samples DA3009 and -11 contain the highest nickel concentrations of both the site and background data sets (0.342 and 0.0548 mg/L, respectively), but they also contain the highest iron concentrations of both data sets (285 and 65.8 mg/L, respectively) and lie on the trend formed by the other samples. These samples also contain the highest aluminum concentrations of the site and background data sets (216 and 89.6 mg/L respectively), as well as elevated turbidity (1000 NTUs). These observations indicate that lead in the site samples is primarily associated with suspended particulates such as iron oxides, and is natural.

Conclusion
Nickel detected in the site groundwater samples is naturally occurring

Potassium

Potassium is a major dissolved constituent in groundwater, and one primary source is the weathering of silicate minerals. Sodium is another major cation that is a principal component of groundwater. The site samples form a generally linear trend in a plot of potassium versus

sodium (Figure 37). The sample with the highest potassium also contains high sodium and lies on the trend established by the other samples. Elevated potassium in the site samples is naturally occurring.

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

Sodium

Sodium and magnesium are major dissolved constituents in groundwater. The site and background samples form a generally linear trend with a positive slope in a plot of sodium versus magnesium (Figure 38). The site samples with high sodium also contain high magnesium, and lie on the trend established by the other samples. 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 3 of the 20 site groundwater samples. As discussed in Section 2.2, vanadium is typically present in oxic groundwater as anionic species, and has an affinity to adsorb on the surfaces of iron oxides, which maintain a positive surface charge. A plot of vanadium versus iron is provided in Figure 39. Comparison to background is hindered by the high percentage of nondetects in the background data set. However, the two site samples with the highest vanadium (DA3009 and -11; 0.297 and 0.145 mg/L, respectively) also have high iron, suggesting that the vanadium in these samples is primarily associated with suspended iron oxides, and is natural. This conclusion is corroborated by the elevated aluminum concentrations of these two samples (216 and 89.6 mg/L, respectively) and the elevated turbidity (1000 NTUs) in the site samples. The elevated aluminum, iron, and turbidity measurements suggest a high mass of suspended particulates (clays and iron oxides) in these samples, and thus high concentrations of associated trace elements are expected.

Conclusion
Vanadium concentrations detected in the site groundwater samples are naturally occurring.

6.0 Results of the Geochemical Evaluation for Calcium in Surface Water

This section presents the results of the geochemical evaluation of calcium in unfiltered surface water samples from the Former Decon Complex. The corresponding correlation plot is provided in Attachment 1.

Field-measured pH readings are available for five of the six site samples (excluding sample DA2008, from sample location FTA-93-SW/SD06) range from 6.26 to 6.93 standard units, with a mean of 6.43. These observations indicate near-neutral to neutral pH conditions at the sample

locations. Field-measured DO readings for these samples range from 1.25 to 7.97 mg/L, with a mean of 4.80 mg/L, and the available ORP readings (for samples DA2002, -04, and -05, from sample locations FTA-93-SW/SD02, -04, and -05, respectively) range from +231 to +294 mV, with a mean of +256 mV. These readings suggest oxidizing conditions in the surface water at the time of sample collection.

Calcium

Calcium and magnesium are both major dissolved constituents in natural waters, and their concentrations typically covary, with samples exhibiting high calcium also exhibiting proportionally higher magnesium. A plot of calcium versus magnesium reveals a strong linear trend with a positive slope for most of the background samples (Figure 40). All of the site samples lie on this linear background trend, and the site samples with the highest calcium also have proportionally higher magnesium. Calcium in these samples is natural.

Conclusion

Calcium in the site surface water samples is naturally occurring.

7.0 Summary

This section summarizes the results of the geochemical evaluations of selected inorganics in surface soil, sediment, groundwater, and surface water samples from the Former Decon Complex.

Soil. Geochemical evaluation indicates that all of the aluminum, barium, beryllium, calcium, cobalt, iron, lead, magnesium, potassium, selenium, and sodium concentrations detected in the surface and subsurface soil samples are naturally occurring. Cadmium, chromium, copper, mercury, nickel, and zinc each have anomalously high concentrations in one or more surface soil samples, and these concentrations should be considered suspect. A list of the samples that contain anomalous element concentrations is provided in Table 1. All of the chromium, copper, mercury, nickel, and zinc concentrations detected in the subsurface soil samples are naturally occurring (cadmium was not detected in any of the subsurface soil samples).

It is important to note that many of the anomalous surface soil samples were obtained from paved and unpaved parking areas, and that the soil boring logs for these locations note the presence of gravel, including chert and tar, in the sampled intervals. These samples may represent nonnative materials used for surfacing the parking areas, which would explain the difference between their trace-versus-major element ratios and those of the background and site subsurface soil samples.

Sediment. Geochemical evaluation indicate that detected concentrations of aluminum, barium, beryllium, cadmium, calcium, chromium, copper, iron, lead, magnesium, and zinc in the sediment samples are naturally occurring. The arsenic and selenium concentrations in sample DA1004 (sample location FTA-93-SW/SD04) are anomalously high relative to the reference element concentrations, indicating potential contamination (Table 1).

Groundwater. Geochemical evaluation indicates that aluminum, barium, beryllium, calcium, chromium, cobalt, iron, lead, magnesium, manganese, nickel, potassium, sodium, and vanadium concentrations detected in the unfiltered groundwater samples are naturally occurring.

Surface Water. Geochemical evaluation indicates that calcium concentrations detected in the surface water samples are naturally occurring.

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ATTACHMENT 1

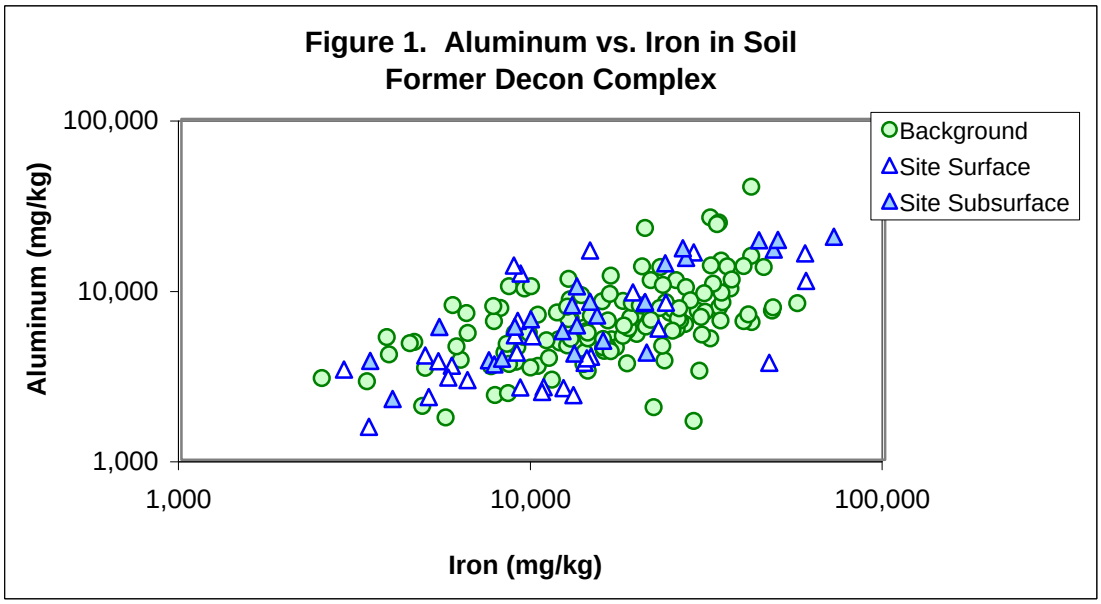
Figure 1. Aluminum vs. Iron in Soil
Former Decon Complex
Aluminum (mg/kg)
100,000
10,000
1,000
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Surface
Site Subsurface

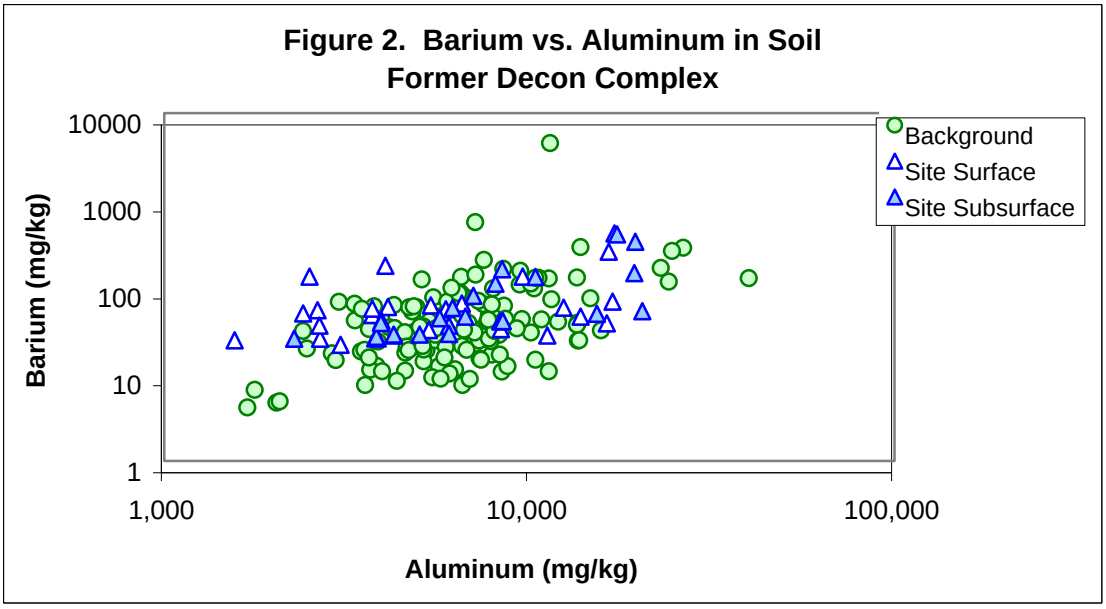
Figure 2. Barium vs. Aluminum in Soil
Former Decon Complex
Barium (mg/kg)
10000
1000
100
10
1
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site Surface
Site Subsurface

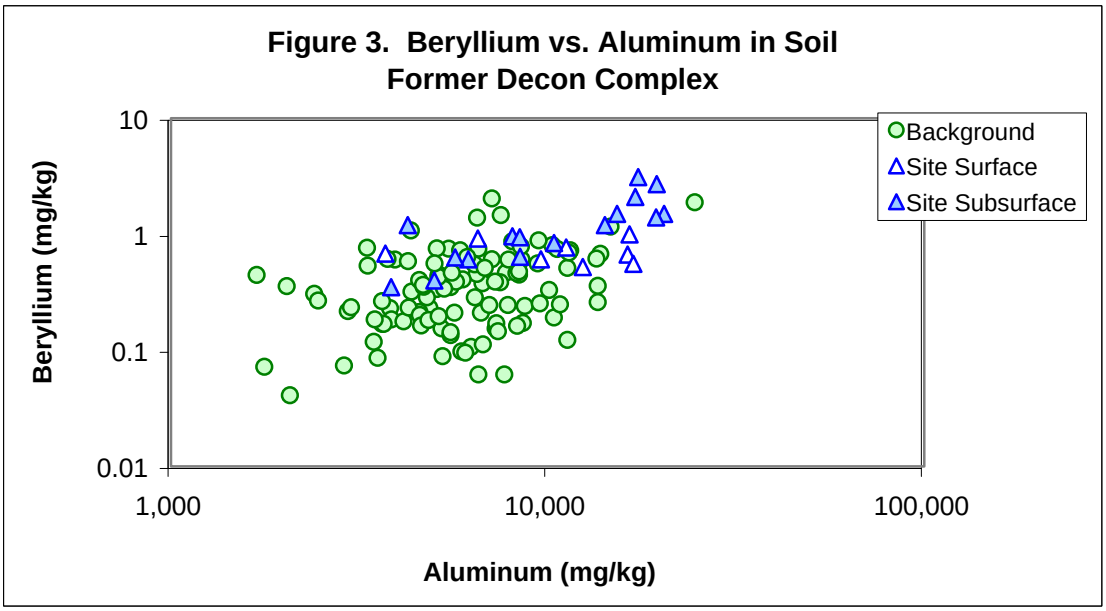
Figure 3. Beryllium vs. Aluminum in Soil
Former Decon Complex
Beryllium (mg/kg)
10
1
0.1
0.01
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site Surface
Site Subsurface

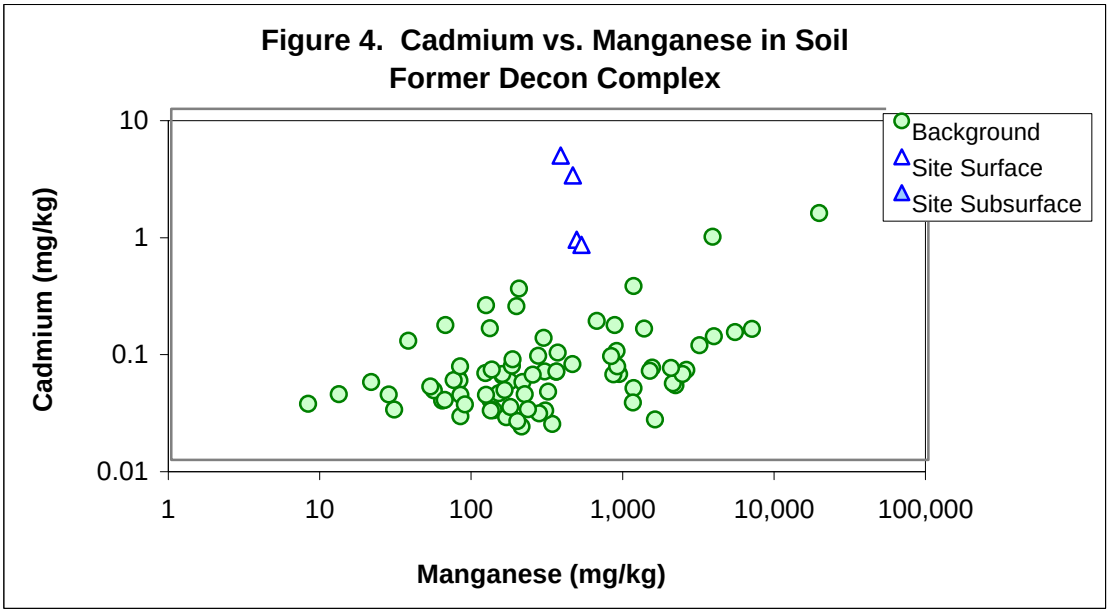
Figure 4. Cadmium vs. Manganese in Soil
Former Decon Complex
Cadmium (mg/kg)
10
1
0.1
0.01
1
10
100
1,000
10,000
100,000
Manganese (mg/kg)
Background
Site Surface
Site Subsurface

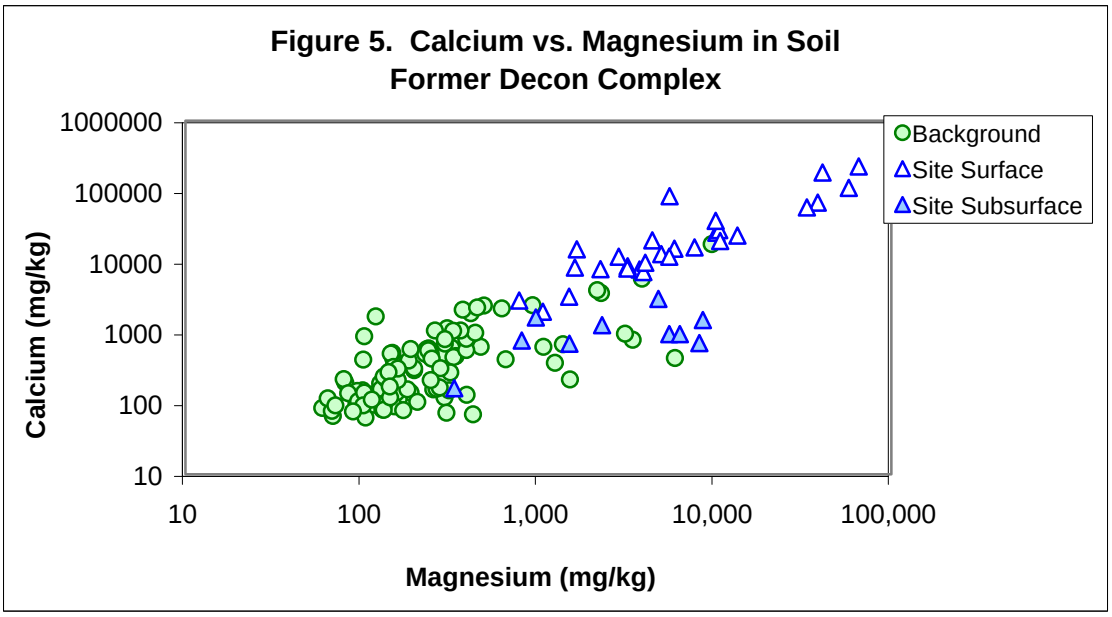
Figure 5. Calcium vs. Magnesium in Soil
Former Decon Complex
Calcium (mg/kg)
1000000
100000
10000
1000
100
10
10
100
1,000
10,000
100,000
Magnesium (mg/kg)
Background
Site Surface
Site Subsurface

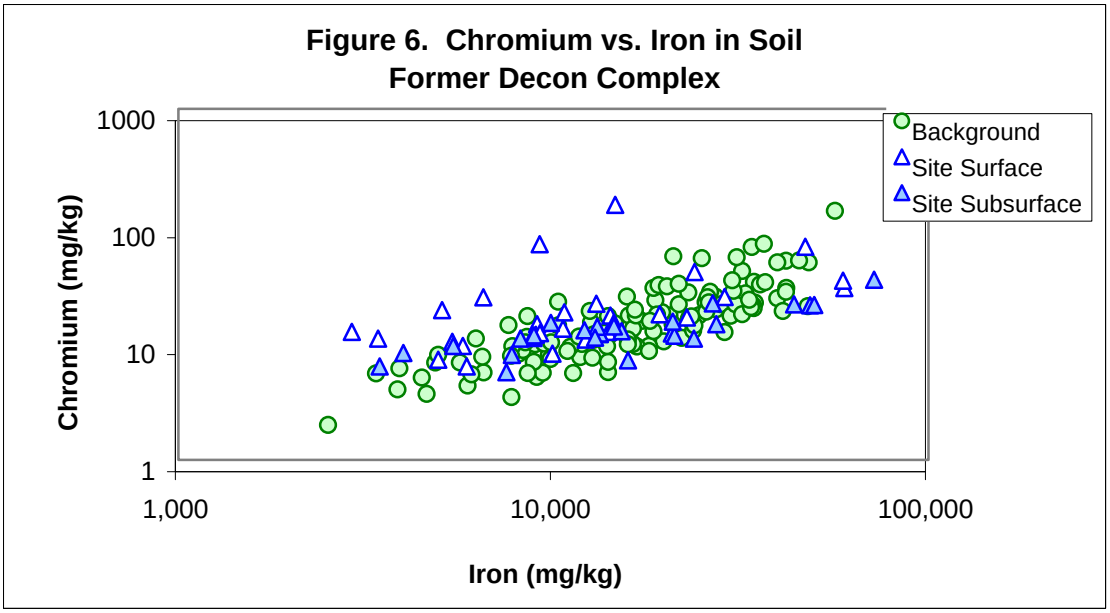
Figure 6. Chromium vs. Iron in Soil
Former Decon Complex
Chromium (mg/kg)
1000
100
10
1
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Surface
Site Subsurface

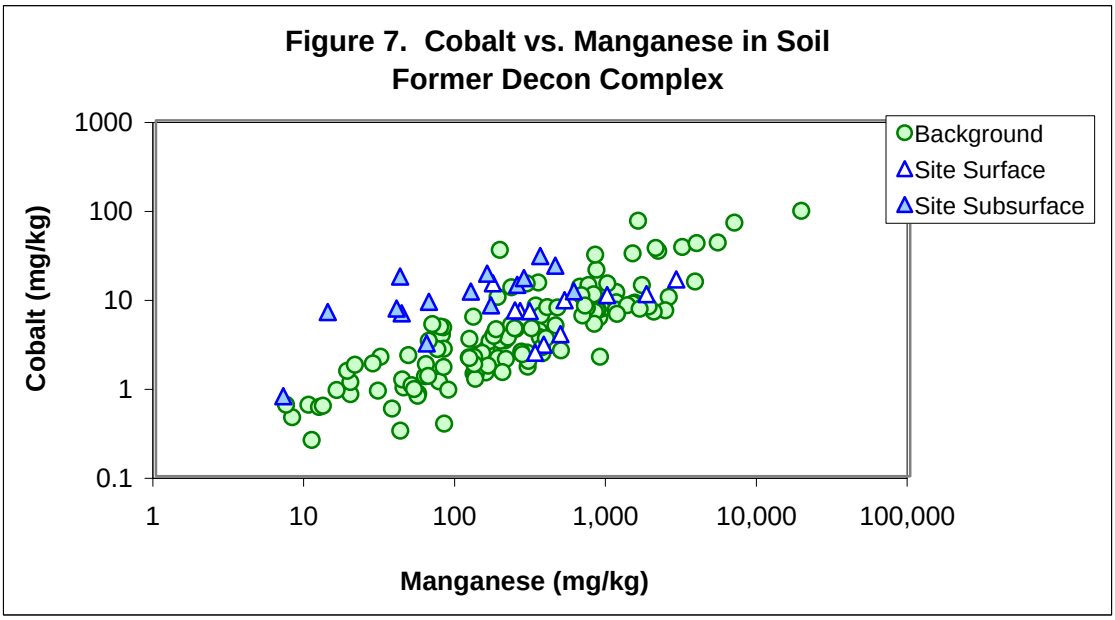
Figure 7. Cobalt vs. Manganese in Soil
Former Decon Complex
Cobalt (mg/kg)
1000
100
10
1
0.1
1
10
100
1,000
10,000
100,000
Manganese (mg/kg)
Background
Site Surface
Site Subsurface

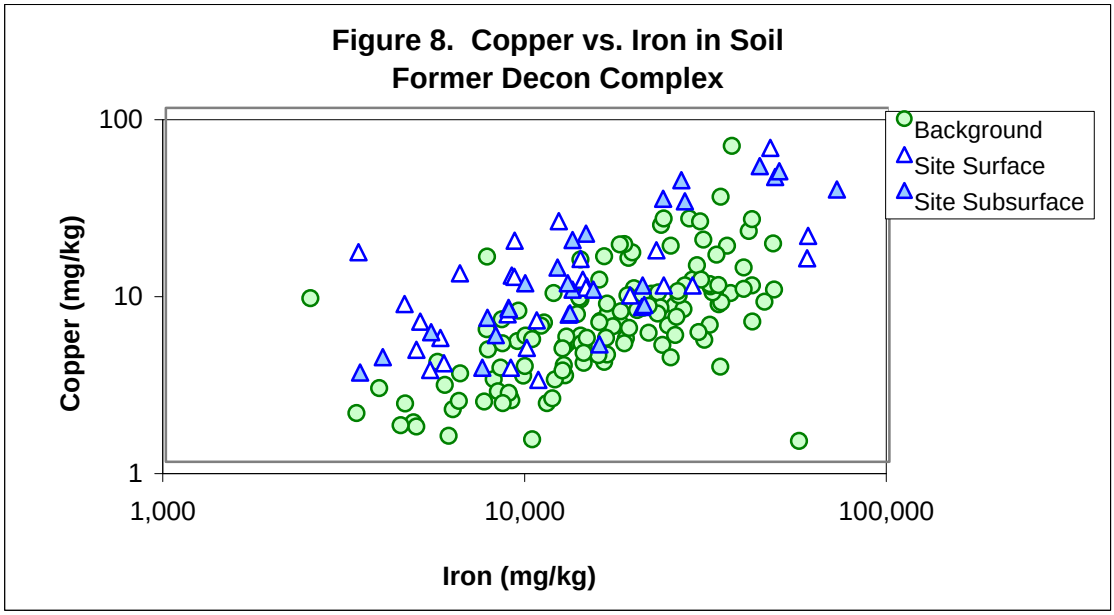
Figure 8. Copper vs. Iron in Soil
Former Decon Complex
Copper (mg/kg)
100
10
1
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Surface
Site Subsurface

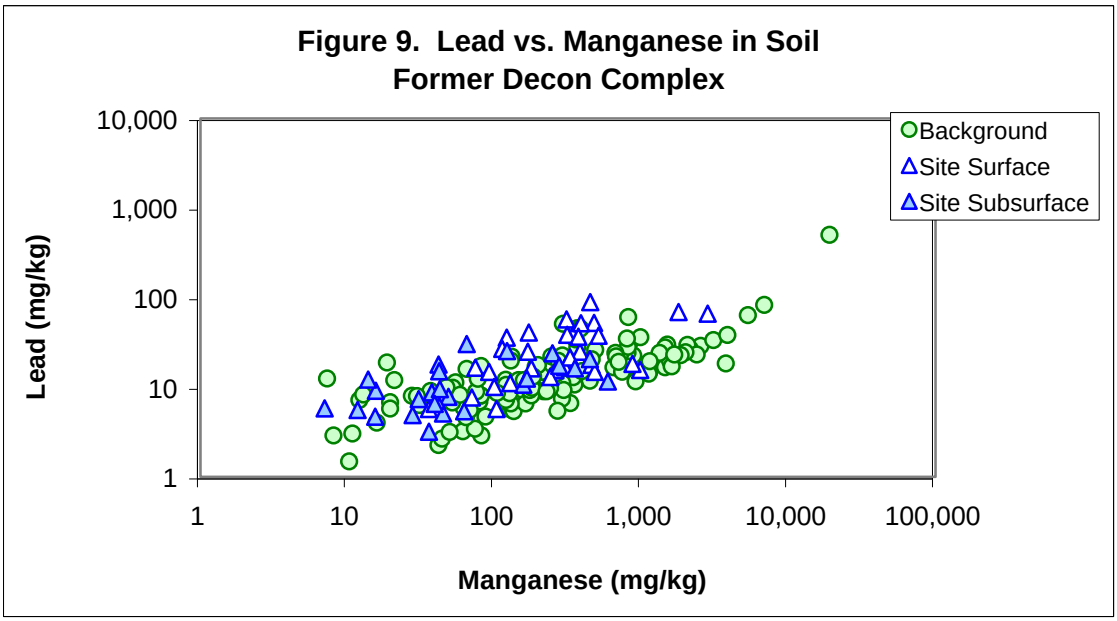
Figure 9. Lead vs. Manganese in Soil
Former Decon Complex
Lead (mg/kg)
10,000
1,000
100
10
1
1
10
100
1,000
10,000
100,000
Manganese (mg/kg)
Background
Site Surface
Site Subsurface

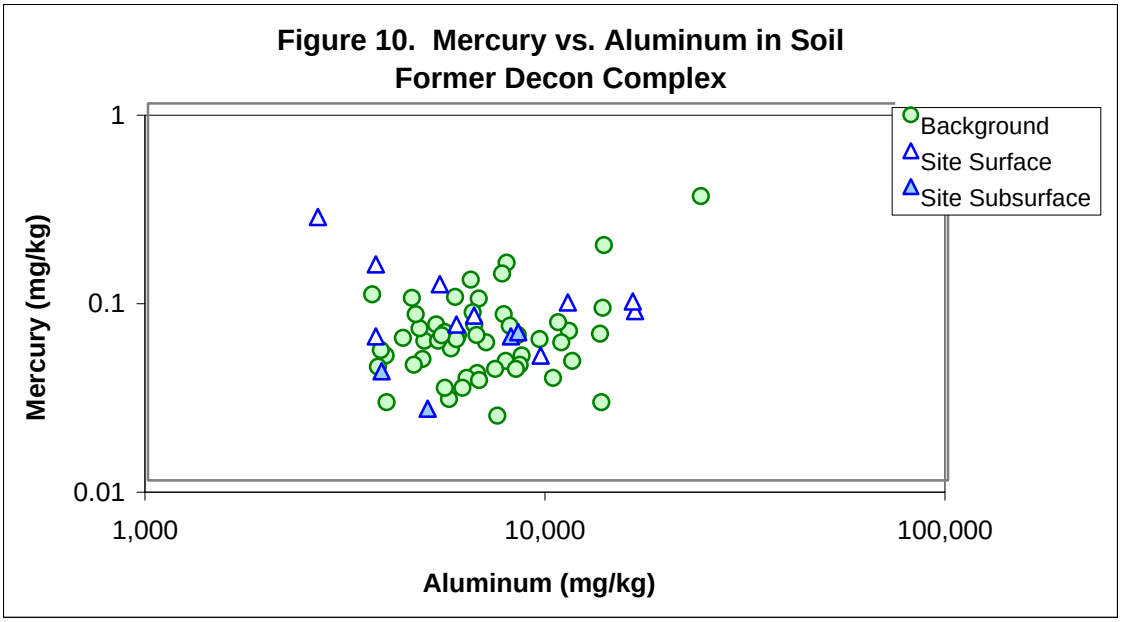
Figure 10. Mercury vs. Aluminum in Soil
Former Decon Complex
Mercury (mg/kg)
1
0.1
0.01
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site Surface
Site Subsurface

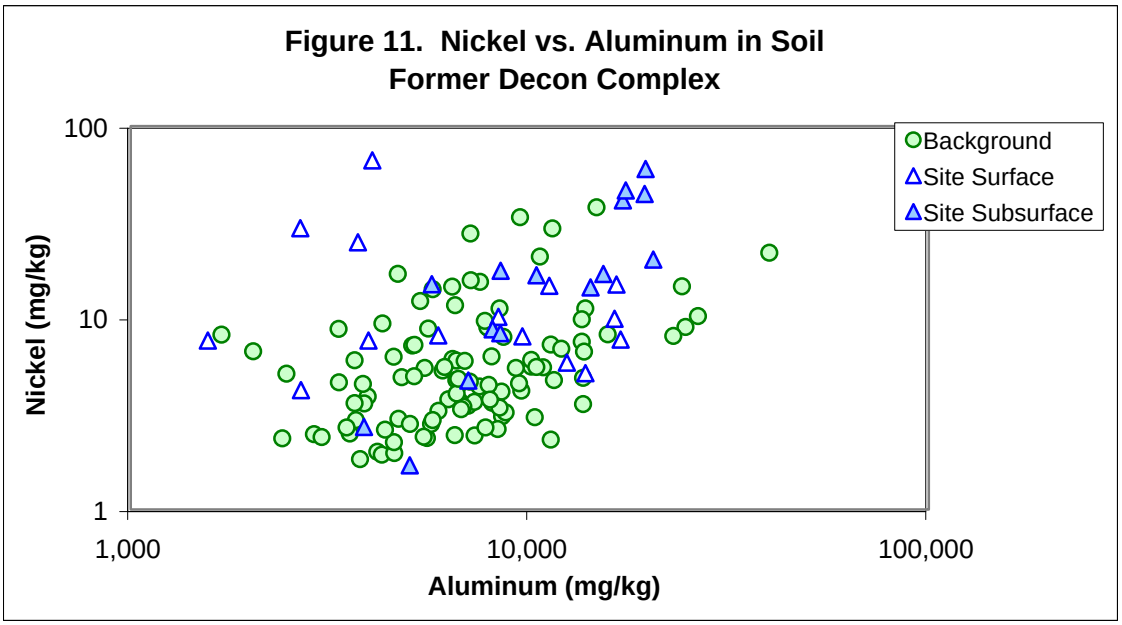
Figure 11. Nickel vs. Aluminum in Soil
Former Decon Complex
Nickel (mg/kg)
100
10
1
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site Surface
Site Subsurface

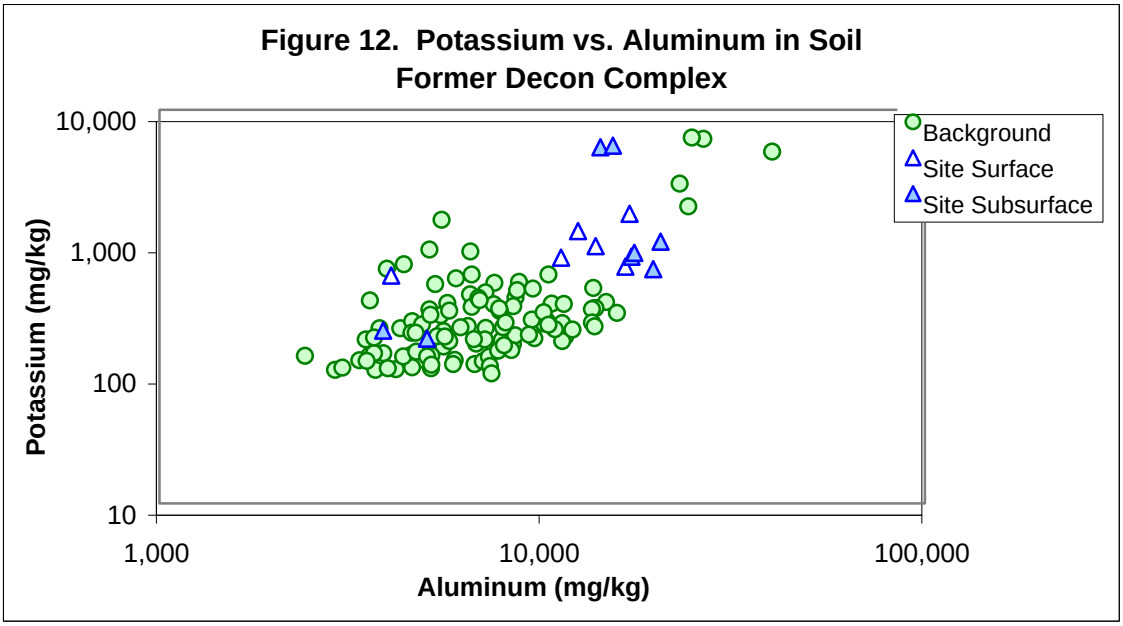
Figure 12. Potassium vs. Aluminum in Soil
Former Decon Complex
Potassium (mg/kg)
10,000
1,000
100
10
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site Surface
Site Subsurface

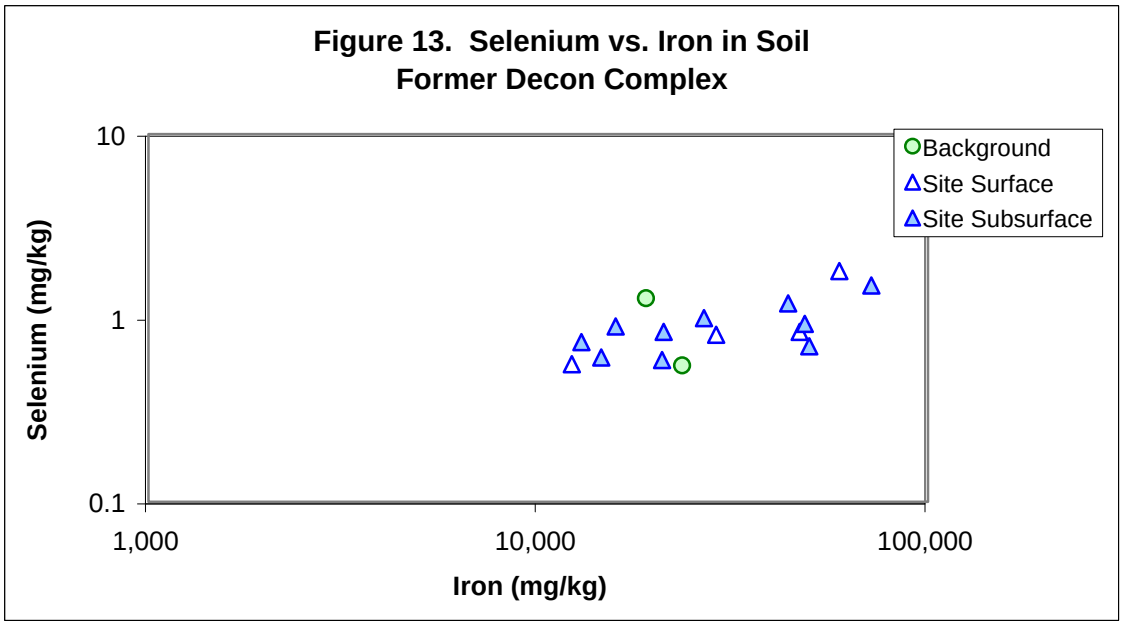
Figure 13. Selenium vs. Iron in Soil
Former Decon Complex
Selenium (mg/kg)
10
1
0.1
1,000
10,000
100,000
Iron (mg/kg)
Background
Site Surface
Site Subsurface

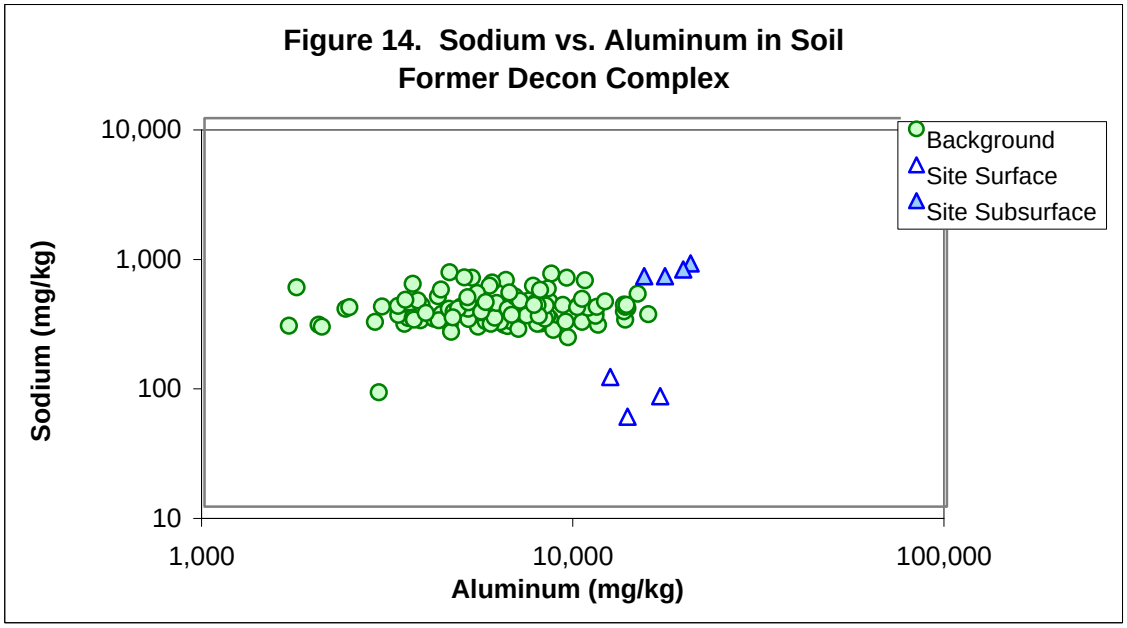
Figure 14. Sodium vs. Aluminum in Soil
Former Decon Complex
Sodium (mg/kg)
10,000
1,000
100
10
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site Surface
Site Subsurface

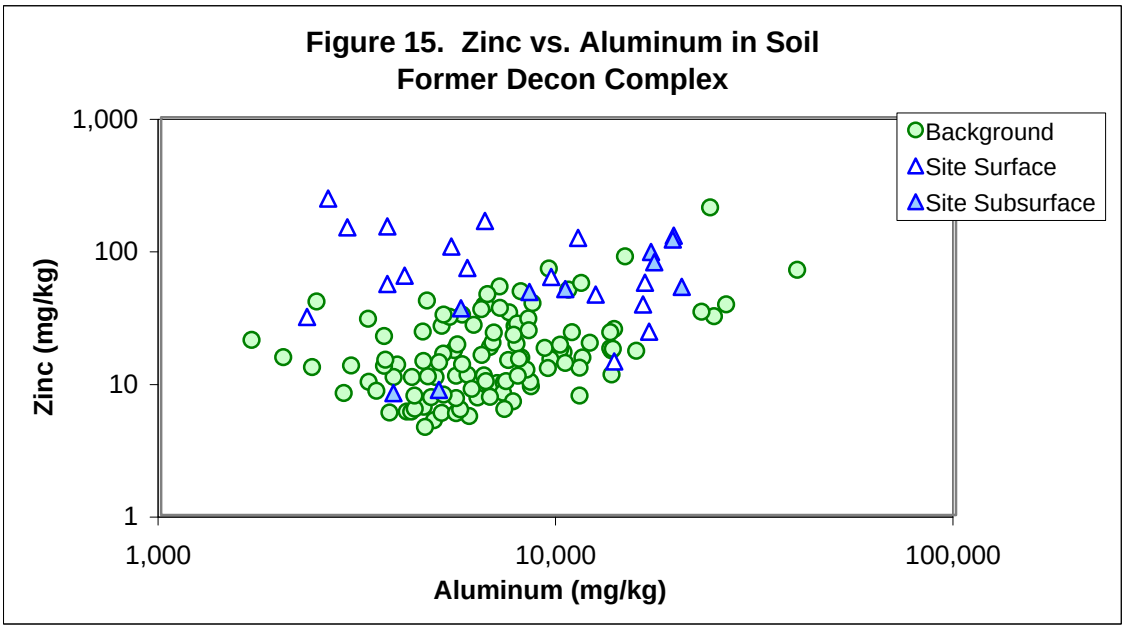
Figure 15. Zinc vs. Aluminum in Soil
Former Decon Complex
1,000
100
10
1
Zinc (mg/kg)
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site Surface
Site Subsurface

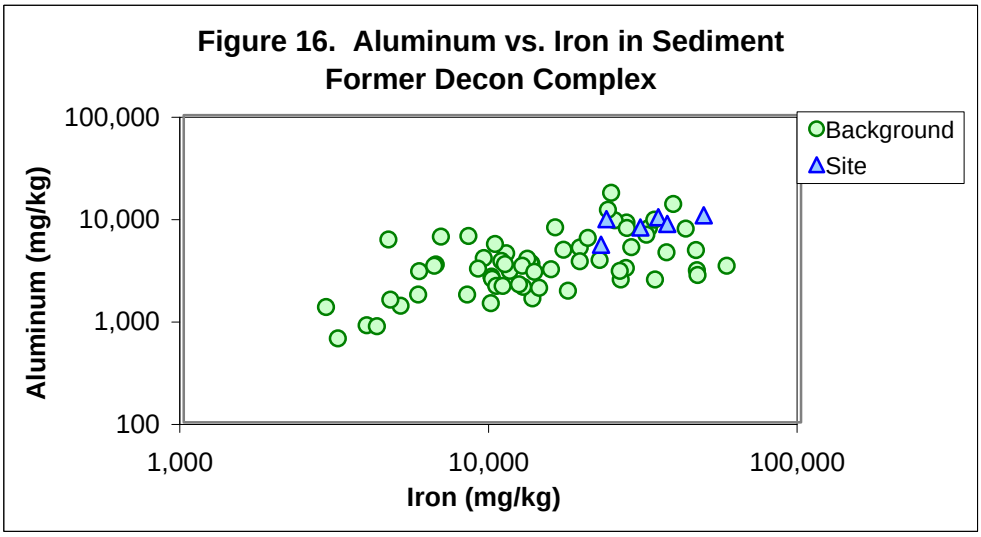
Figure 16. Aluminum vs. Iron in Sediment
Former Decon Complex
Aluminum (mg/kg)
100,000
10,000
1,000
100
1,000
10,000
100,000
Iron (mg/kg)
Background
Site

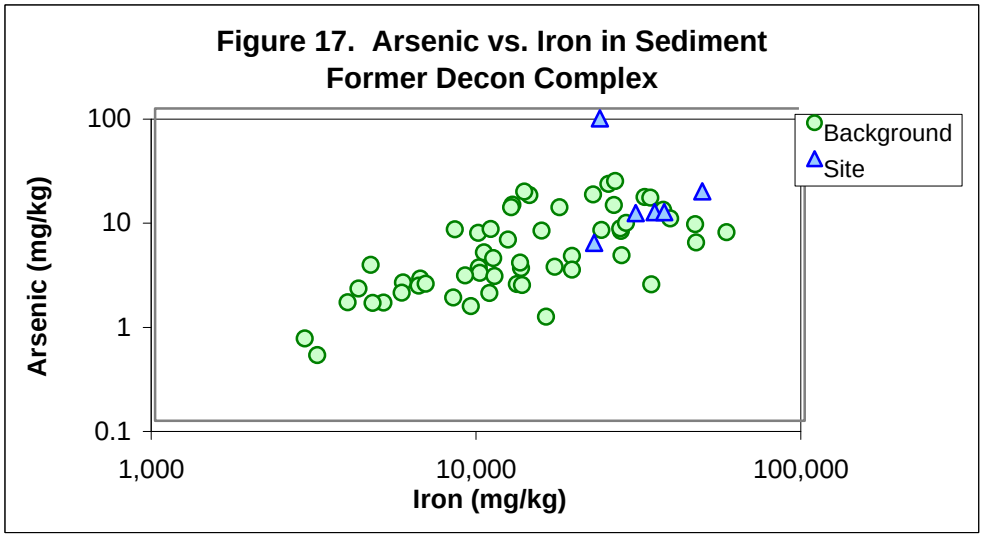
Figure 17. Arsenic vs. Iron in Sediment
Former Decon Complex
Arsenic (mg/kg)
100
10
1
0.1
1,000
10,000
100,000
Iron (mg/kg)
Background
Site

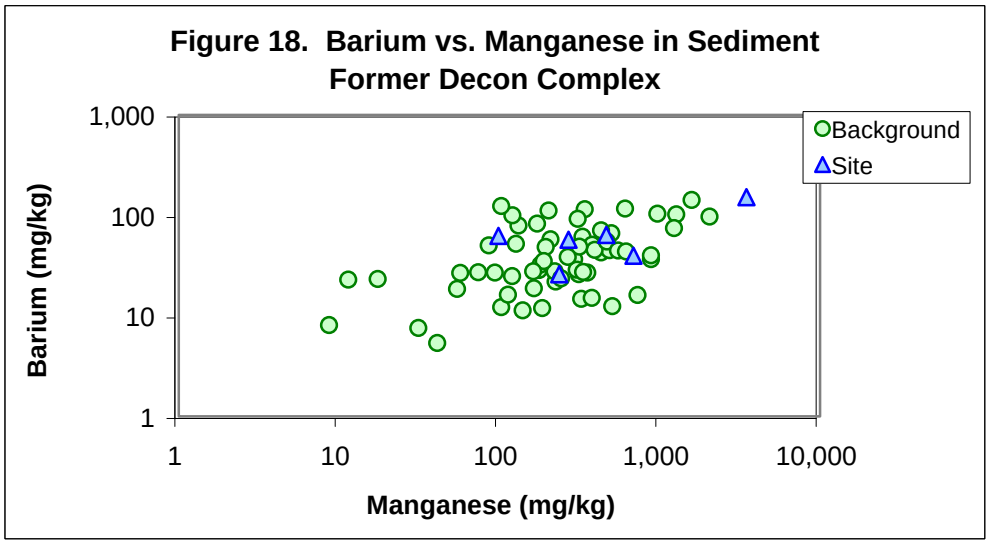
Figure 18. Barium vs. Manganese in Sediment
Former Decon Complex
Barium (mg/kg)
1,000
100
10
1
1
10
100
1,000
10,000
Manganese (mg/kg)
Background
Site

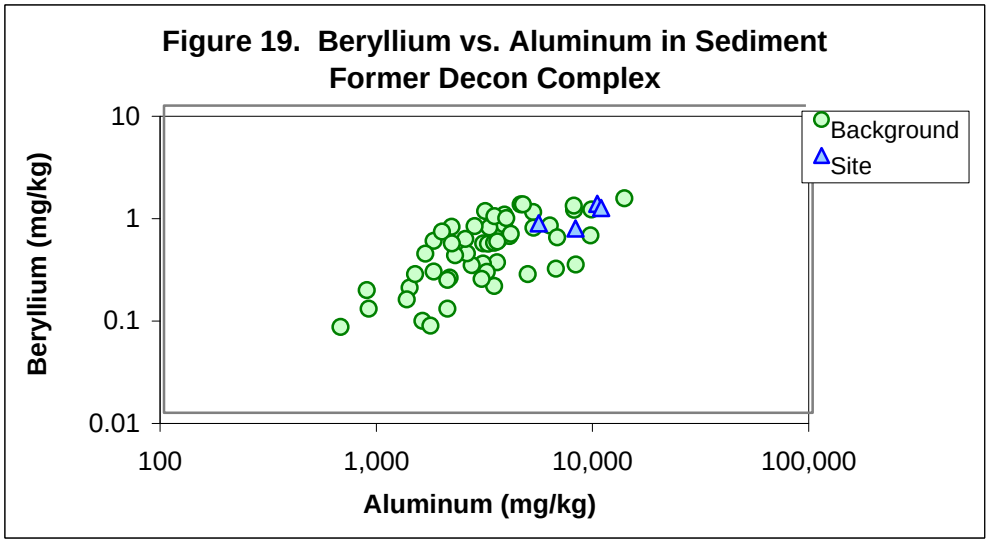
Figure 19. Beryllium vs. Aluminum in Sediment
Former Decon Complex
Beryllium (mg/kg)
10
1
0.1
0.01
100
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site

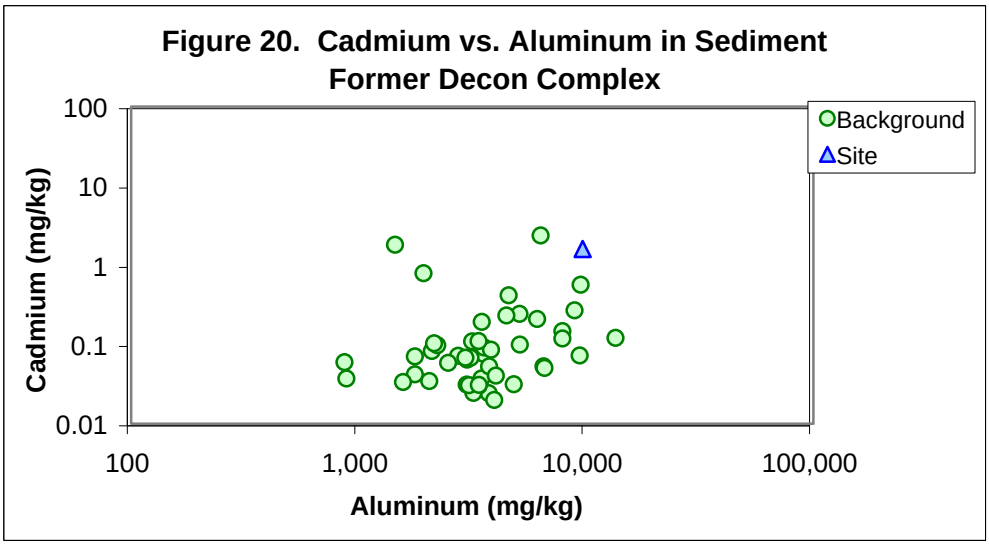
Figure 20. Cadmium vs. Aluminum in Sediment
Former Decon Complex
Cadmium (mg/kg)
100
10
1
0.1
0.01
100
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site

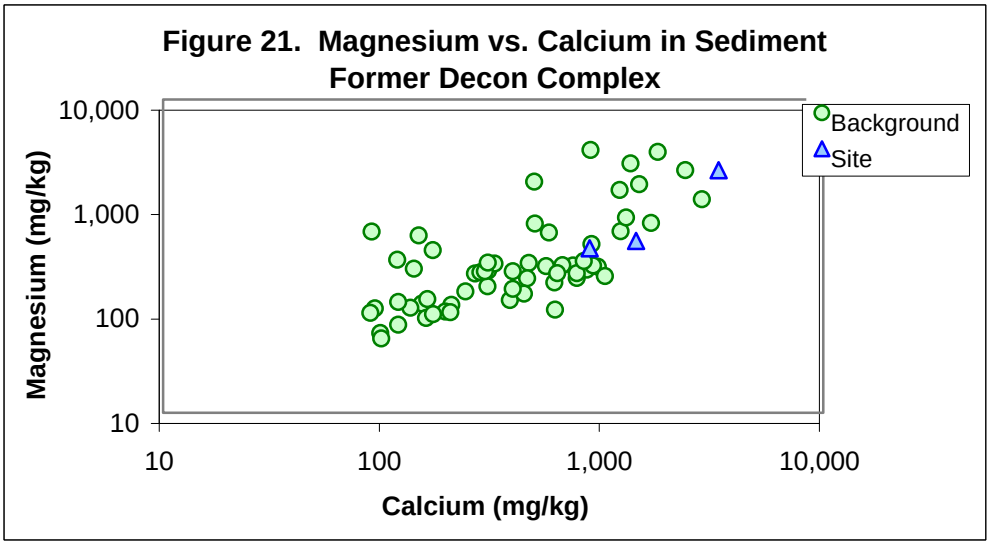
Figure 21. Magnesium vs. Calcium in Sediment
Former Decon Complex
Magnesium (mg/kg)
10,000
1,000
100
10
10
100
1,000
10,000
Calcium (mg/kg)
Background
Site

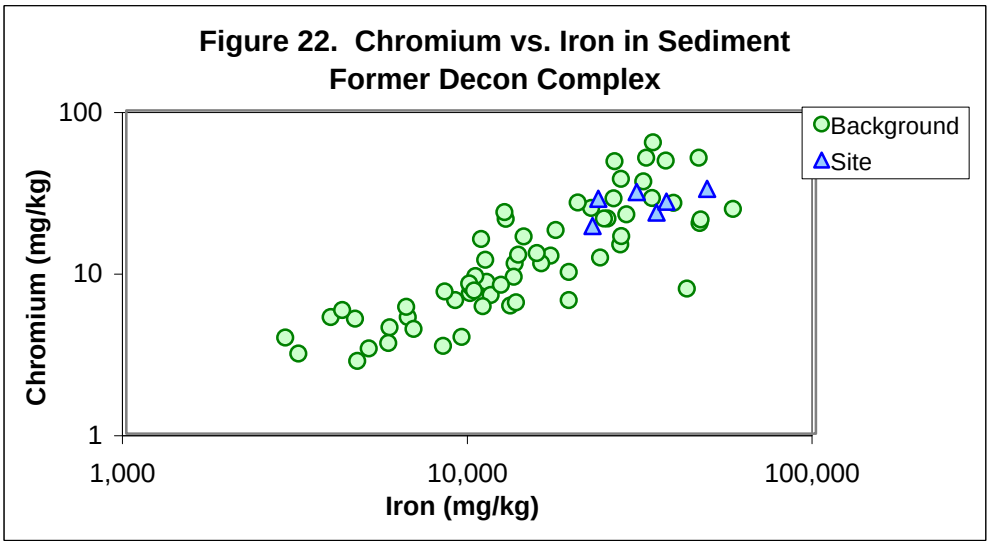
Figure 22. Chromium vs. Iron in Sediment
Former Decon Complex
Chromium (mg/kg)
100
10
1
1,000
10,000
100,000
Iron (mg/kg)
Background
Site

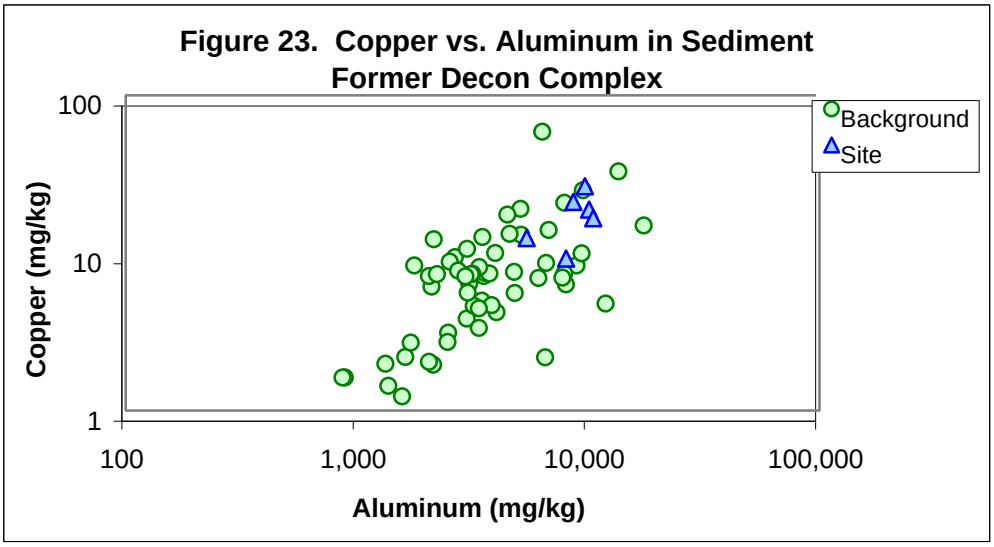
Figure 23. Copper vs. Aluminum in Sediment
Former Decon Complex
Copper (mg/kg)
100
10
1
100
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site

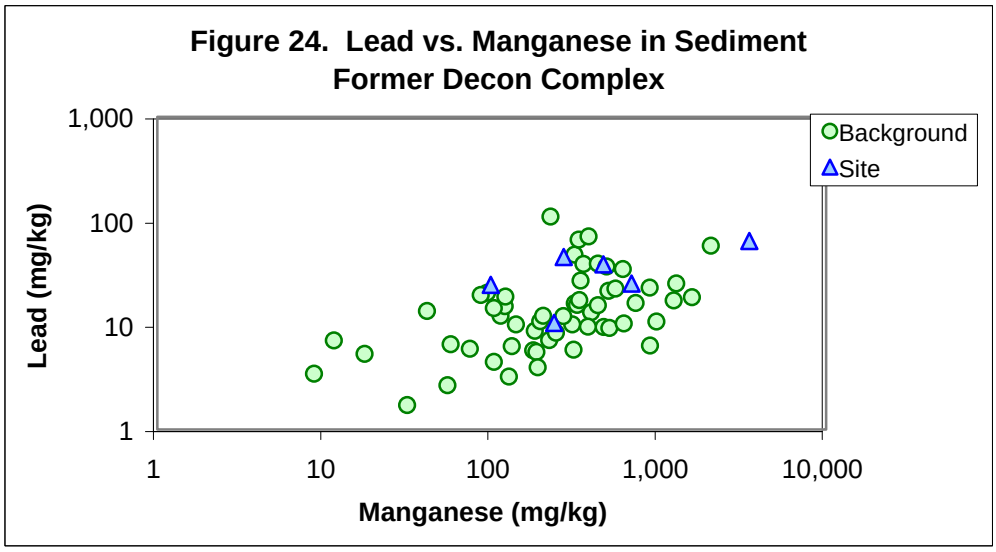
Figure 24. Lead vs. Manganese in Sediment
Former Decon Complex
Lead (mg/kg)
1,000
100
10
1
1
10
100
1,000
10,000
Manganese (mg/kg)
Background
Site

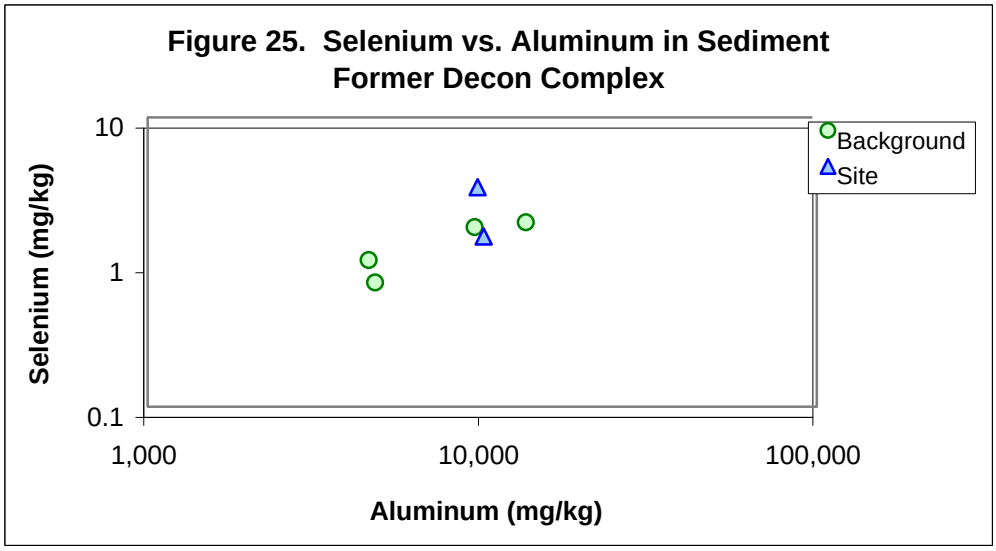
Figure 25. Selenium vs. Aluminum in Sediment
Former Decon Complex
Selenium (mg/kg)
10
1
0.1
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site

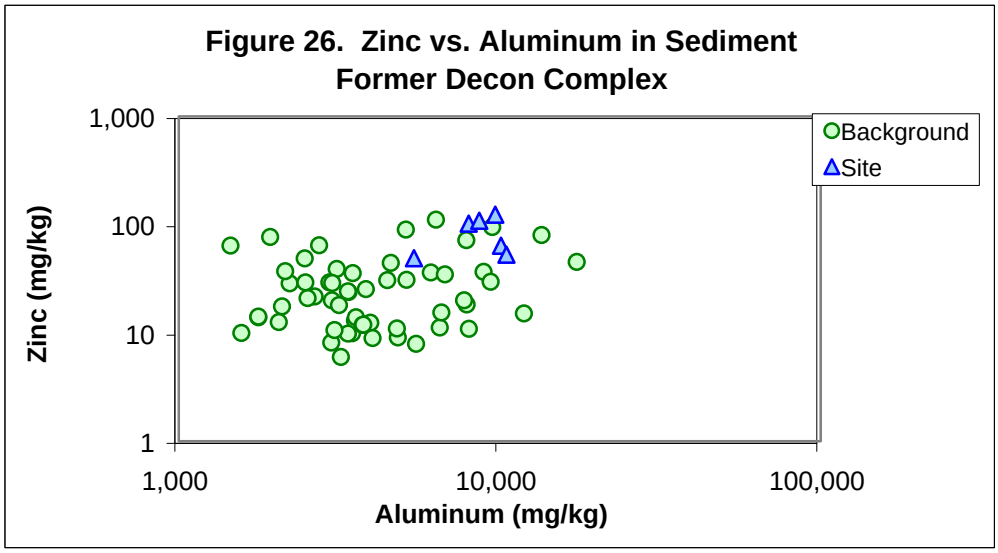
Figure 26. Zinc vs. Aluminum in Sediment
Former Decon Complex
Zinc (mg/kg)
1,000
100
10
1
1,000
10,000
100,000
Aluminum (mg/kg)
Background
Site

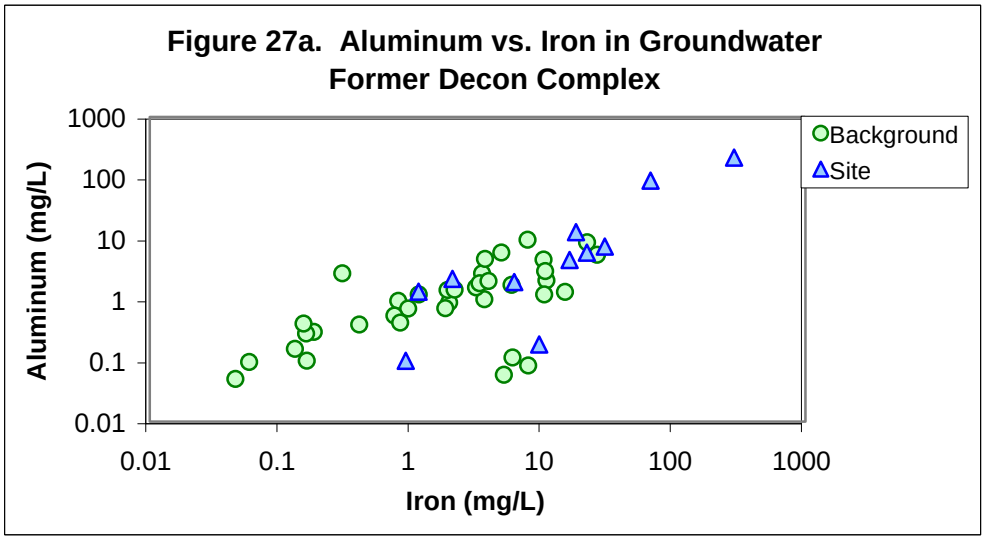
Figure 27a. Aluminum vs. Iron in Groundwater
Former Decon Complex
Aluminum (mg/L)
1000
100
10
1
0.1
0.01
0.01
0.1
1
10
100
1000
Iron (mg/L)
Background
Site

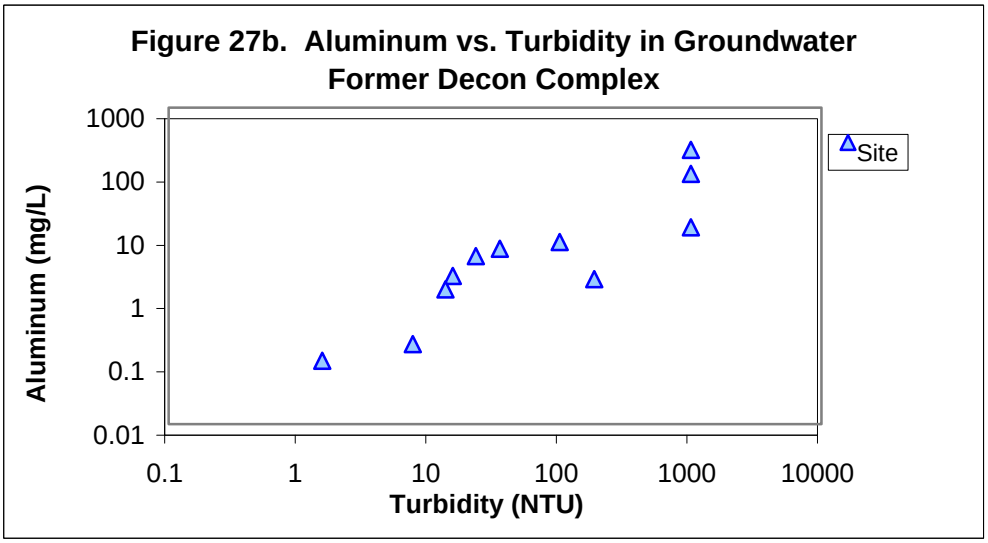
Figure 27b. Aluminum vs. Turbidity in Groundwater
Former Decon Complex
Aluminum (mg/L)
1000
100
10
1
0.1
0.01
0.1
1
10
100
1000
10000
Turbidity (NTU)
Site

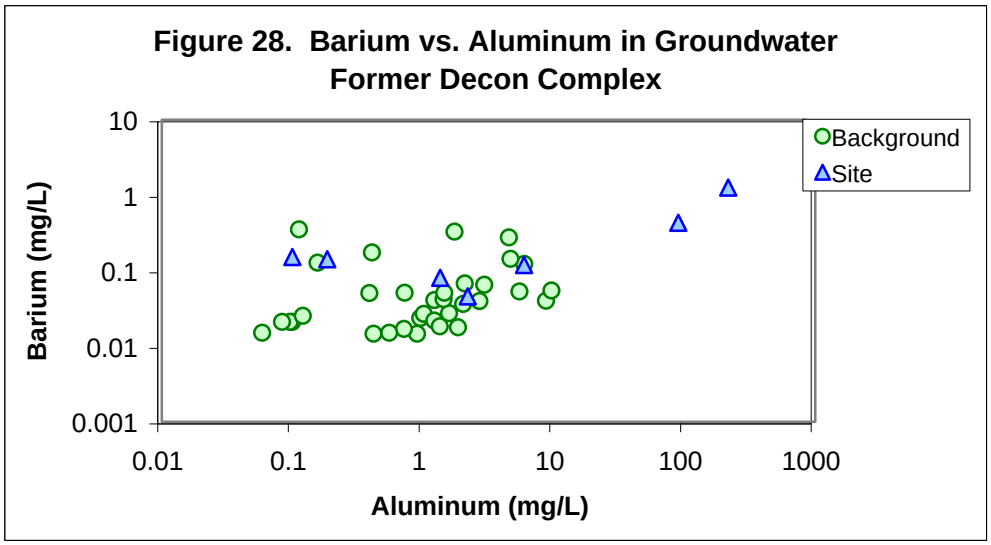
Figure 28. Barium vs. Aluminum in Groundwater
Former Decon Complex
Barium (mg/L)
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000
Aluminum (mg/L)
Background
Site

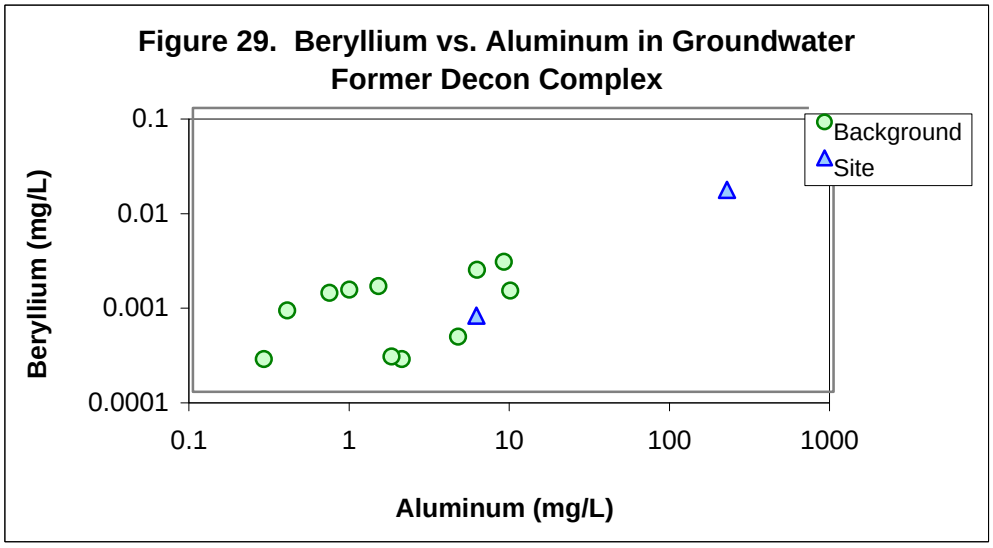
Figure 29. Beryllium vs. Aluminum in Groundwater
Former Decon Complex
Beryllium (mg/L)
0.1
0.01
0.001
0.0001
0.1
1
10
100
1000
Aluminum (mg/L)
Background
Site

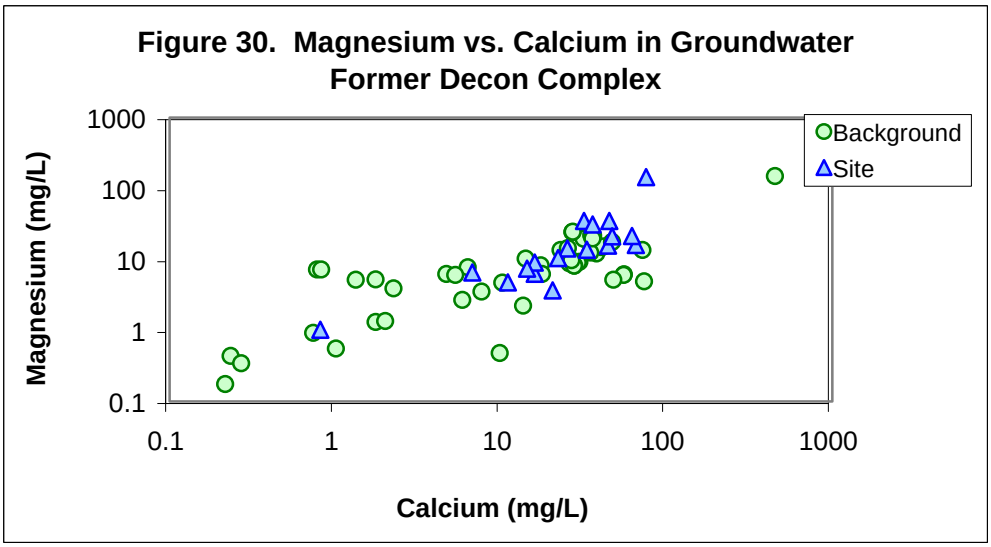
Figure 30. Magnesium vs. Calcium in Groundwater
Former Decon Complex
Magnesium (mg/L)
1000
100
10
1
0.1
0.1
1
10
100
1000
Calcium (mg/L)
Background
Site

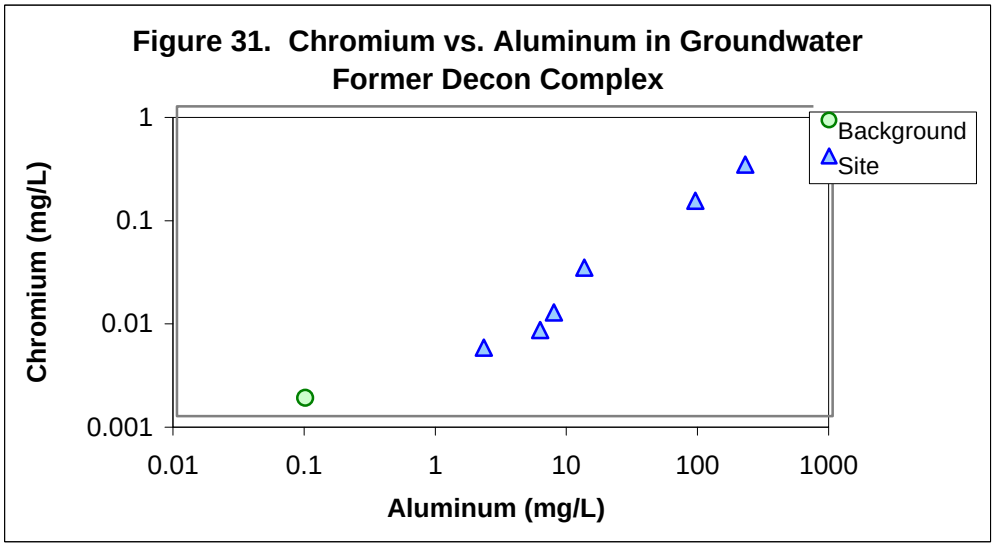
Figure 31. Chromium vs. Aluminum in Groundwater
Former Decon Complex
Chromium (mg/L)
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000
Aluminum (mg/L)
Background
Site

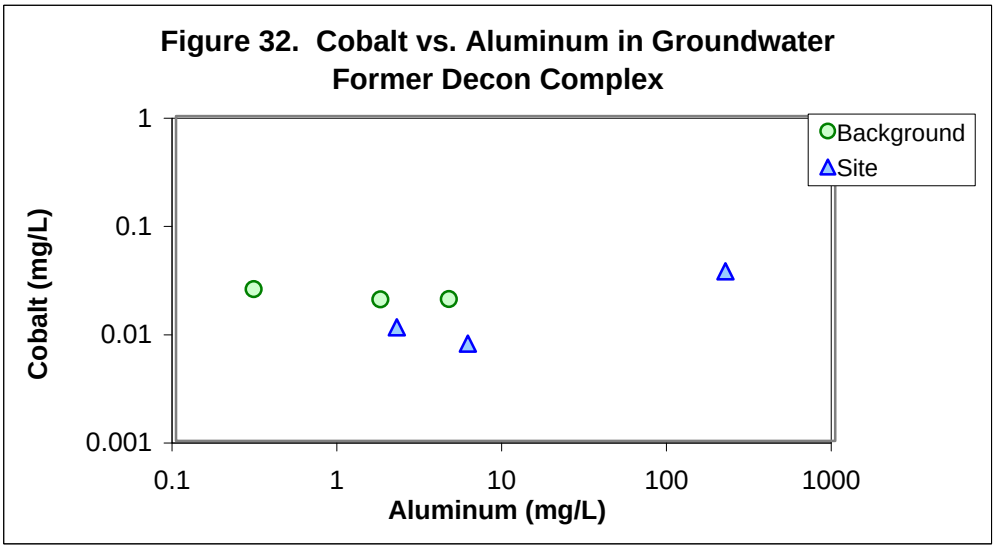
Figure 32. Cobalt vs. Aluminum in Groundwater
Former Decon Complex
Cobalt (mg/L)
1
0.1
0.01
0.001
0.1
1
10
100
1000
Aluminum (mg/L)
Background
Site

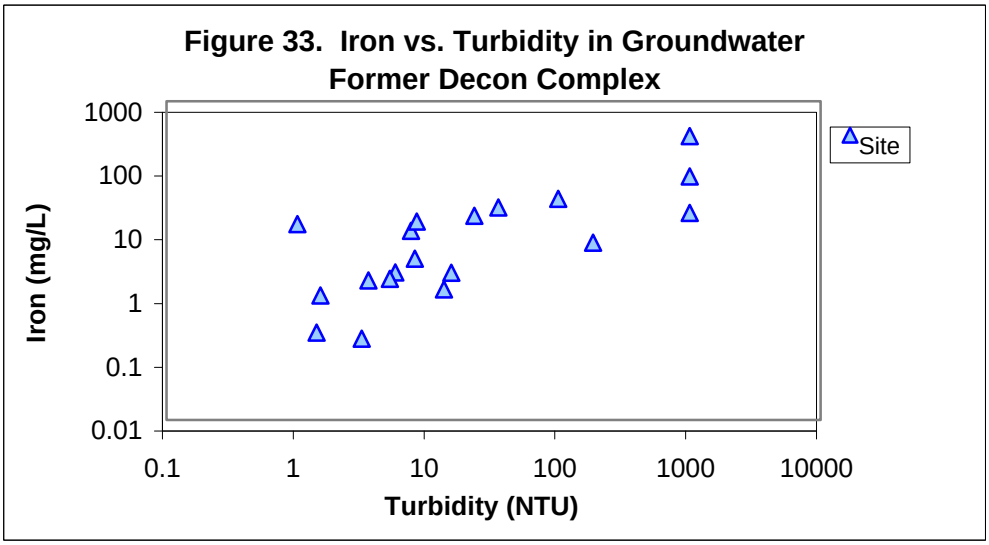
Figure 33. Iron vs. Turbidity in Groundwater
Former Decon Complex
Iron (mg/L)
1000
100
10
1
0.1
0.01
0.1
1
10
100
1000
10000
Turbidity (NTU)
Site

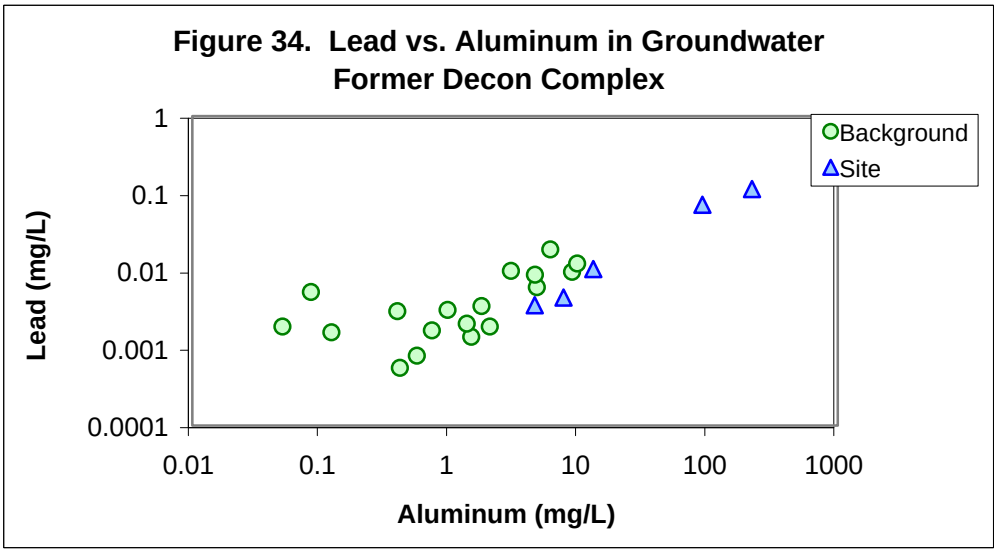
Figure 34. Lead vs. Aluminum in Groundwater
Former Decon Complex
Lead (mg/L)
1
0.1
0.01
0.001
0.0001
0.01
0.1
1
10
100
1000
Aluminum (mg/L)
Background
Site

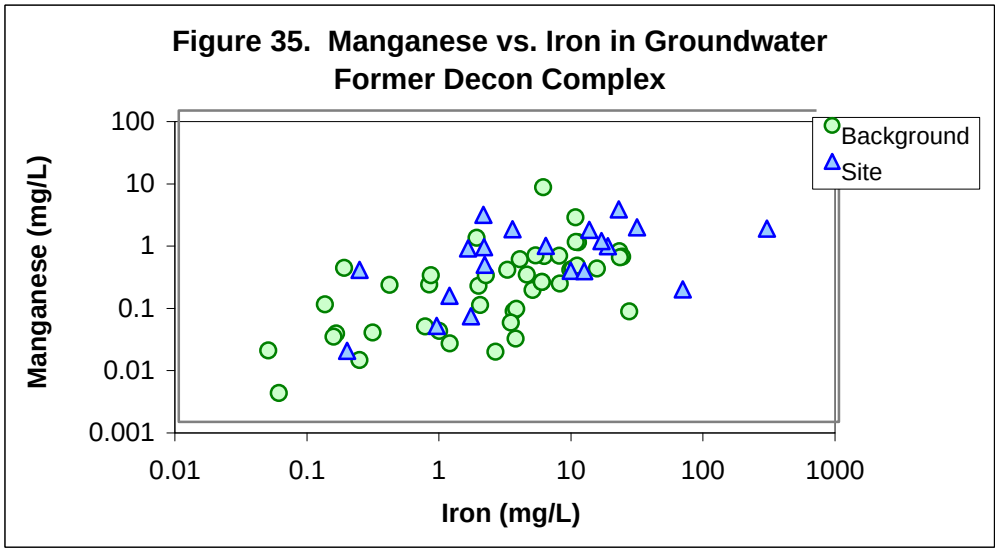
Figure 35. Manganese vs. Iron in Groundwater
Former Decon Complex
Manganese (mg/L)
100
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000
Iron (mg/L)
Background
Site

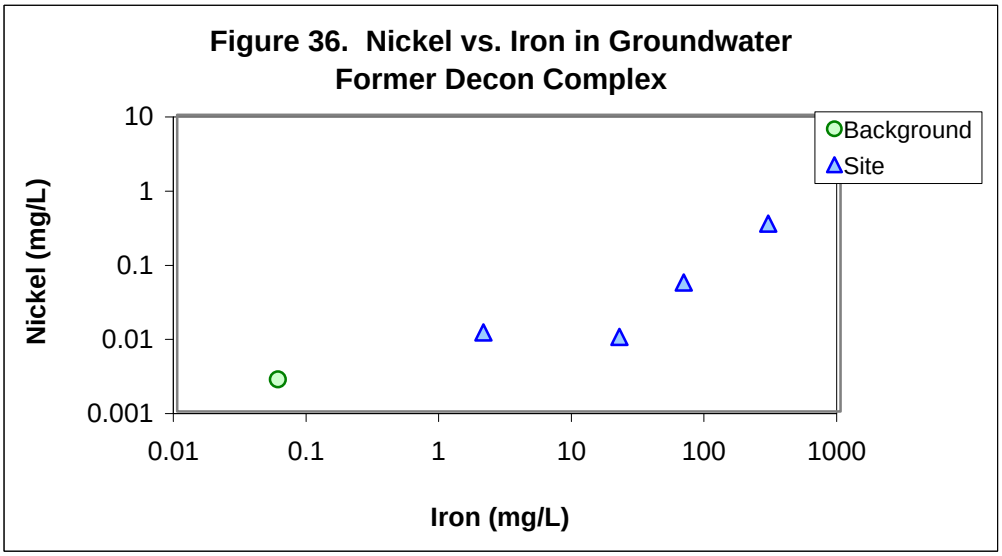
Figure 36. Nickel vs. Iron in Groundwater
Former Decon Complex
Nickel (mg/L)
10
1
0.1
0.01
0.001
0.01
0.1
1
10
100
1000
Iron (mg/L)
Background
Site

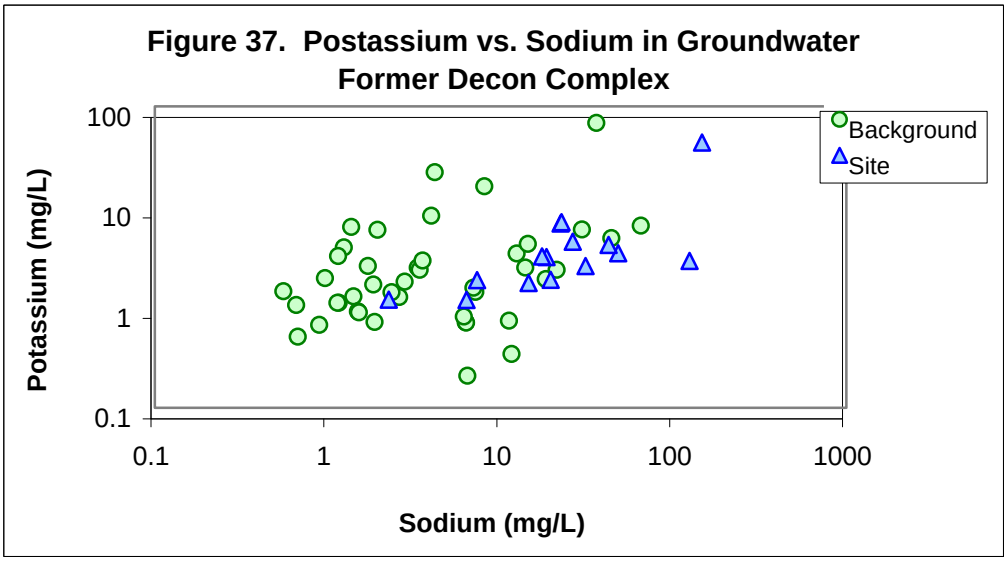
Figure 37. Postassium vs. Sodium in Groundwater
Former Decon Complex
Potassium (mg/L)
100
10
1
0.1
0.1
1
10
100
1000
Sodium (mg/L)
Background
Site

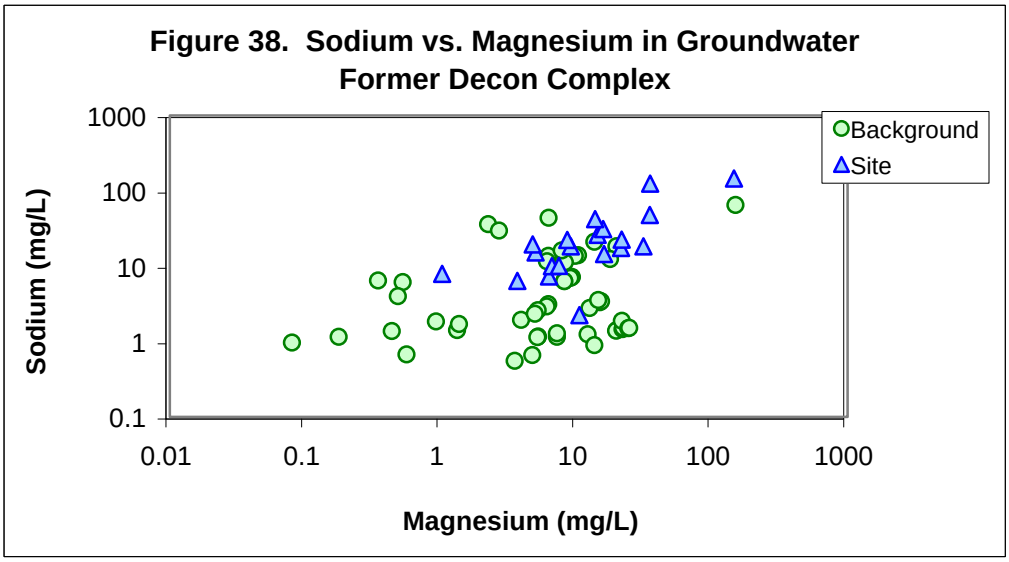
Figure 38. Sodium vs. Magnesium in Groundwater
Former Decon Complex
Sodium (mg/L)
1000
100
10
1
0.1
0.01
0.1
1
10
100
1000
Magnesium (mg/L)
Background
Site

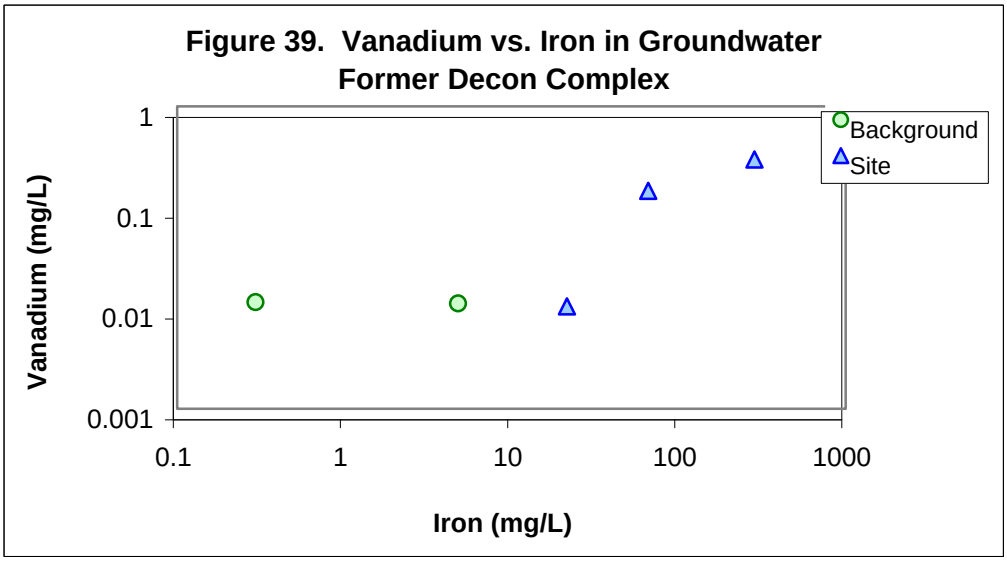
Figure 39. Vanadium vs. Iron in Groundwater
Former Decon Complex
Vanadium (mg/L)
1
0.1
0.01
0.001
0.1
1
10
100
1000
Iron (mg/L)
Background
Site

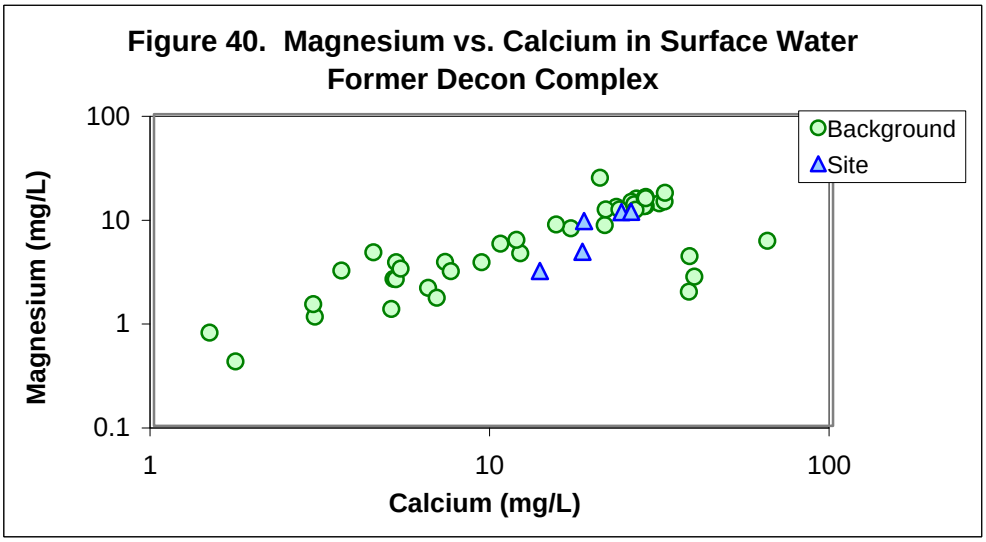
Figure 40. Magnesium vs. Calcium in Surface Water
Former Decon Complex
Background
Site
Magnesium (mg/L)
100
10
1
0.1
1
10
100
Calcium (mg/L)