

**APPENDIX G**

**STATISTICAL AND GEOCHEMICAL EVALUATION  
OF SITE METALS DATA**

# Memorandum

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**Date:** 14 March 2005

**To:** Ft. McClellan Project File

**From:** Karen Thorbjornsen, Jonathan Myers, and Paul Goetchius

**RE:** Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC: Revision 3

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This memo describes the protocol for site-to-background comparisons performed to select site-related chemicals at Fort McClellan (FTMC). It represents modifications to the original protocol set forth in the 28 April 2003 and 24 June 2003 technical memos.

Background screening is performed to differentiate between elements that have elevated concentrations due to natural processes versus elements that have elevated concentrations due to releases from site activities. The original protocol, which used the Slippage test, has been shown to provide an unacceptably high false-negative error rate due to the highly right-skewed nature of trace element distributions in many FTMC site data sets. The identification of exactly which site samples exhibit anomalously high elemental ratios on geochemical correlation plots was also an issue of concern. This memo reflects agreement reached between the Army (via USACE and Shaw E & I) and EPA Region 4 during the project meeting on 25 January 2005 in Atlanta, Georgia. The modifications to the methodology include the substitution of the hot measurement test for the Slippage test during the Tier 2 evaluation, and the addition of ratio plots to identify samples with anomalously high elemental ratios during the Tier 3 evaluation. The ratio plots are used in conjunction with the correlation plots when conducting the Tier 3 evaluation.

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 consists of two complementary statistical tests: (a) The hot measurement test is performed as the test of upper tails. This test consists of comparison of the site MDC to the background 95 UTL (for lognormally and normally distributed analytes) or the background 95<sup>th</sup> percentile (for nonparametric

distributions). (b) The Wilcoxon rank sum test is performed to compare the central tendencies of the site and background distributions, for those analytes with less than 50 percent nondetects in both the site and background data sets. The background data are provided in the installation-wide background study report (SAIC, 1998). Metals that fail either of these statistical tests are then subjected to the Tier 3 evaluation. "Failure" of a statistical test means that the site data are shown to be elevated with respect to background.

**Tier 3:** 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 ( $\text{HAsO}_4^{-2}$ ,  $\text{HSeO}_3^-$ ,  $\text{H}_2\text{VO}_4^-$ ) (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 ( $\text{Cd}^{+2}$ ,  $\text{Ni}^{+2}$ ,  $\text{Pb}^{+2}$ ,  $\text{Zn}^{+2}$ ) (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  $\text{Cr}(\text{OH})_2^+$ ,  $\text{Cr}(\text{OH})_3^0$ , and  $\text{Cr}(\text{OH})_4^-$ , 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 ( $\text{MnO}_2$ ) and nsutite ( $\text{MnO}_{1.9}$ ) will form that strongly adsorb Ba, Co, and Pb. Under reducing, low  $\text{CO}_2$

conditions, the minerals  $MnO\cdot OH$ ,  $Mn_2O_3$  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; the presence of detectable ferrous iron; 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. Field measurements of oxidation-reduction potential, and concentrations of dissolved oxygen, ferrous iron, and sulfide are useful in identifying natural or contaminant-induced changes in redox conditions that may alter elemental ratios. Data are also evaluated for pH anomalies and the presence of organic contaminants that may alter the geochemical environment.

**Ratio Plots.** Site samples with a trace element present as a contaminant will exhibit anomalously high trace-versus-major element ratios compared to background trace-versus-major element ratios. These elevated ratios may not

always be apparent in log-log correlation plots, especially at the upper range of concentrations. Therefore, ratio plots – which depict trace element concentrations on the y-axis and trace/major element ratios on the x-axis – are employed in conjunction with correlation plots in those cases where it is not immediately apparent which site samples have anomalously high elemental ratios on the correlation plots. The ratio plots permit easy identification of samples with anomalously high elemental ratios relative to background, and they have high resolution over the entire concentration range.

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## **STATISTICAL (TIERS 1 AND 2)**

# **Statistical Comparison of Site and Background Data Former Mortar Firing Point, Parcel 105Q-X and Former Defendamm Range (Eastern), Parcel 225Q Fort McClellan, Alabama**

## **1.0 Introduction**

This report provides the Tier 1 and Tier 2 site-to-background comparison results for the Former Mortar Firing Point, Parcel 105Q-X, and Former Defendamm Range (Eastern), Parcel 225Q, located at Fort McClellan in Calhoun County, Alabama. Tier 1 and Tier 2 evaluations (Shaw Environmental, Inc., 2005) have been performed for target analyte list (TAL) metals in the surface soil, subsurface soil, sediment, and surface water data sets. In the first step of the comparison, the maximum detected concentration (MDC) of each element is compared to two times the arithmetic mean of the background data (SAIC, 1998). Any metal that has an MDC greater than the background screening value is carried forward for Tier 2 evaluation, which includes the Wilcoxon Rank Sum Test (WRS) and Hot Measurement Test.

The methodology and results of the Tier 1 and Tier 2 comparisons are summarized in Tables 1 through 4, and described in more detail in the following sections. Site samples used in the site-to-background comparison include 23 surface soil samples (0 to 1 foot below ground surface [bgs]), 20 subsurface soil samples (1 to 4 feet bgs), three sediment samples, and three surface water samples that were collected at the site.

Background distributions and screening values have been established for TAL metals in surface soil (0 to 1 foot bgs), subsurface soil (0 to 12 feet bgs), sediment, and surface water for Fort McClellan (SAIC, 1998).

## **2.0 Comparison Methodology**

This section describes the statistical techniques that were employed in the Parcels 105Q-X and 225Q site-to-background comparison.

### **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

Table 1

**Summary of Site to Background Comparison for Surface Soil  
Parcels 105Q-X and 225Q  
Fort McClellan, Alabama**

<b>Metal</b>	<b>Frequency of Detection</b>	<b>Tier 1 Evaluation</b>	<b>Hot Measurement Test<sup>b</sup></b>	<b>Wilcoxon Rank Sum Test<sup>b</sup></b>	<b>Carried Forward for Tier 3 Geochemical Evaluation</b>
<b>Aluminum</b>	23 / 23	Failed	Passed	Failed	Yes
Antimony	0 / 23	NA	NA	NA	No
Arsenic	22 / 23	Passed	NA	NA	No
<b>Barium</b>	23 / 23	Failed	Failed	Passed	Yes
Beryllium	8 / 23	Failed	Passed	NA <sup>c</sup>	No
Cadmium	0 / 23	NA	NA	NA	No
Calcium	23 / 23	Passed	NA	NA	No
Chromium	23 / 23	Failed	Passed	Passed	No
<b>Cobalt</b>	20 / 23	Failed	Failed	Passed	Yes
Copper	23 / 23	Failed	Passed	Passed	No
Iron	23 / 23	Passed	NA	NA	No
<b>Lead</b>	23 / 23	Failed	Failed	Passed	Yes
Magnesium	23 / 23	Passed	NA	NA	No
Manganese	23 / 23	Failed	Passed	Passed	No
Mercury	13 / 23	Failed	Passed	NA <sup>c</sup>	No
Nickel	23 / 23	Failed	Passed	Passed	No
Potassium	15 / 23	Passed	NA	NA	No
<b>Selenium</b>	3 / 23	Failed	Failed	NA <sup>c</sup>	Yes
Silver	0 / 23	NA	NA	NA	No
Sodium	19 / 23	Passed	NA	NA	No
Thallium	2 / 23	Passed	NA	NA	No
Vanadium	23 / 23	Passed	NA	NA	No
Zinc	23 / 23	Failed	Passed	Passed	No

Metals listed in **bold** were carried forward for geochemical evaluation.

NA = not applicable; MDC = maximum detected concentration

<sup>a</sup> Tier 1 evaluation (site MDC compared to 2 x the background mean) per Shaw (2005), *Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 3*, Technical Memorandum, March 14..

<sup>b</sup> Part of Tier 2 evaluation per the above referenced memo.

<sup>c</sup> WRS test is not performed on data sets containing 50% or more nondetects.

Table 2

Summary of Site to Background Comparison for Subsurface Soil  
Parcels 105Q-X and 225Q  
Fort McClellan, Alabama

Metal	Frequency of Detection	Tier 1 Evaluation	Hot Measurement Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Carried Forward for Tier 3 Geochemical Evaluation
<b>Aluminum</b>	20 / 20	Failed	Failed	Failed	Yes
Antimony	1 / 20	Failed	Passed	NA <sup>c</sup>	No
Arsenic	19 / 20	Passed	NA	NA	No
<b>Barium</b>	20 / 20	Failed	Failed	Failed	Yes
Beryllium	6 / 20	Failed	Passed	NA <sup>c</sup>	No
Cadmium	0 / 20	NA	NA	NA	No
Calcium	20 / 20	Passed	NA	NA	No
Chromium	20 / 20	Failed	Passed	Passed	No
Cobalt	15 / 20	Failed	Passed	Passed	No
<b>Copper</b>	20 / 20	Failed	Failed	Passed	Yes
<b>Iron</b>	20 / 20	Failed	Failed	Passed	Yes
<b>Lead</b>	20 / 20	Failed	Failed	Failed	Yes
<b>Magnesium</b>	20 / 20	Failed	Passed	Failed	Yes
Manganese	20 / 20	Failed	Passed	Passed	No
<b>Mercury</b>	13 / 20	Failed	Failed	NA <sup>c</sup>	Yes
Nickel	19 / 20	Failed	Passed	Passed	No
<b>Potassium</b>	13 / 20	Failed	Failed	Failed	Yes
<b>Selenium</b>	1 / 20	Failed	Failed	NA <sup>c</sup>	Yes
Silver	0 / 20	NA	NA	NA	No
Sodium	20 / 20	Passed	NA	NA	No
Thallium	2 / 20	Failed	Passed	NA <sup>c</sup>	No
Vanadium	20 / 20	Failed	Passed	Passed	No
Zinc	20 / 20	Failed	Passed	Passed	No

Metals listed in **bold** were carried forward for geochemical evaluation.

NA = not applicable; MDC = maximum detected concentration

<sup>a</sup> Tier 1 evaluation (site MDC compared to 2 x the background mean) per Shaw (2005), *Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 3*, Technical Memorandum, March 14..

<sup>b</sup> Part of Tier 2 evaluation per the above referenced memo.

<sup>c</sup> WRS test is not performed on data sets containing 50% or more nondetects.

Table 3

Summary of Site to Background Comparison for Sediment  
Parcels 105Q-X and 225Q  
Fort McClellan, Alabama

Metal	Frequency of Detection	Tier 1 Evaluation	Hot Measurement Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	3 / 3	Passed	NA	NA	No
Antimony	0 / 3	NA	NA	NA	No
Arsenic	3 / 3	Passed	NA	NA	No
Barium	3 / 3	Passed	NA	NA	No
Beryllium	2 / 3	Passed	NA	NA	No
Cadmium	0 / 3	NA	NA	NA	No
Calcium	3 / 3	Passed	NA	NA	No
Chromium	3 / 3	Passed	NA	NA	No
Cobalt	3 / 3	Passed	NA	NA	No
Copper	3 / 3	Passed	NA	NA	No
Iron	3 / 3	Passed	NA	NA	No
Lead	3 / 3	Passed	NA	NA	No
Magnesium	3 / 3	Passed	NA	NA	No
Manganese	3 / 3	Passed	NA	NA	No
Mercury	0 / 3	NA	NA	NA	No
Nickel	3 / 3	Passed	NA	NA	No
Potassium	3 / 3	Passed	NA	NA	No
<b>Selenium</b>	3 / 3	Failed	Failed	NA <sup>c</sup>	Yes
Silver	0 / 3	NA	NA	NA	No
Sodium	1 / 3	Passed	NA	NA	No
Thallium	0 / 3	NA	NA	NA	No
<b>Vanadium</b>	3 / 3	Failed	Passed	Failed	Yes
Zinc	3 / 3	Passed	NA	NA	No

Metals listed in **bold** were carried forward for geochemical evaluation.

NA = not applicable; MDC = maximum detected concentration

<sup>a</sup> Tier 1 evaluation (site MDC compared to 2 x the background mean) per Shaw (2005), *Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 3*, Technical Memorandum, March 14..

<sup>b</sup> Part of Tier 2 evaluation per the above referenced memo.

<sup>c</sup> WRS test is not performed on data sets containing 50% or more nondetects.

Table 4

Summary of Site to Background Comparison for Surface Water  
Parcels 105Q-X and 225Q  
Fort McClellan, Alabama

Metal	Frequency of Detection	Tier 1 Evaluation	Hot Measurement Test <sup>b</sup>	Wilcoxon Rank Sum Test <sup>b</sup>	Carried Forward for Tier 3 Geochemical Evaluation
Aluminum	3 / 3	Passed	NA	NA	No
Antimony	0 / 3	NA	NA	NA	No
Arsenic	0 / 3	NA	NA	NA	No
Barium	3 / 3	Passed	NA	NA	No
Beryllium	0 / 3	NA	NA	NA	No
Cadmium	0 / 3	NA	NA	NA	No
Calcium	0 / 3	NA	NA	NA	No
<b>Chromium</b>	1 / 3	Failed	Failed	NA <sup>c</sup>	Yes
Cobalt	0 / 3	NA	NA	NA	No
Copper	0 / 3	NA	NA	NA	No
Iron	3 / 3	Passed	NA	NA	No
Lead	0 / 3	NA	NA	NA	No
Magnesium	0 / 3	NA	NA	NA	No
Manganese	3 / 3	Passed	NA	NA	No
Mercury	0 / 3	NA	NA	NA	No
Nickel	0 / 3	NA	NA	NA	No
Potassium	0 / 3	NA	NA	NA	No
Selenium	0 / 3	NA	NA	NA	No
Silver	0 / 3	NA	NA	NA	No
Sodium	3 / 3	Passed	NA	NA	No
Thallium	0 / 3	NA	NA	NA	No
Vanadium	0 / 3	NA	NA	NA	No
Zinc	0 / 3	NA	NA	NA	No

Metals listed in **bold** were carried forward for geochemical evaluation.

NA = not applicable; MDC = maximum detected concentration

<sup>a</sup> Tier 1 evaluation (site MDC compared to 2 x the background mean) per Shaw (2005), *Selecting Site-Related Chemicals for Human Health and Ecological Risk Assessments for FTMC, Revision 3*, Technical Memorandum, March 14..

<sup>b</sup> Part of Tier 2 evaluation per the above referenced memo.

<sup>c</sup> WRS test is not performed on data sets containing 50% or more nondetects.

concentrations in a small percentage of the total number of site samples. No single two-sample statistical comparison test is sensitive to both of these modes of contamination. For this reason, the use of several simultaneous tests is recommended for a valid and complete comparison of site versus background distributions (U.S. Environmental Protection Agency [EPA], 1989, 1992, and 1994; U.S. Navy, 2002).

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

### **2.1.1 Tier 1**

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

### **2.1.2 Tier 2**

**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 95<sup>th</sup> upper tolerance limit (95<sup>th</sup> UTL) is recommended as a screening value for normally or lognormally distributed analytes and the 95<sup>th</sup> 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 95<sup>th</sup> UTL or 95<sup>th</sup> 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.

**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, 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 75<sup>th</sup> percentile and the bottom of the box represents the 25<sup>th</sup> 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.

### **2.1.3 Geochemical Evaluation**

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

## **3.0 Results of the Site-to-Background Comparison**

This section presents the results of the site-to-background comparison for 23 TAL metals in the surface soil, subsurface soil, sediment, and surface water samples from Parcels 105Q-X and 225Q. The WRS test results with corresponding box plots are provided in Attachment 1. Tables 1 through 4 summarize the Tier 1 and Tier 2 test results for each media as discussed in the following sections.

### **3.1 Surface Soil**

Twenty-three TAL metals were evaluated in the Parcels 105Q-X and 225Q surface soil data set. The site samples are 100 percent nondetect for antimony, cadmium, and silver. Eight metals (arsenic, calcium, iron, magnesium, potassium, sodium, thallium, and vanadium) passed the Tier 1 evaluation, and they will not be discussed further. The remaining twelve metals are carried forward for Tier 2 evaluation.

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

#### **Aluminum**

##### Tier 1 Evaluation

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

##### Hot Measurement Test

The site MDC of aluminum does not exceed the background 95<sup>th</sup> percentile of 22,900 mg/kg.

##### WRS Test

The p-level of 0.103 indicates weak agreement between the site and background distributions.

##### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-1).

##### Conclusion

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

#### **Barium**

##### Tier 1 Evaluation

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

##### Hot Measurement Test

The site MDC of barium exceeds the background 95<sup>th</sup> UTL of 193.8 mg/kg.

##### WRS Test

The p-level of 0.857 indicates excellent agreement between the site and background distributions.

##### Box Plots

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

### Conclusion

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

### **Beryllium**

#### Tier 1 Evaluation

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

#### Hot Measurement Test

The site MDC of beryllium does not exceed the background 95<sup>th</sup> UTL of 1.189 mg/kg.

#### WRS Test

The WRS test was not performed because the site data set contains 65 percent nondetects.

#### Box Plots

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-3).

### Conclusion

Because beryllium in surface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

### **Chromium**

#### Tier 1 Evaluation

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

#### Hot Measurement Test

The site MDC of chromium does not exceed the background 95<sup>th</sup> UTL of 64.4 mg/kg.

#### WRS Test

The p-level of 0.184 indicates weak agreement between the site and background distributions. The reason for the low p-level is that the site data are shifted lower relative to background.

#### Box Plot

The site minimum is higher than the background minimum, and the site median and maximum are lower than the corresponding background values (Figure 1-4).

### Conclusion

Because chromium in surface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

### **Cobalt**

#### Tier 1 Evaluation

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

### Hot Measurement Test

The site MDC of cobalt exceeds the background 95<sup>th</sup> UTL of 32.5 mg/kg.

### WRS Test

The p-level of 0.897 indicates excellent agreement between the site and background distributions.

### Box Plot

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

### Conclusion

Because cobalt in surface soil 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 12.71 mg/kg.

### Hot Measurement Test

The site MDC of copper does not exceed the background 95<sup>th</sup> UTL of 22.5 mg/kg.

### WRS Test

The p-level of 0.426 indicates good agreement between the site and background distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-6).

### Conclusion

Because copper in surface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

## **Lead**

### Tier 1 Evaluation

Four site samples exceed the background screening value of 40.05 mg/kg.

### Hot Measurement Test

The site MDC of lead exceeds the background 95<sup>th</sup> UTL of 63.8 mg/kg.

### WRS Test

The p-level of 0.817 indicates excellent agreement between the site and background distributions.

### Box Plot

The site minimum is slightly higher than the background minimum, and the site median and maximum are higher than the corresponding background values (Figure 1-7).

### Conclusion

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

## **Manganese**

### Tier 1 Evaluation

Three site samples exceed the background screening value of 1,579 mg/kg.

### Hot Measurement Test

The site MDC of manganese does not exceed the background 95<sup>th</sup> UTL of 4,658 mg/kg.

### WRS Test

The p-level of 0.429 indicates a good agreement between the site and background distributions.

### Box Plot

The site minimum is higher than the background minimum, and the site median and maximum are lower than the corresponding background values (Figure 1-8).

### Conclusion

Because manganese in surface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

## **Mercury**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 0.08 mg/kg.

### Hot Measurement Test

The site MDC of mercury does not exceed the background 95<sup>th</sup> percentile of 0.125 mg/kg.

### WRS Test

The WRS test was not performed because the background data set contains 66 percent nondetects.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-9).

### Conclusion

Because mercury in surface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

## **Nickel**

### Tier 1 Evaluation

Four site samples exceed the background screening value of 10.33 mg/kg.

### Hot Measurement Test

The site MDC of nickel does not exceed the background 95<sup>th</sup> percentile of 19.96 mg/kg.

### WRS Test

The p-level of 0.307 indicates good agreement between the site and background distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-10).

### Conclusion

Because nickel in surface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

## **Selenium**

### Tier 1 Evaluation

Three site samples exceed the background screening value of 0.48 mg/kg.

### Hot Measurement Test

The site MDC of selenium exceeds the background 95<sup>th</sup> percentile of 0.563 mg/kg.

### WRS Test

The WRS test was not performed because the background and site data sets contain 99 and 87 percent nondetects, respectively.

### Box Plots

The background and site data sets are characterized by high percentages of nondetects (99 and 87 percent, respectively), so the background and site box plots reflect the replacement values of one-half the reporting limit (Figure 1-11). The site minimum, median, and maximum are higher than the corresponding background values.

### 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

One site sample exceeds the background screening value of 40.64 mg/kg.

### Hot Measurement Test

The site MDC of zinc does not exceed the background 95<sup>th</sup> UTL of 73.7 mg/kg.

### WRS Test

The p-level of 0.890 indicates excellent agreement between the site and background distributions.

### Box Plot

The site minimum is higher than the background minimum, and the site median and maximum are lower than the corresponding background values (Figure 1-12).

### Conclusion

Because zinc in surface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

## **3.2 Subsurface Soil**

Twenty-three TAL metals were evaluated in the subsurface soil data set for Parcels 105Q-X and 225Q. The site samples are 100 percent nondetect for cadmium and silver. Three metals (arsenic, calcium, and sodium) passed the Tier 1 evaluation, and they will not be discussed further. The remaining eighteen metals are carried forward for Tier 2 evaluation. Table 2 summarizes the subsurface soil statistical site to background comparison results. Box plots are provided in Attachment 1.

## **Aluminum**

### Tier 1 Evaluation

Six site samples exceed the background screening value of 13,591 mg/kg.

### Hot Measurement Test

The site MDC of aluminum exceeds the background 95<sup>th</sup> UTL of 16,574 mg/kg.

### WRS Test

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

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-13).

### Conclusion

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

## **Antimony**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 1.31 mg/kg.

### Hot Measurement Test

The site MDC of antimony does not exceed the background 95<sup>th</sup> percentile of 7.14 mg/kg.

### WRS Test

The WRS test was not performed because the site data set contains 95 percent nondetects.

### Box Plot

The shape and location of the site box plot reflect the high percentage of nondetects (95 percent), and the replacement values of one-half the reporting limit (Figure 1-14). The site minimum, median, and maximum are higher than the corresponding background values.

### Conclusion

Because antimony in subsurface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

## **Barium**

### Tier 1 Evaluation

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

### Hot Measurement Test

The site MDC of barium exceeds the background 95<sup>th</sup> UTL of 320 mg/kg.

### WRS Test

The p-level of 0.018 indicates weak agreement between the background and site distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-15).

### 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

One site sample exceeds the background screening value of 0.86 mg/kg.

### Hot Measurement Test

The site MDC of beryllium does not exceed the background 95<sup>th</sup> UTL of 2.19 mg/kg.

### WRS Test

The WRS test was not performed because the site data set contains 70 percent nondetects.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-16).

### Conclusion

Because beryllium in subsurface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

### **Chromium**

#### Tier 1 Evaluation

One site sample exceeds the background screening value of 38.25 mg/kg.

#### Hot Measurement Test

The site MDC of chromium does not exceed the background 95<sup>th</sup> UTL of 53.4 mg/kg.

#### WRS Test

The p-level of 0.028 indicates weak agreement between the site and background distributions. The reason for the low p-level is that the site data are shifted lower relative to background.

#### Box Plot

The site minimum is slightly higher than the background minimum, and the site median and maximum are lower than the corresponding background values (Figure 1-17).

### Conclusion

Because chromium in subsurface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

### **Cobalt**

#### Tier 1 Evaluation

Two site samples exceed the background screening value of 17.54 mg/kg.

#### Hot Measurement Test

The site MDC of cobalt does not exceed the background 95<sup>th</sup> UTL of 54.7 mg/kg.

#### WRS Test

The p-level of 0.217 indicates good agreement between the site and background distributions.

#### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-18).

### Conclusion

Because cobalt in subsurface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

### **Copper**

#### Tier 1 Evaluation

One site sample exceeds the background screening value of 19.43 mg/kg.

### Hot Measurement Test

The site MDC of copper exceeds the background 95<sup>th</sup> UTL of 34.2 mg/kg.

### WRS Test

The p-level of 0.506 indicates good agreement between the site and background distributions.

### Box Plot

The site minimum is slightly higher than the background minimum, and the site median and maximum are lower than the corresponding background values (Figure 1-19).

### 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

One site sample exceeds the background screening value of 44,817 mg/kg.

### Hot Measurement Test

The site MDC of iron exceeds the background 95<sup>th</sup> percentile of 41,800 mg/kg.

### WRS Test

The p-level of 0.005 indicates a significant difference between the site and background distributions. The reason for low p-level is that the site data are shifted lower relative to background.

### Box Plot

The site minimum, median, and maximum are lower than the corresponding background values (Figure 1-20).

### Conclusion

Because iron in subsurface soil 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 38.53 mg/kg.

### Hot Measurement Test

The site MDC of lead exceeds the background 95<sup>th</sup> percentile of 28.8 mg/kg.

### WRS Test

The p-level of 0.130 indicates weak agreement between the site and background distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-21).

### Conclusion

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

## **Magnesium**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 766.24 mg/kg.

### Hot Measurement Test

The site MDC of magnesium does not exceed the background 95<sup>th</sup> percentile of 2,270 mg/kg.

### WRS Test

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

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-22).

### Conclusion

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

## **Manganese**

### Tier 1 Evaluation

Two site samples exceed the background screening value of 1,355 mg/kg.

### Hot Measurement Test

The site MDC of manganese does not exceed the background 95<sup>th</sup> UTL of 3,790 mg/kg.

### WRS Test

The p-level of 0.200 indicates good agreement between the site and background distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-23).

### Conclusion

Because manganese in subsurface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

## **Mercury**

### Tier 1 Evaluation

Two site samples exceed the background screening value of 0.07 mg/kg.

### Hot Measurement Test

The site MDC of mercury exceeds the background 95<sup>th</sup> percentile of 0.094 mg/kg.

### WRS Test

The WRS test was not performed because the background 53 percent nondetects.

### Box Plot

The site minimum, median, and maximum are higher than the corresponding background values (Figure 1-24).

### Conclusion

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

## **Nickel**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 12.89 mg/kg.

### Hot Measurement Test

The site MDC of nickel does not exceed the background 95<sup>th</sup> percentile of 29.2 mg/kg.

### WRS Test

The p-level of 0.253 indicates good agreement between the site and background distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-25).

### Conclusion

Because nickel in subsurface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

## **Potassium**

### Tier 1 Evaluation

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

### Hot Measurement Test

The site MDC of potassium exceeds the background 95<sup>th</sup> UTL of 1,420 mg/kg.

### WRS Test

The p-level of 0.039 indicates poor agreement between the site and background distributions.

### Box Plot

The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum (Figure 1-26).

### 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

One site sample exceeds the background screening value of 0.47 mg/kg.

### Hot Measurement Test

The site MDC of selenium exceeds the background 95<sup>th</sup> percentile of 0.574 mg/kg.

### WRS Test

The WRS test was not performed because the background and site data sets contain 98 and 95 percent nondetects, respectively.

### Box Plot

The background and site data sets are characterized by high percentages of nondetects (98 and 95 percent, respectively), so the background and site box plots reflect the replacement values of one-half the reporting limit (Figure 1-27). The site minimum, median, and maximum are higher than the respective background values.

### Conclusion

Because selenium in subsurface soil 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 1.4 mg/kg.

### Hot Measurement Test

The site MDC of thallium does not exceed the background 95<sup>th</sup> percentile of 6.62 mg/kg.

### WRS Test

The WRS test was not performed because the site data set contains 90 percent nondetects.

### Box Plot

The site data set is characterized by a high percentage of nondetects (90 percent), so the background box plot reflects the replacement values of one-half the reporting limit (Figure 1-28). The site minimum and median are higher than the corresponding background values, and the site maximum is lower than the background maximum.

### Conclusion

Because thallium in subsurface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

### **Vanadium**

#### Tier 1 Evaluation

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

#### Hot Measurement Test

The site MDC of vanadium does not exceed the background 95<sup>th</sup> UTL of 91.7 mg/kg.

#### WRS Test

The p-level of 0.084 indicates poor agreement between the site and background distributions. The reason for the low p-level is that the site data are shifted lower relative to background.

#### Box Plot

The site minimum, median, and maximum are lower than the corresponding background values (Figure 1-29).

### Conclusion

Because vanadium in subsurface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

### **Zinc**

#### Tier 1 Evaluation

One site sample exceeds the background screening value of 34.86 mg/kg.

#### Hot Measurement Test

The site MDC of zinc does not exceed the background 95<sup>th</sup> percentile of 85 mg/kg.

#### WRS Test

The p-level of 0.476 indicates good agreement between the site and background distributions.

#### Box Plot

The site minimum and median are higher than the respective background values, and the site maximum is lower than background maximum (Figure 1-30).

### Conclusion

Because zinc in subsurface soil is within the range of background, it will not be carried forward for Tier 3 geochemical evaluation.

### **3.3 Sediment**

This section presents results of the site-to-background comparison for TAL metals in the sediment samples collected at Parcels 105Q-X and 225Q. The site samples are 100 percent nondetect for antimony, cadmium, mercury, silver, and thallium. Sixteen metals (aluminum,

arsenic, barium, beryllium, calcium, chromium, cobalt, copper, iron, lead, magnesium, manganese, nickel, potassium, sodium, and zinc) passed the Tier 1 evaluation, and they will not be discussed further. The remaining two metals (selenium and vanadium) are carried forward for Tier 2 evaluation. The results of these evaluations are summarized in Table 3 and discussed in detail below. Box plots are provided in Attachment 1.

## **Selenium**

### Tier 1 Evaluation

All three site samples exceed the background screening value of 0.72 mg/kg.

### Hot Measurement Test

The site MDC of selenium exceeds the background 95<sup>th</sup> percentile of 1.03 mg/kg.

### WRS Test

The WRS test was not performed because the background data contains 93 percent nondetects.

### Box Plots

The shape and location of the background box plot reflect the high percentage of nondetects (93 percent), and the replacement values of one-half the reporting limit (Figure 1-31). The site minimum is higher than the background minimum, and the site median and maximum are higher than the background maximum.

### Conclusion

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

## **Vanadium**

### Tier 1 Evaluation

One site sample exceeds the background screening value of 40.87 mg/kg.

### Hot Measurement Test

The site MDC of vanadium does not exceed the background 95<sup>th</sup> UTL of 67.7 mg/kg.

### WRS Test

The p-level of 0.088 indicates weak agreement between the background and site distributions.

### Box Plots

The site minimum and median are higher than the corresponding background values, and the site maximum lower than the background maximum (Figure 1-32).

### Conclusion

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

### **3.4 Surface Water**

This section presents the results of the site-to-background comparisons for TAL metals in the surface water samples collected at Parcels 105Q-X and 225Q. The site samples are 100 percent nondetect for antimony, arsenic, beryllium, cadmium, calcium, cobalt, copper, lead, magnesium, mercury, nickel, potassium, selenium, silver, thallium, vanadium, and zinc. Five metals (aluminum, barium, iron, manganese, and sodium) passed the Tier 1 evaluation, and they will not be discussed further. The remaining metal (chromium) is carried forward for Tier 2 evaluation. Table 3 summarizes the results of the surface water statistical site-to-background comparison. Box Plot is provided in Attachment 1.

#### **Chromium**

##### Tier 1 Evaluation

One site sample exceeds the background screening value of 0.01113 mg/L.

##### Hot Measurement Test

The site MDC of chromium exceeds the background 95<sup>th</sup> percentile of 0.0168 mg/L.

##### WRS Test

The WRS test was not performed because the background and site data sets contain 98 and 67 percent nondetects, respectively.

##### Box Plots

The shape and location of the background box plot reflects the high percentage of nondetects (98 percent) and the replacement values of one-half the reporting limit (Figure 1-33). The site minimum, median, and maximum are higher than the corresponding background values.

##### Conclusion

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

### **4.0 Summary and Conclusions**

The statistical methodology used to compare the Parcels 105Q-X and 225Q and background data sets for 23 elements in surface soil, subsurface soil, sediment, and surface water included a comparison of the site MDC to the two times the background mean (Tier 1 evaluation). Analytes that failed this comparison were subjected to the Slippage test and WRS test (Tier 2 evaluation). Box-and-whisker plots were prepared to visually compare the two data sets and properly interpret the WRS test results. The Hot Measurement test was performed for elements with data sets that precluded either the Slippage test or WRS test. Analytes that failed any of the statistical tests in the Tier 2 evaluation are carried forward for geochemical evaluation to determine if

natural processes can explain the elevated concentrations. Tables 1 through 4 summarize the comparison test results and identify the metals carried forward for geochemical evaluation.

## **5.0 References**

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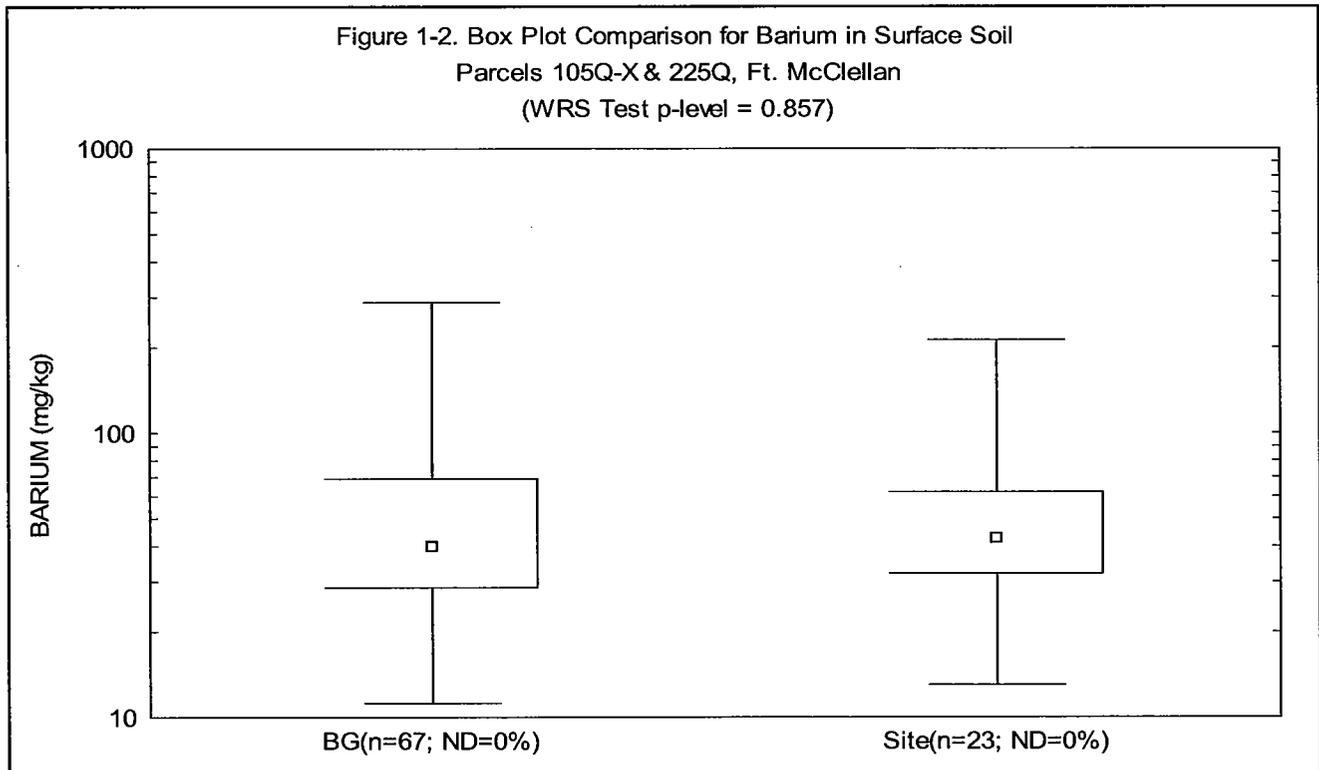
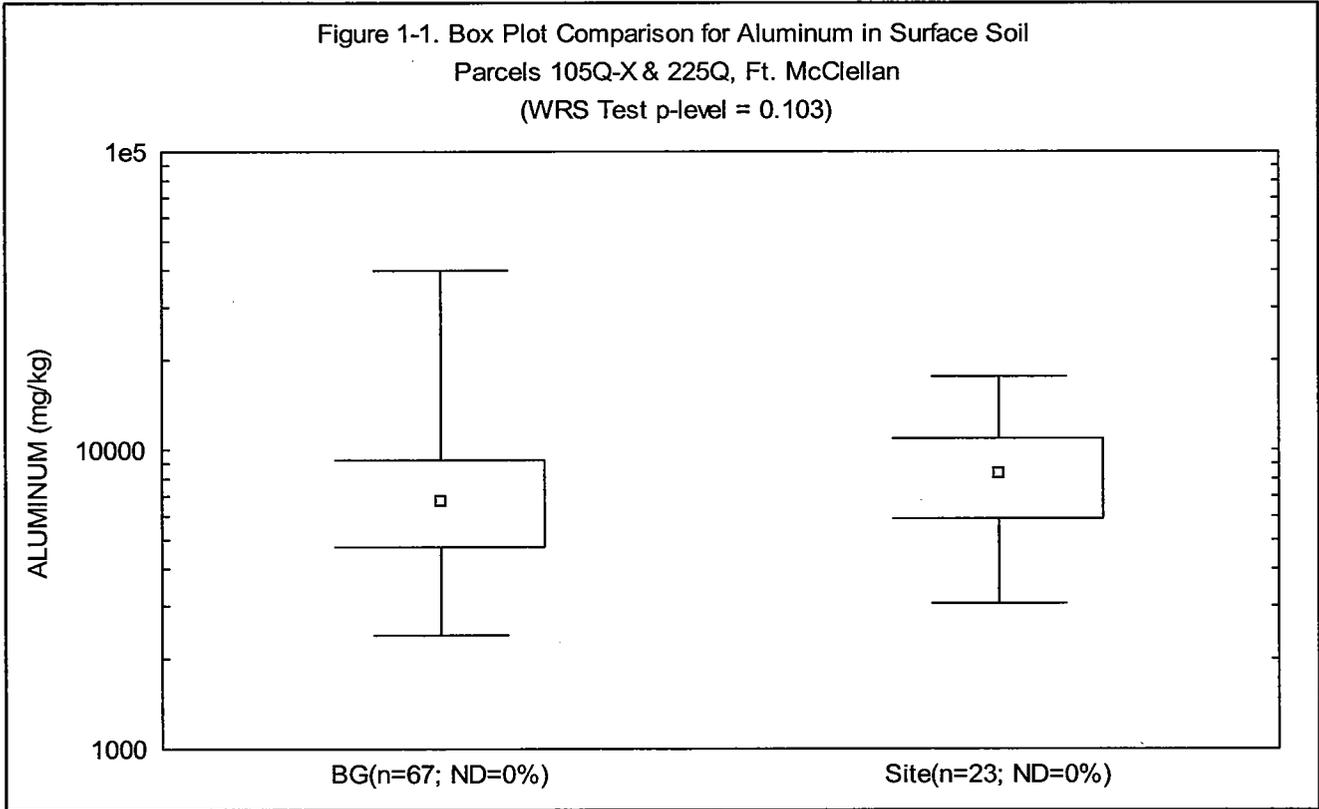
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**ATTACHMENT 1**

**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**

Figure 1-3. Box Plot Comparison for Beryllium in Surface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan

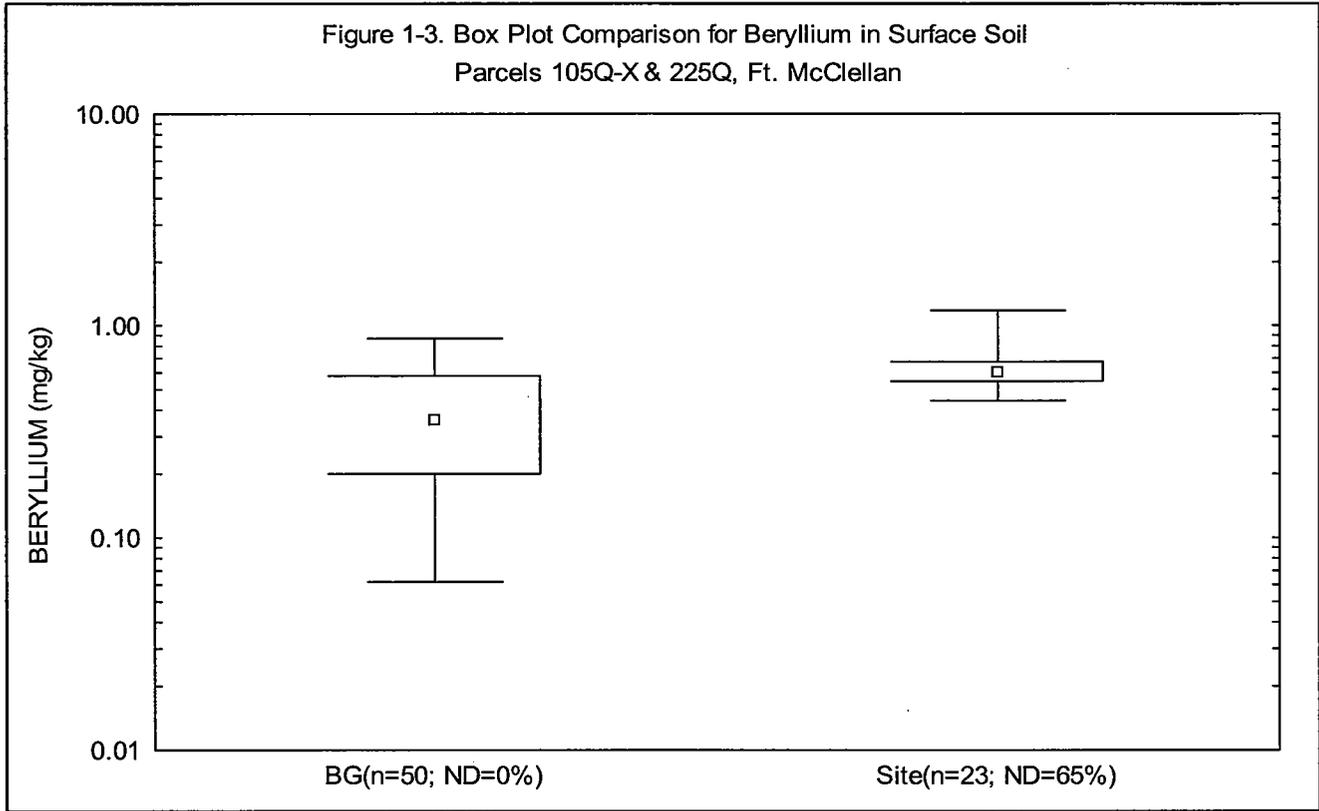
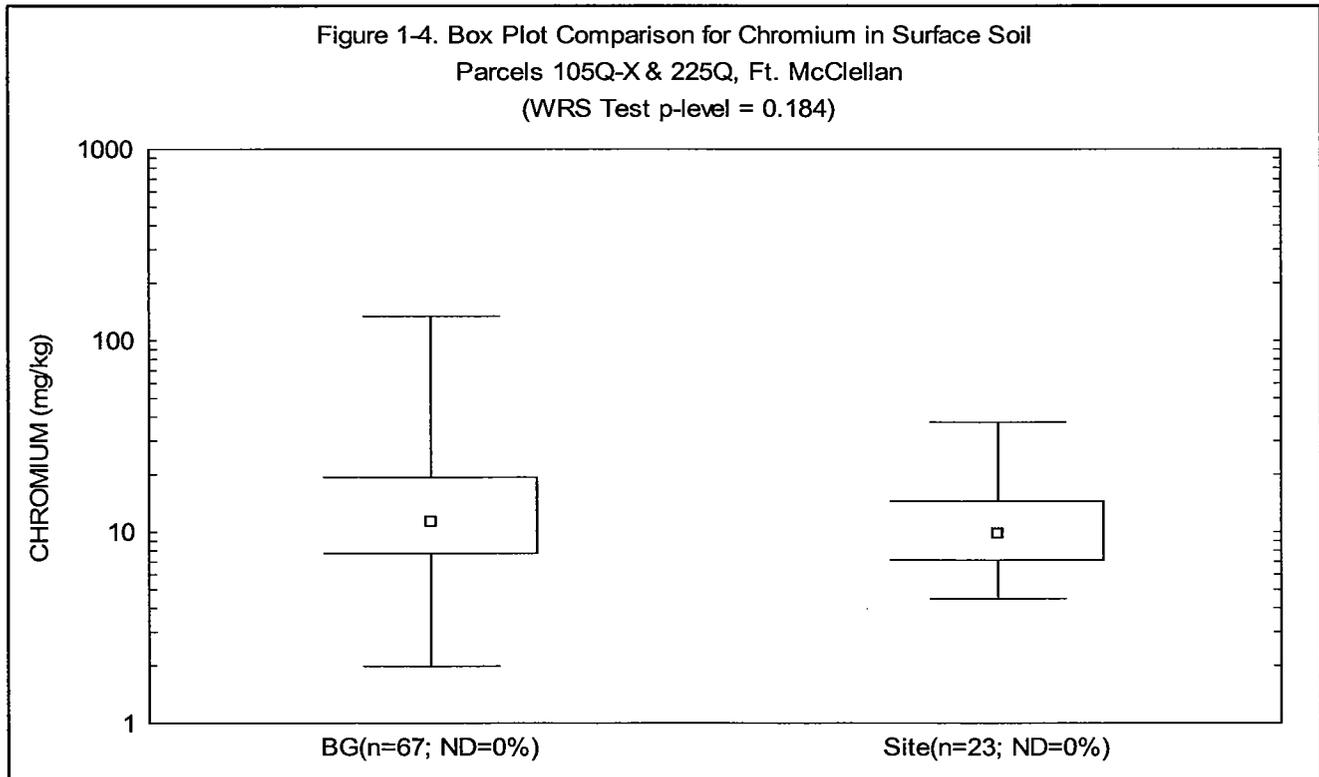


Figure 1-4. Box Plot Comparison for Chromium in Surface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.184)



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**

Figure 1-5. Box Plot Comparison for Cobalt in Surface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.897)

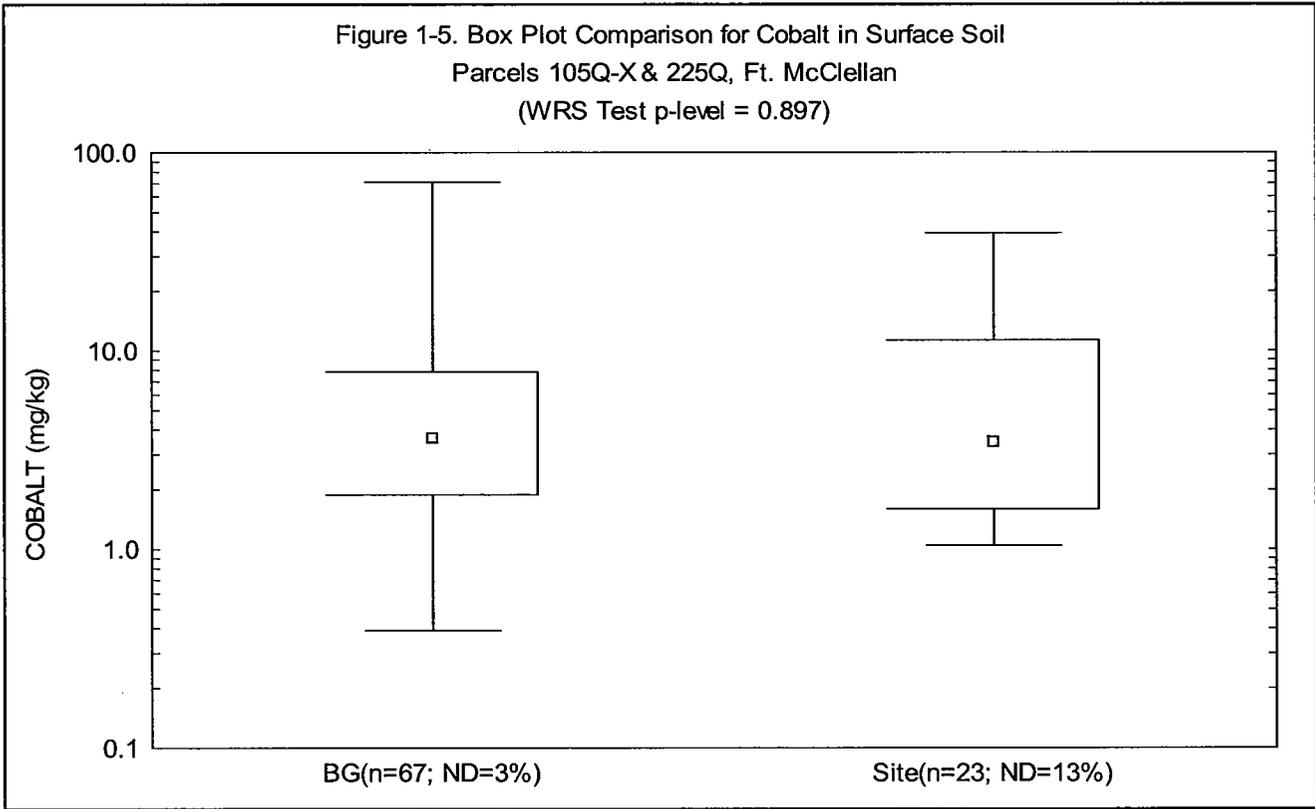
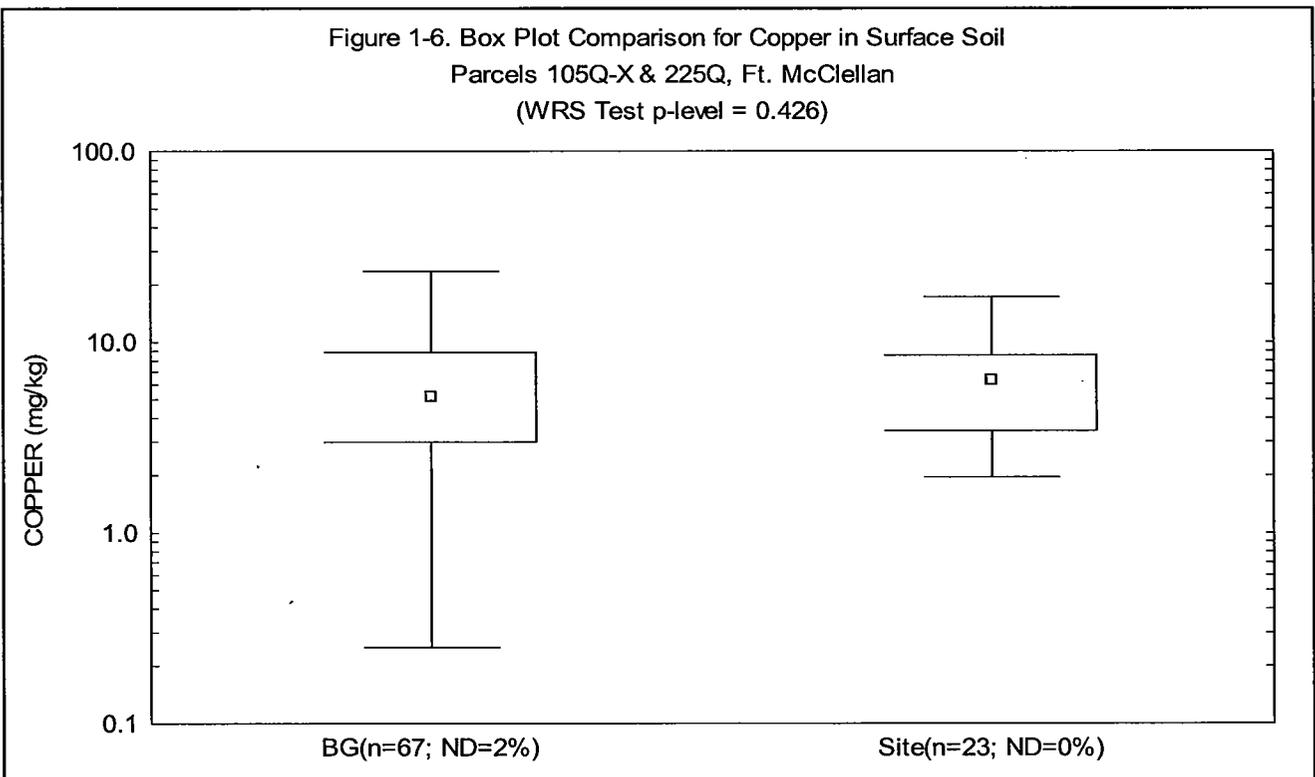
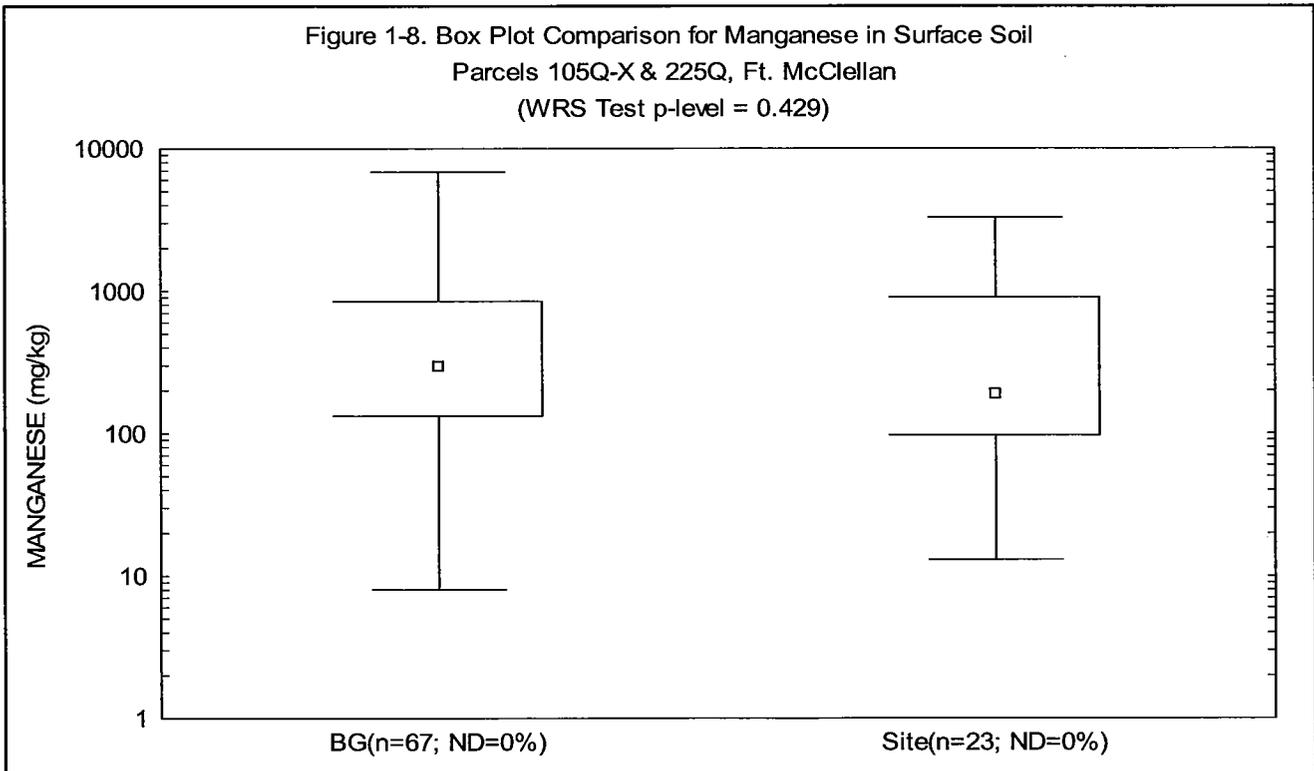
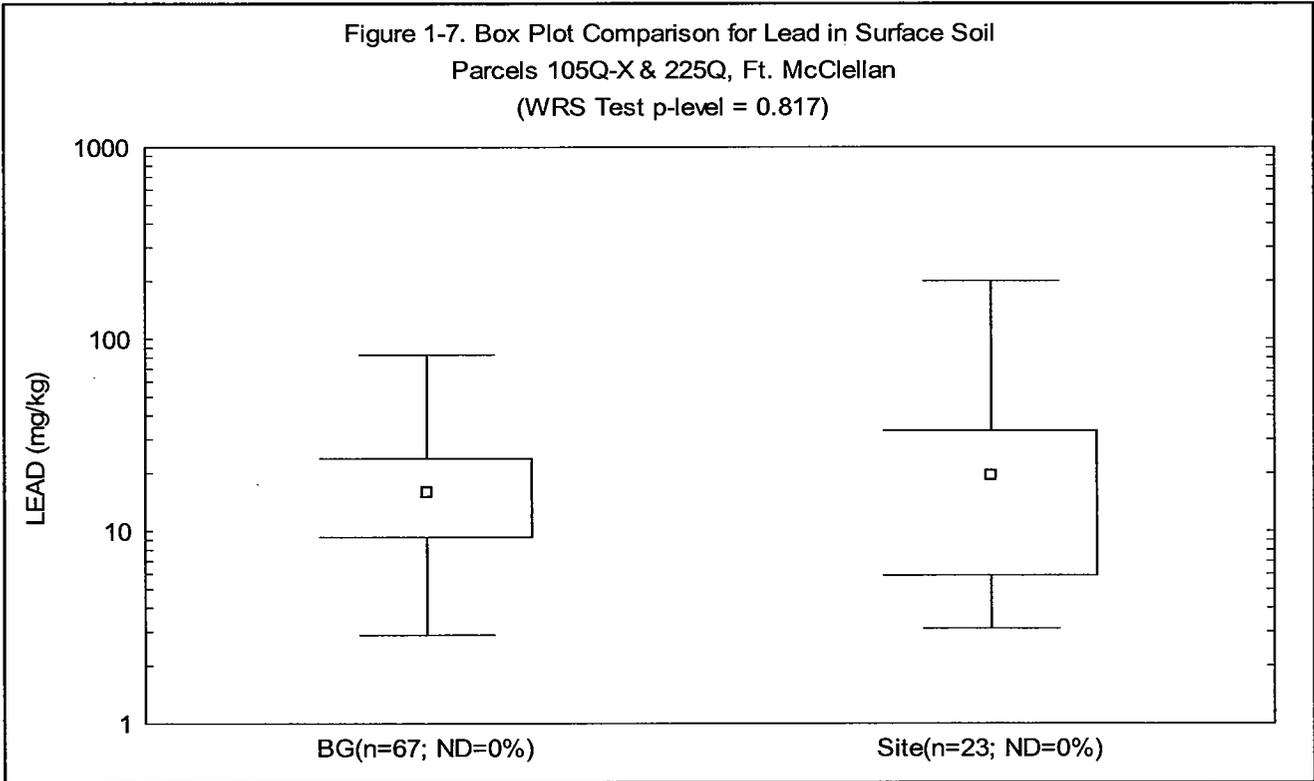


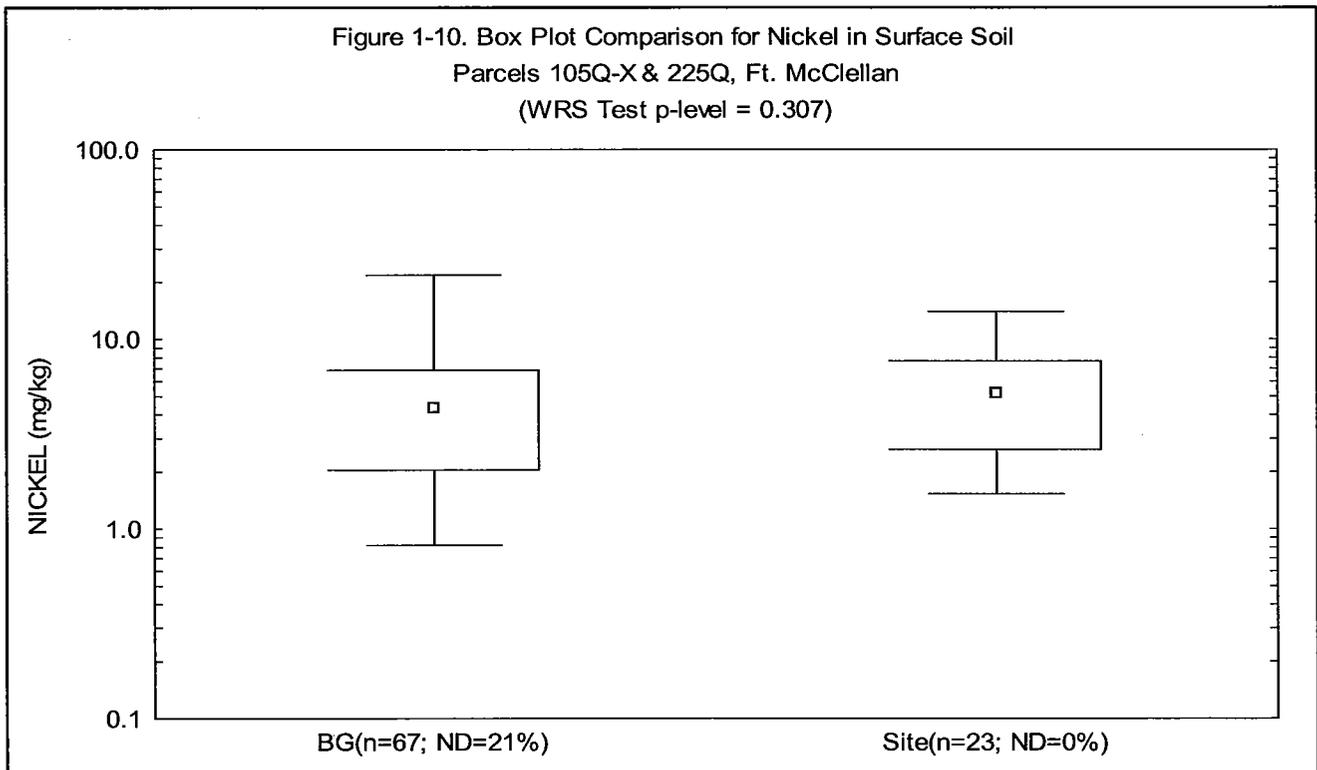
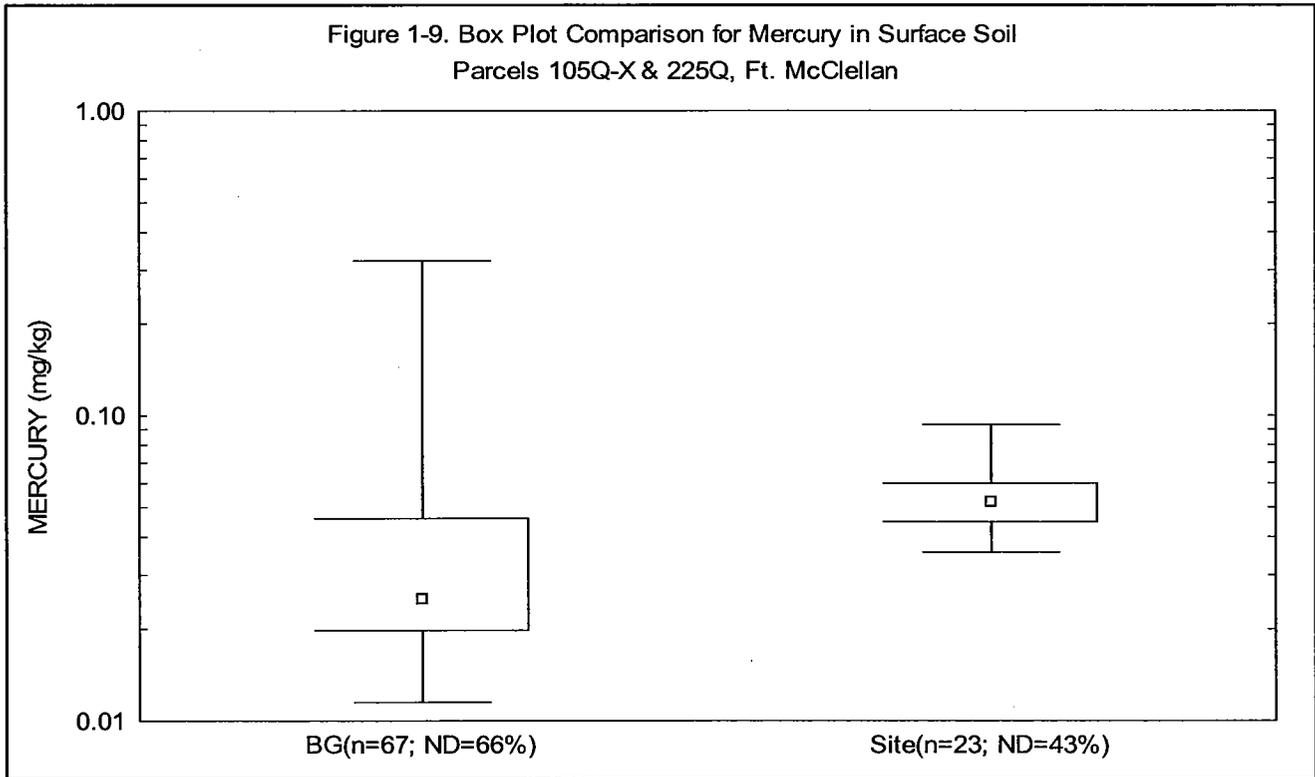
Figure 1-6. Box Plot Comparison for Copper in Surface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.426)



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**

Figure 1-11. Box Plot Comparison for Selenium in Surface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan

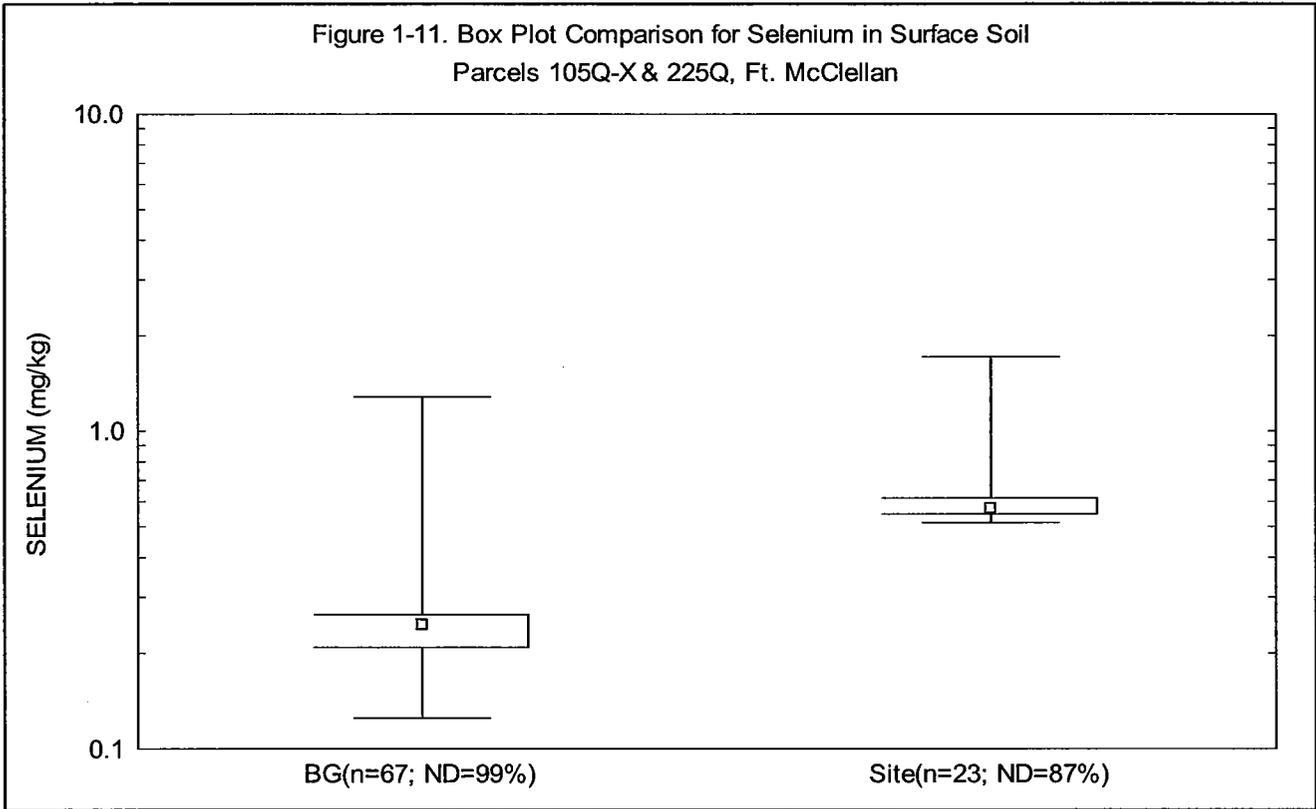
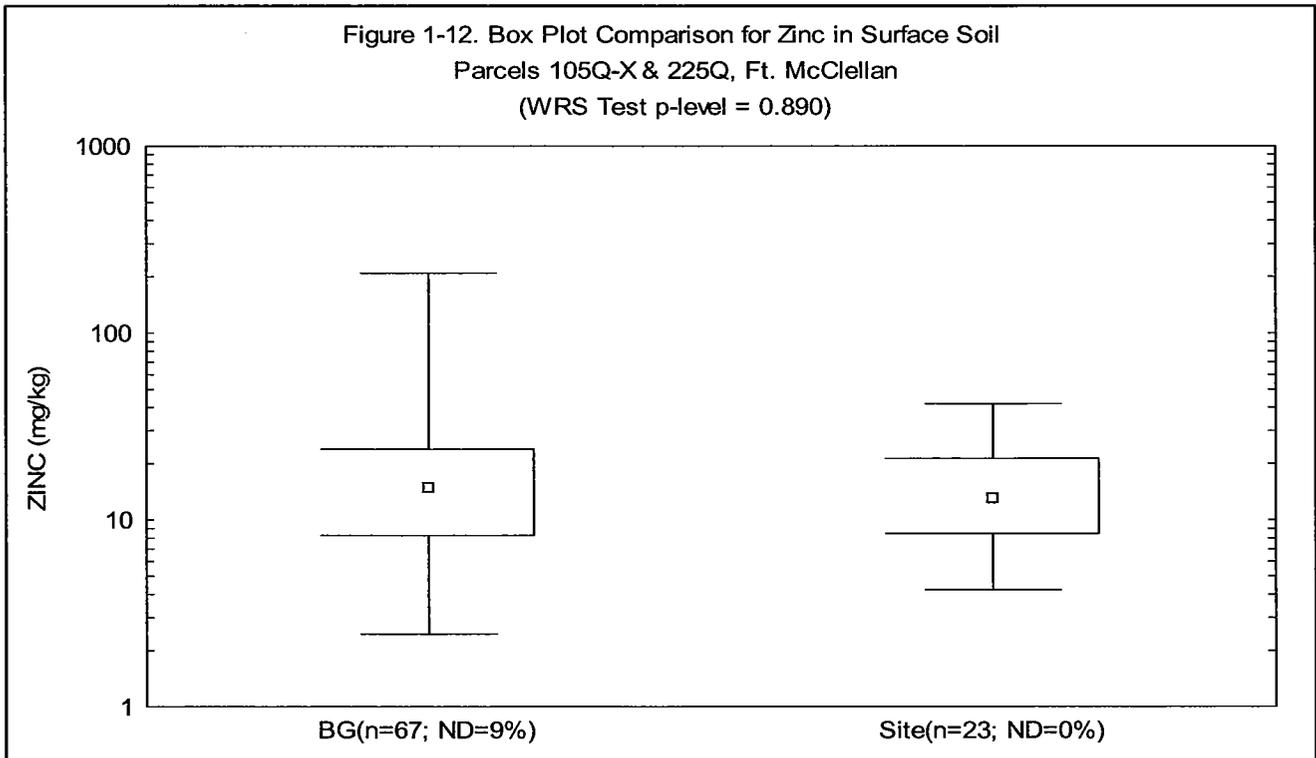
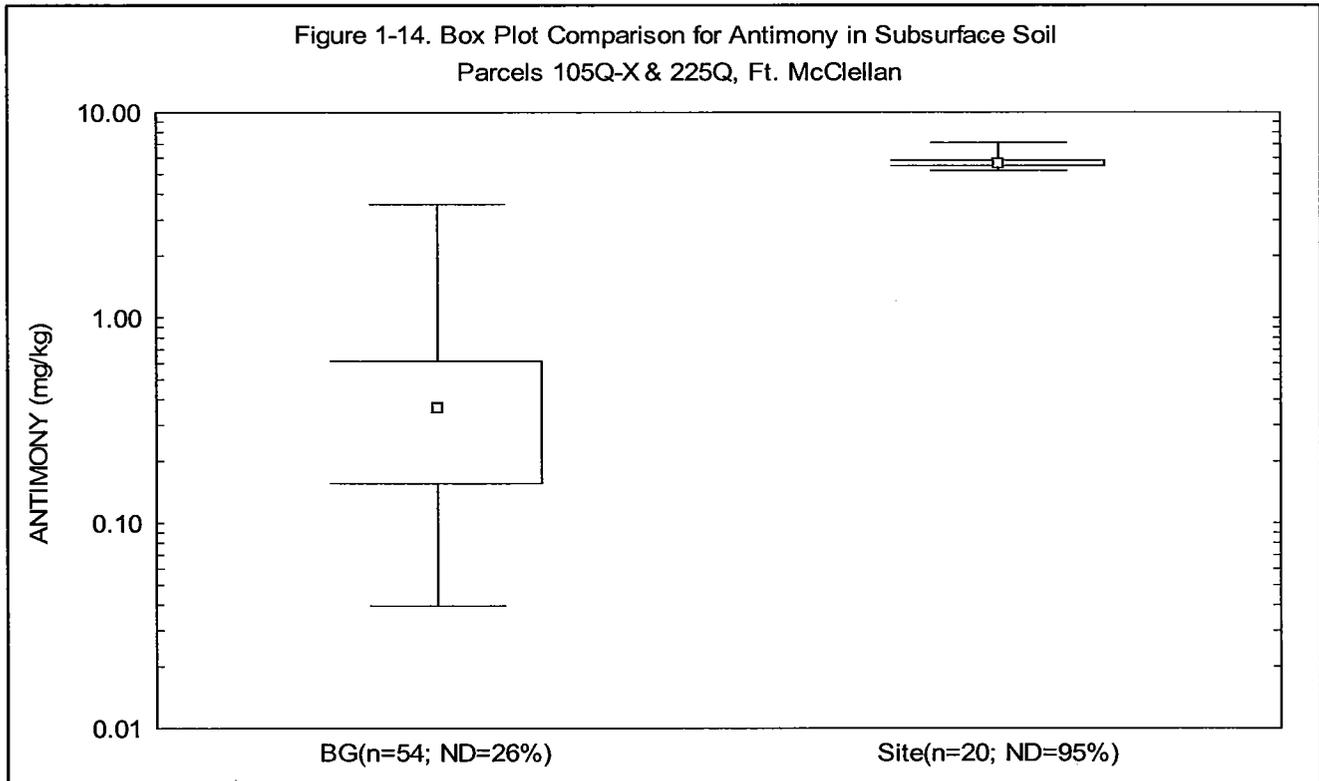
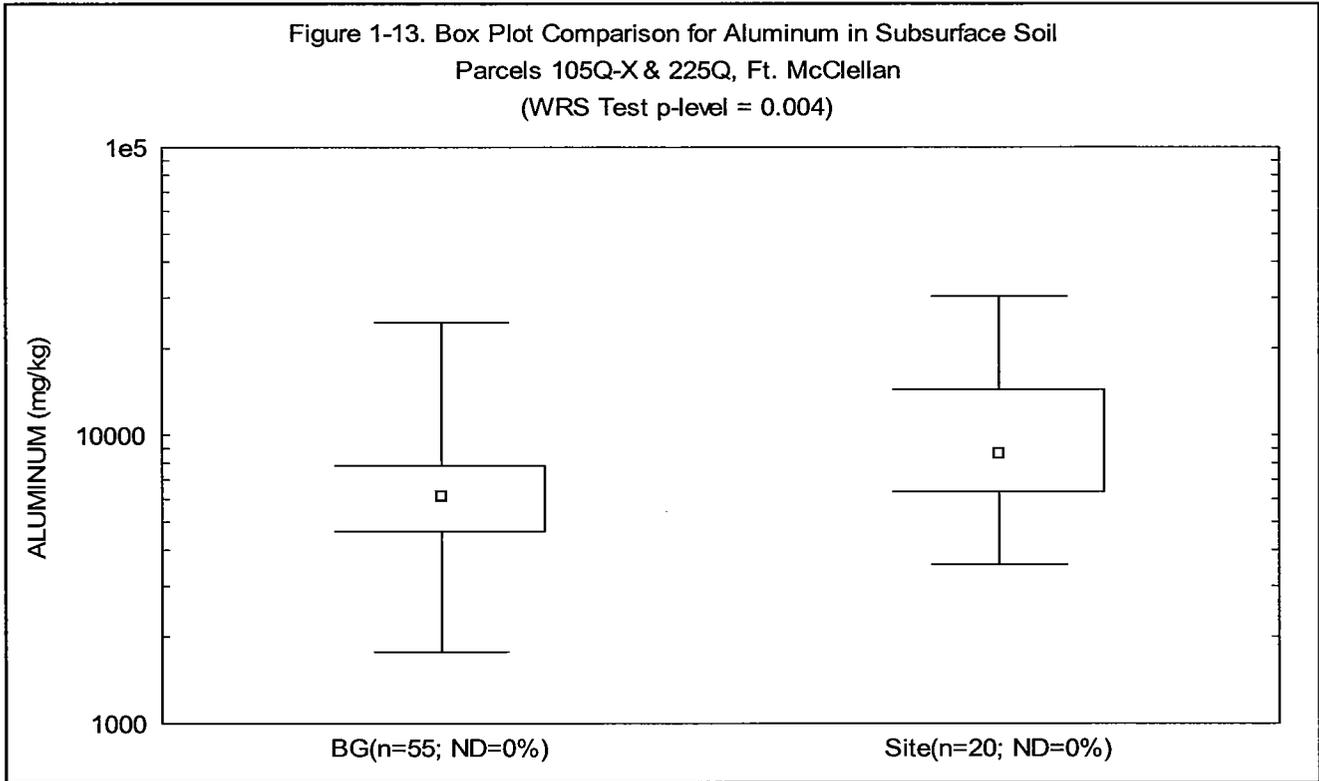


Figure 1-12. Box Plot Comparison for Zinc in Surface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.890)



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**

Figure 1-15. Box Plot Comparison for Barium in Subsurface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.018)

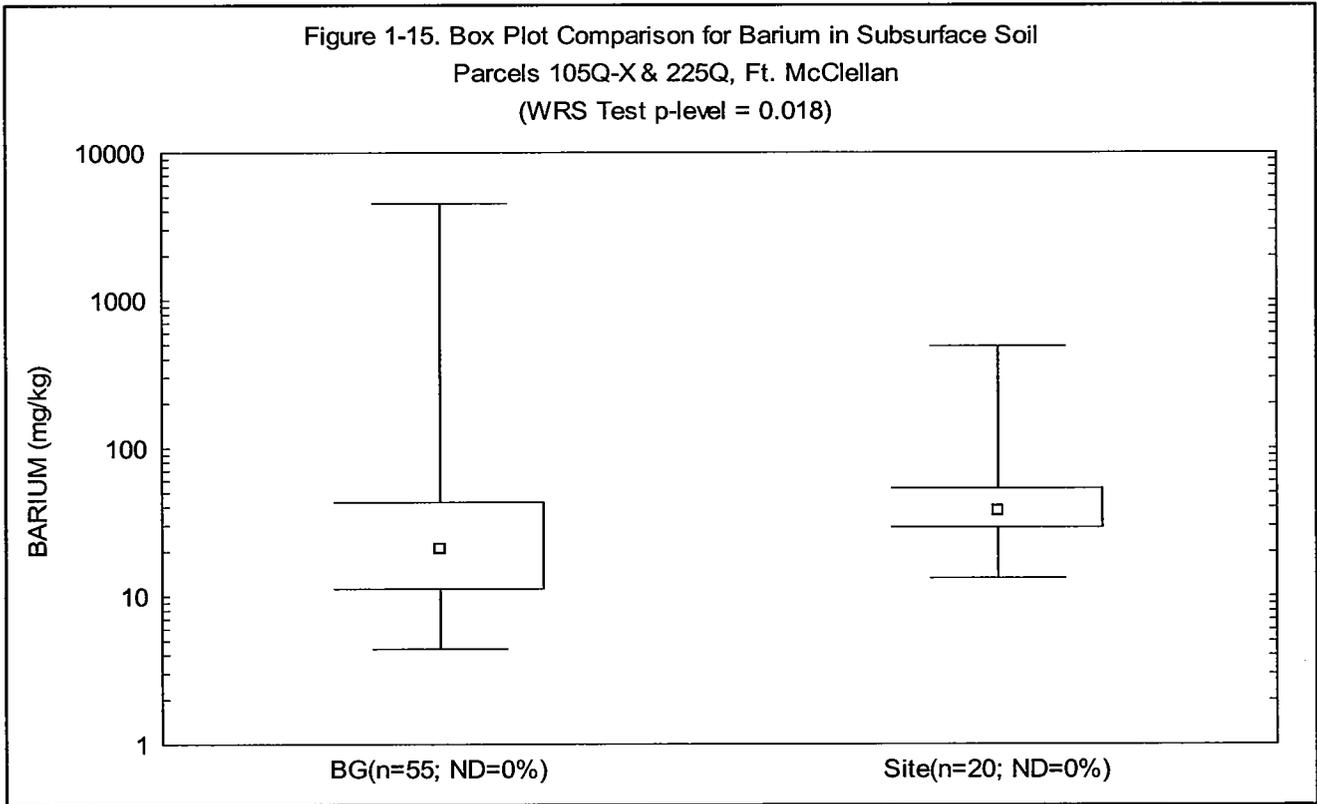
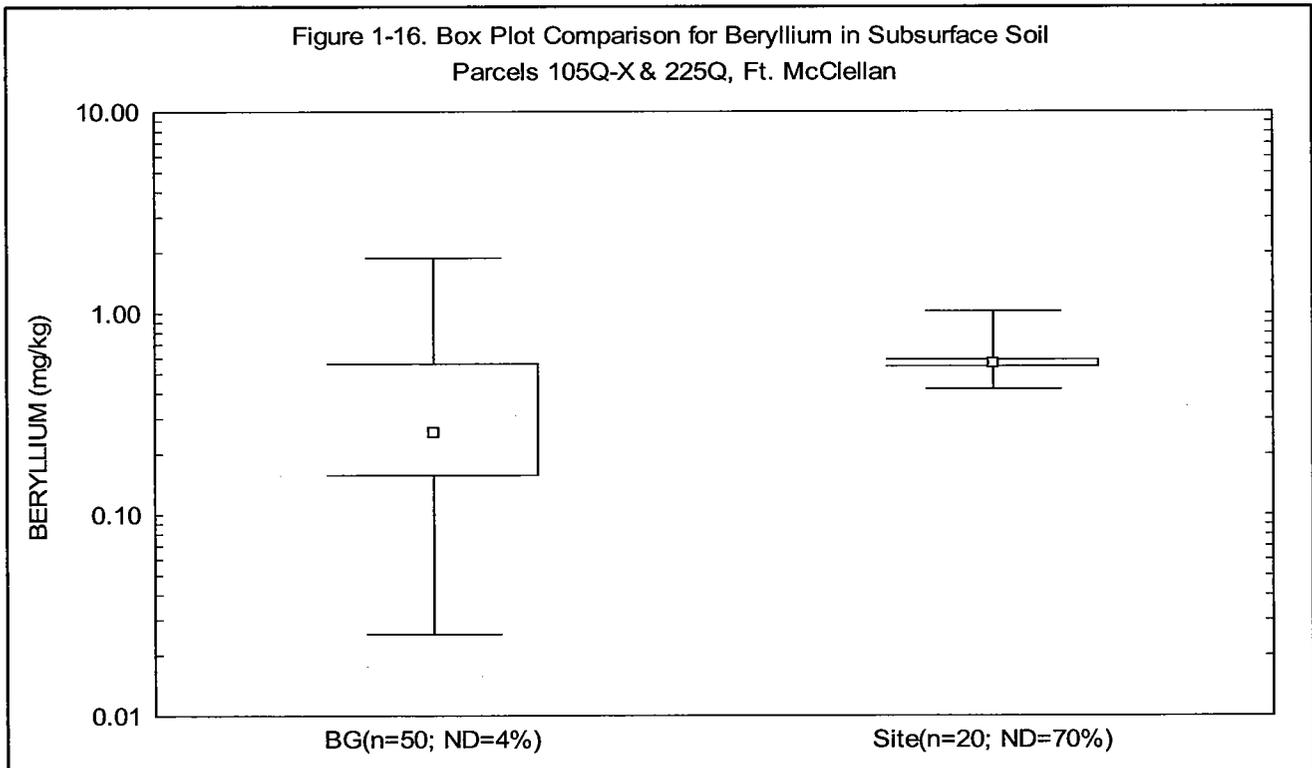


Figure 1-16. Box Plot Comparison for Beryllium in Subsurface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**

Figure 1-17. Box Plot Comparison for Chromium in Subsurface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.028)

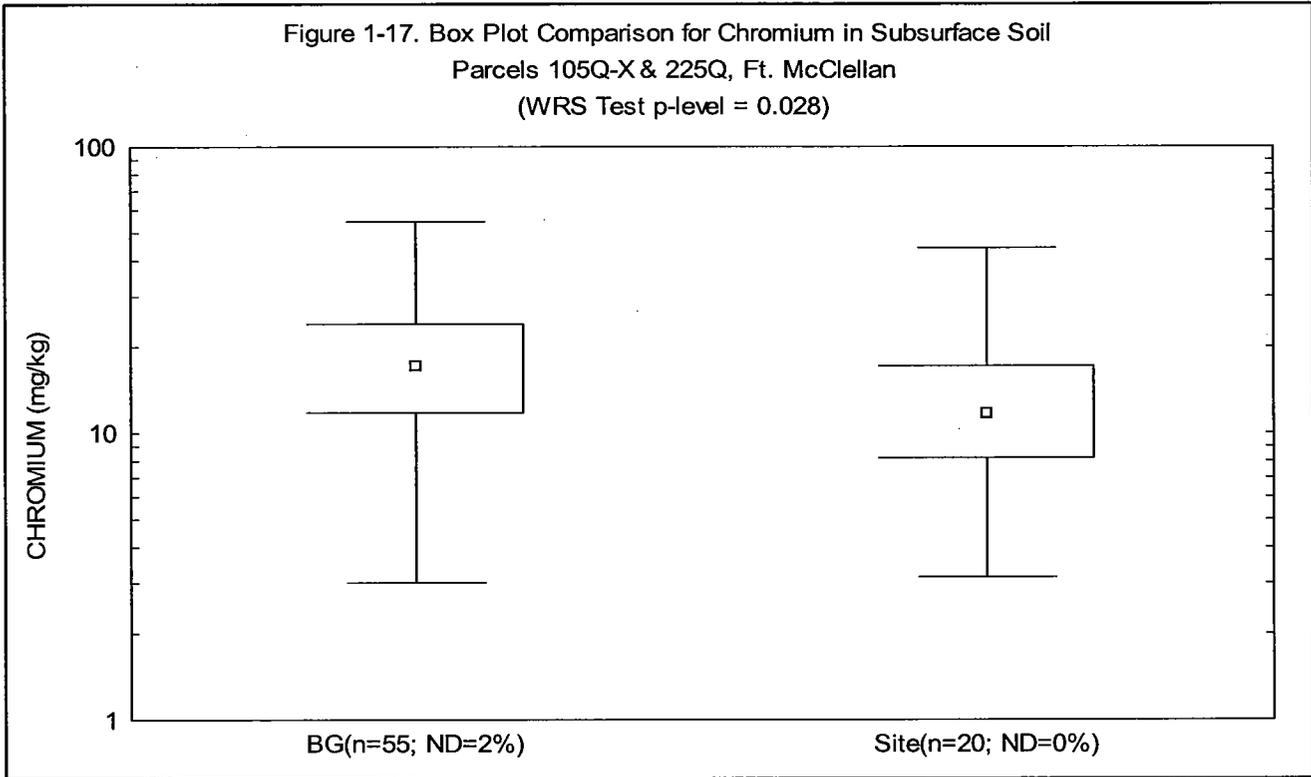
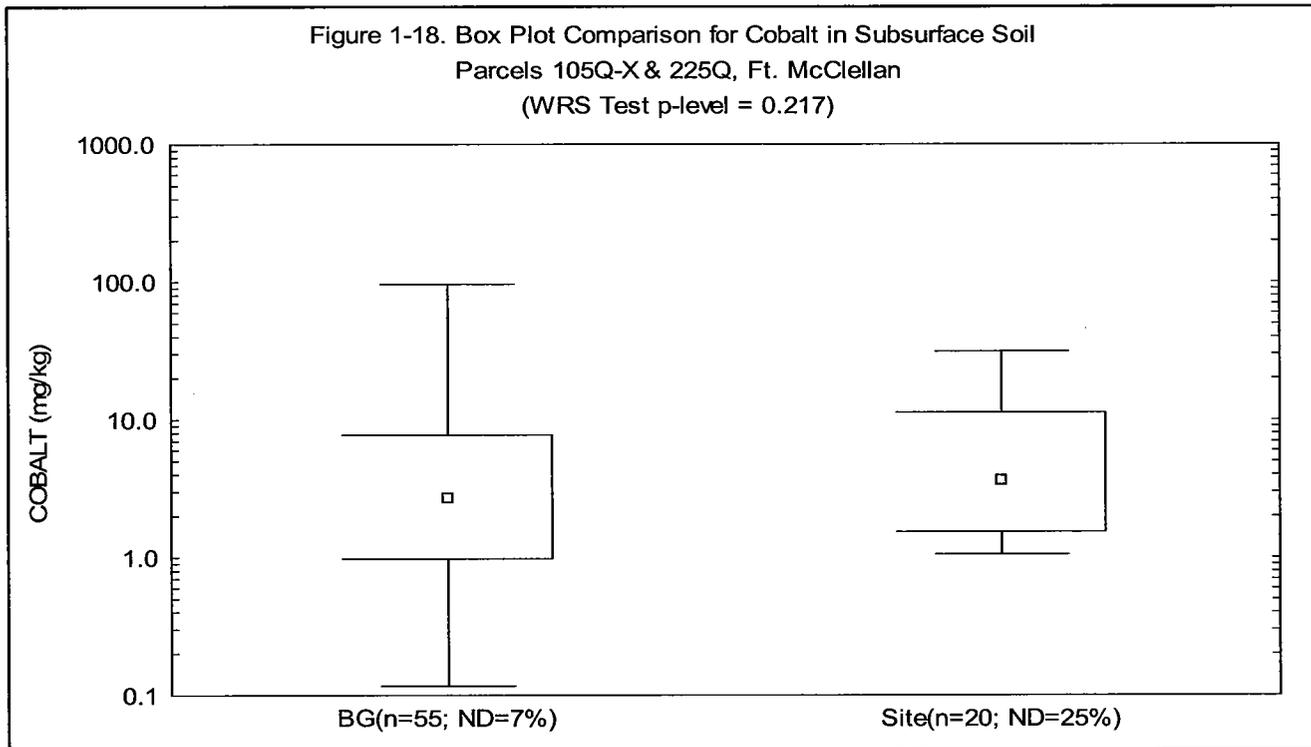
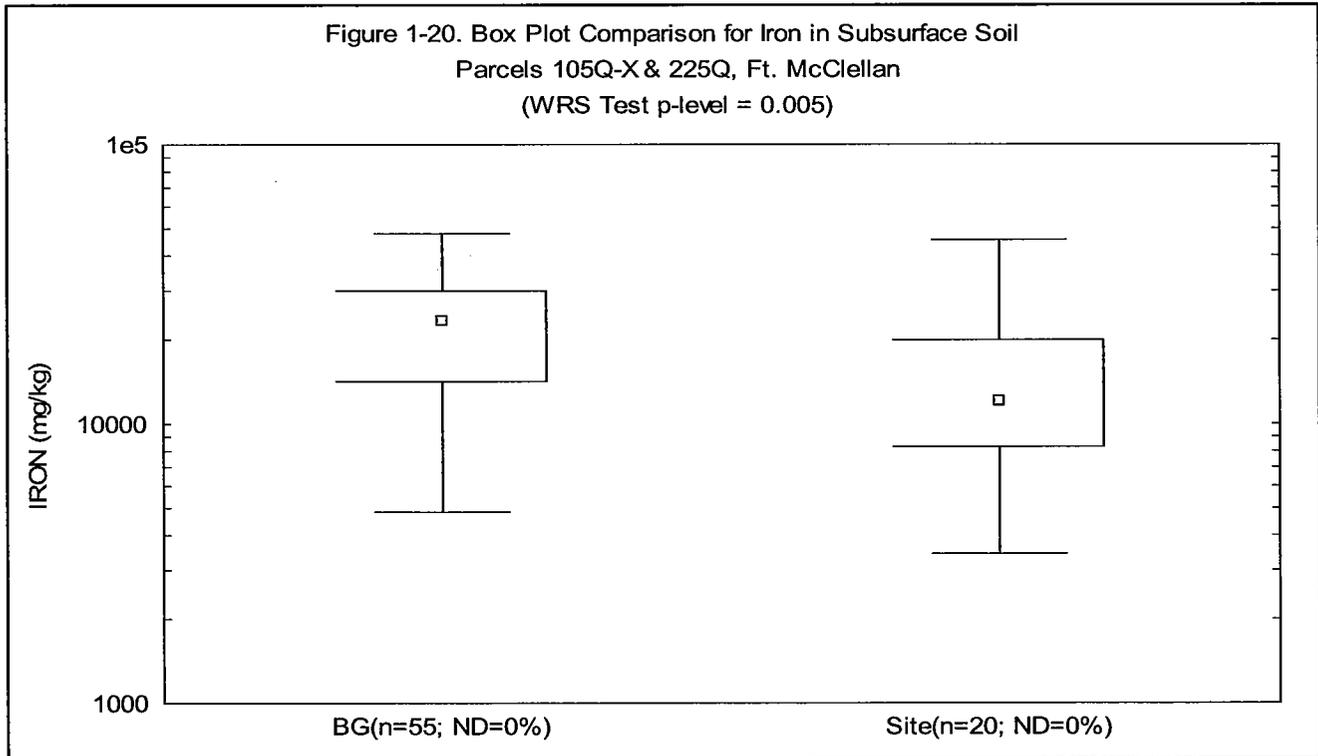
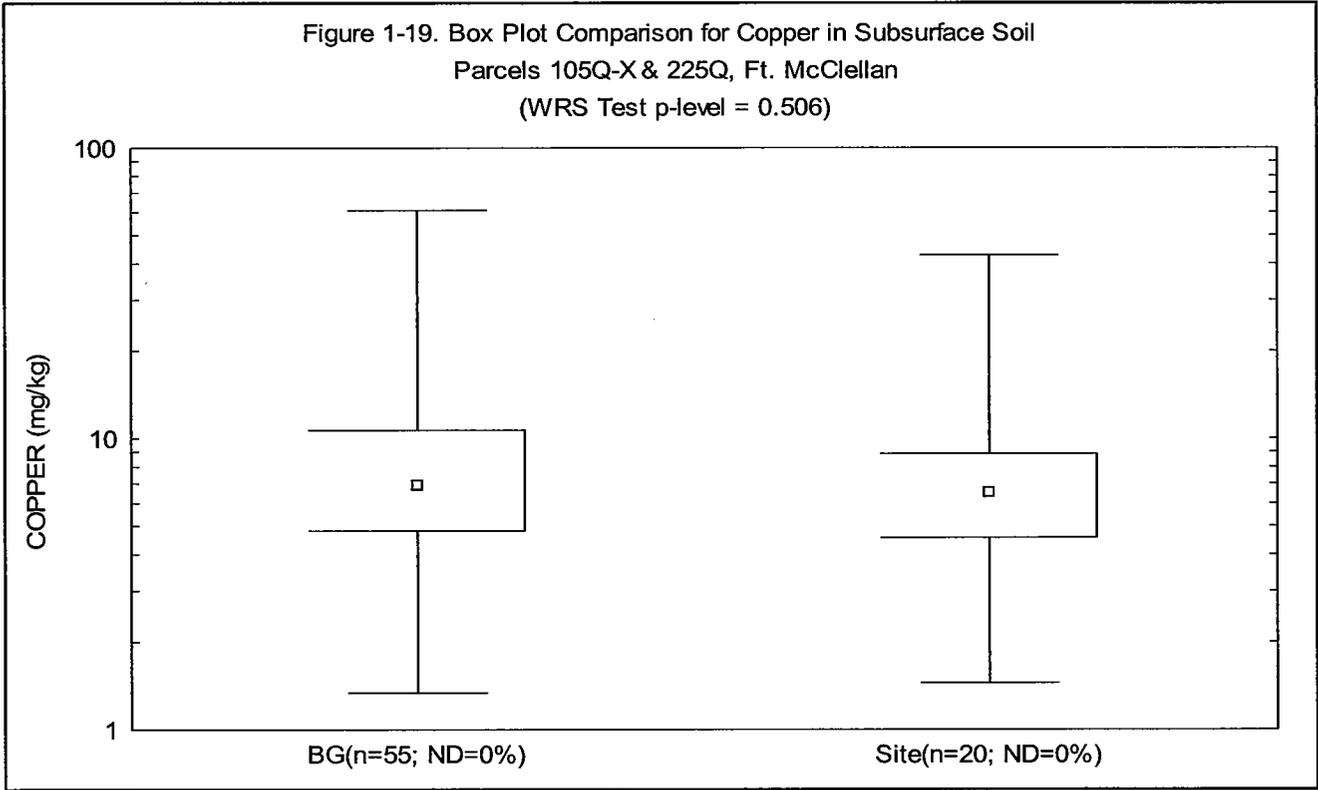


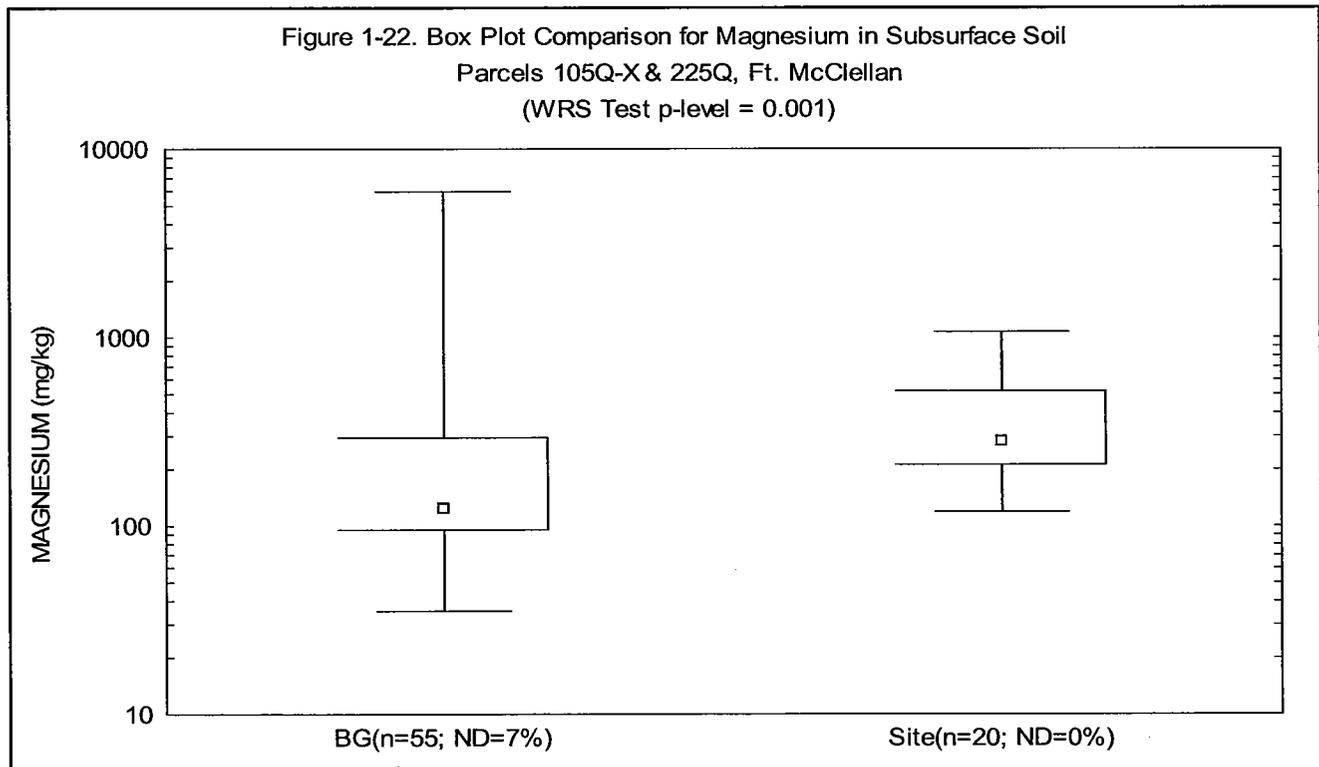
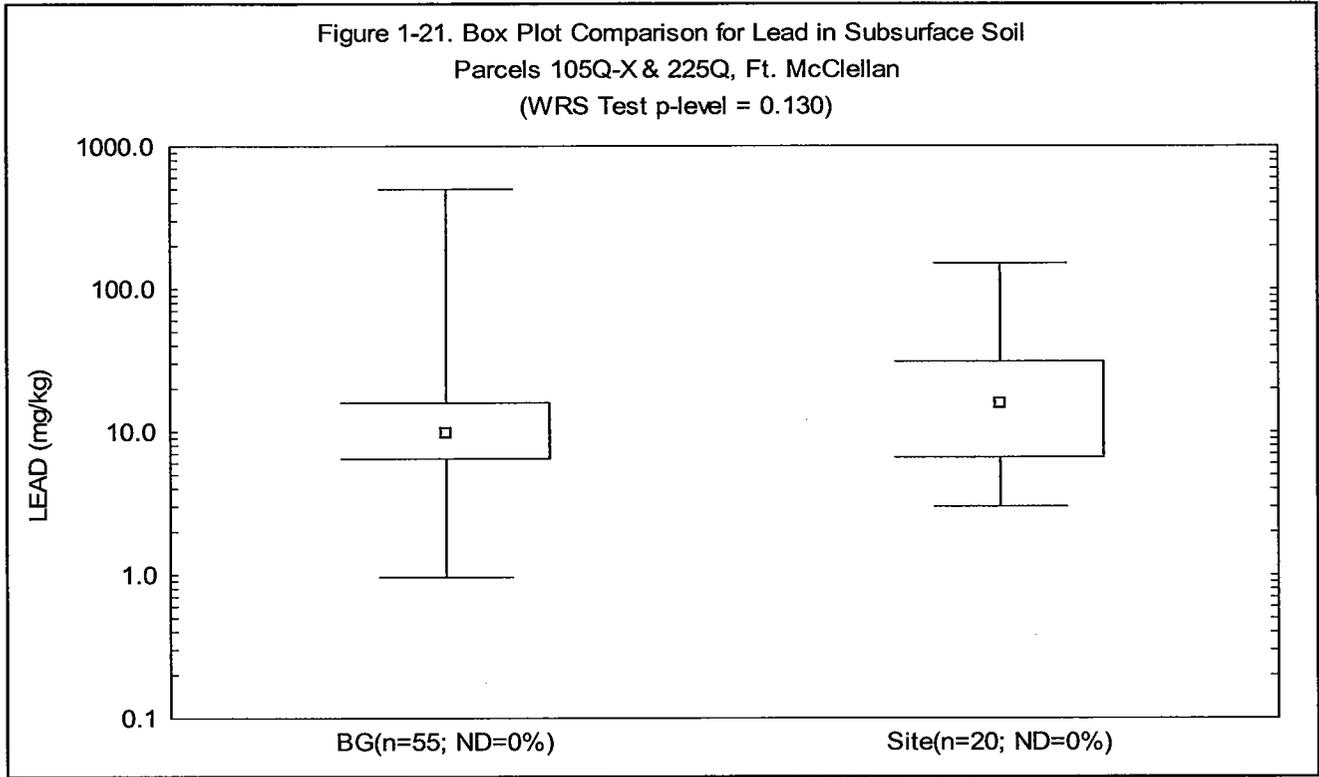
Figure 1-18. Box Plot Comparison for Cobalt in Subsurface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.217)



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**

Figure 1-23. Box Plot Comparison for Manganese in Subsurface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.200)

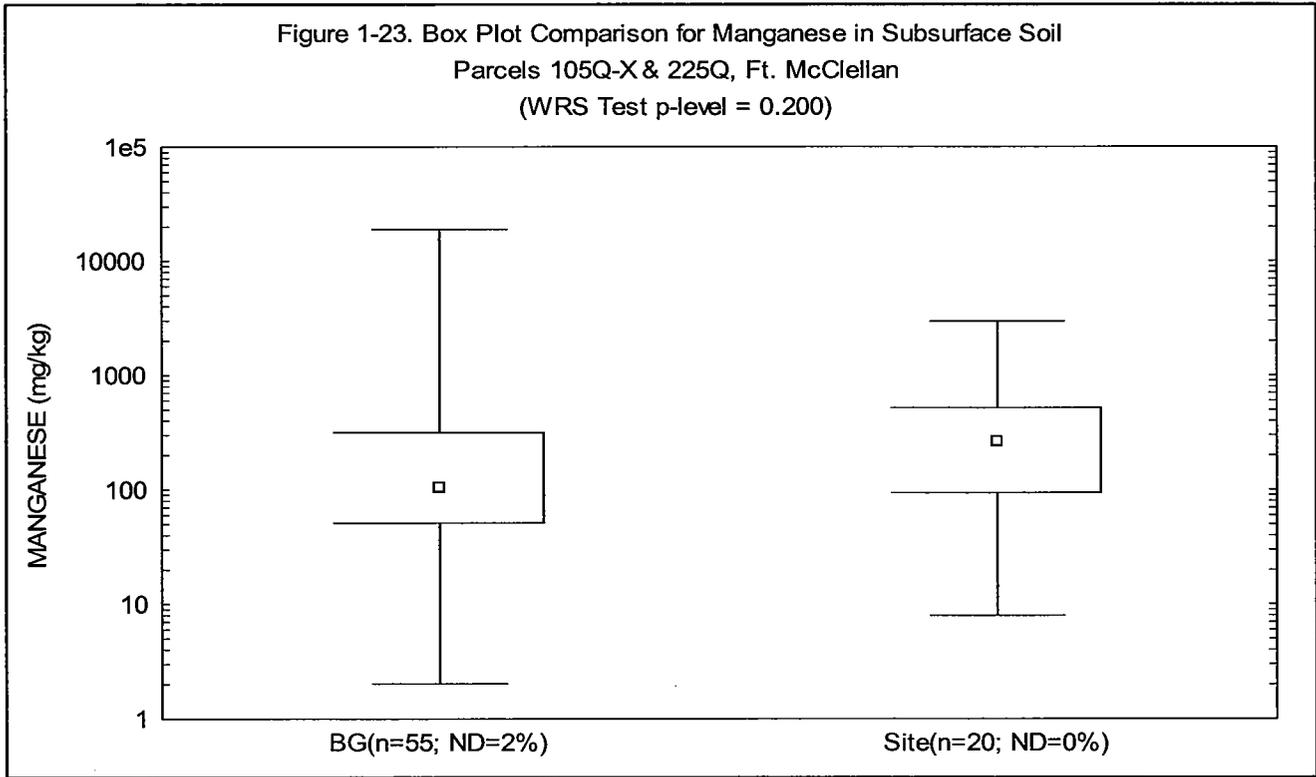
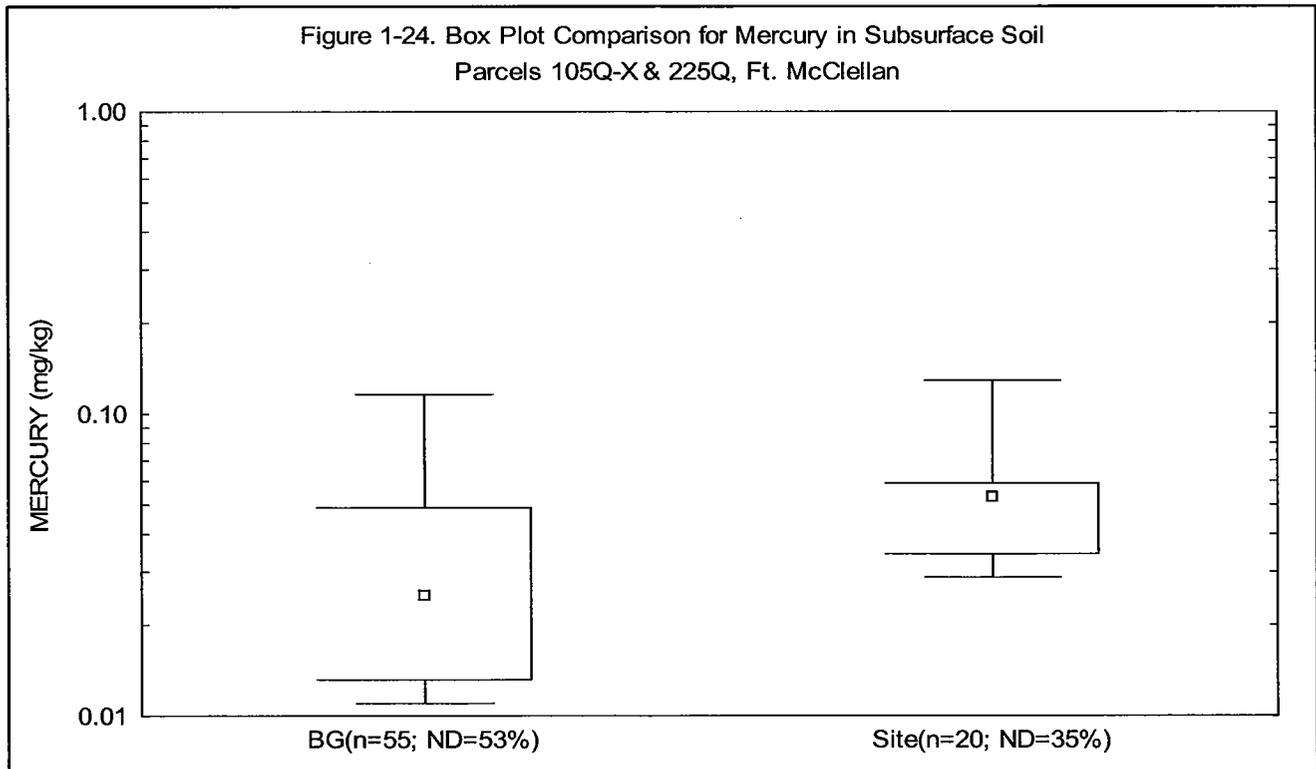


Figure 1-24. Box Plot Comparison for Mercury in Subsurface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**

Figure 1-25. Box Plot Comparison for Nickel in Subsurface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.253)

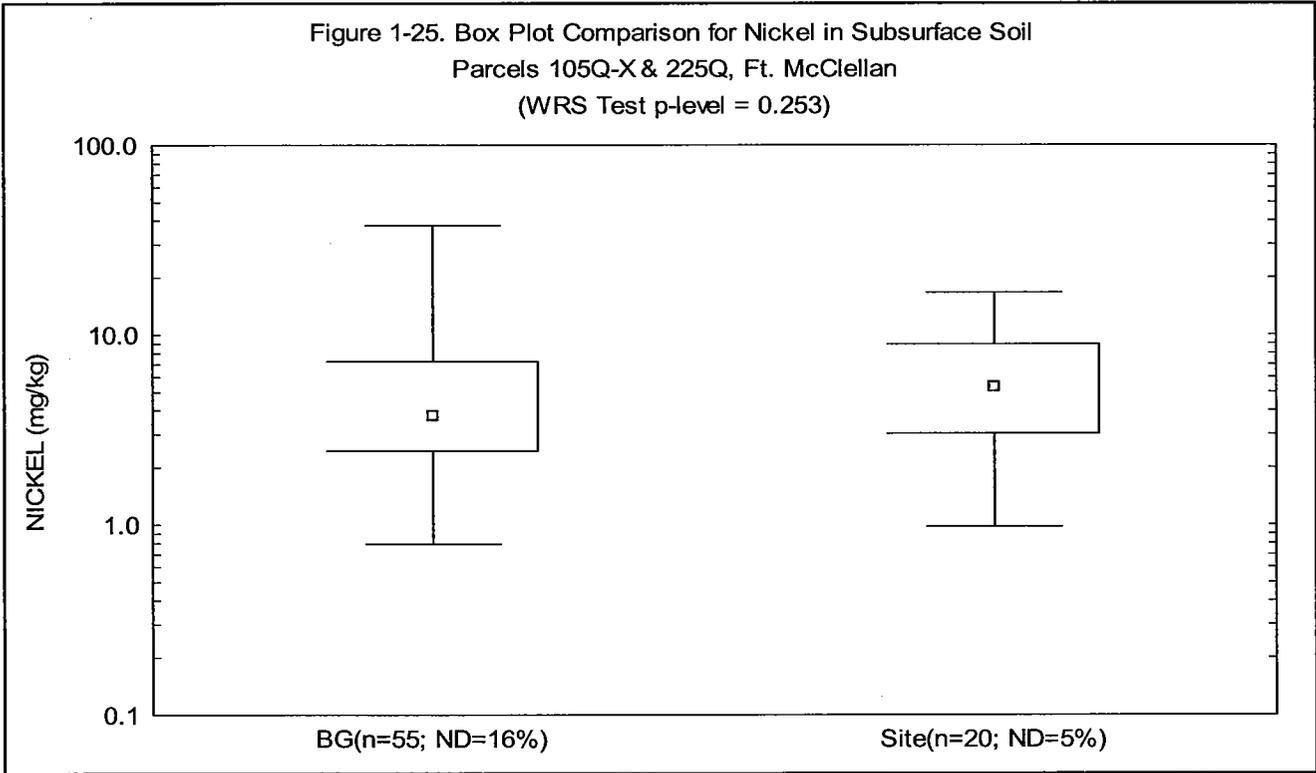
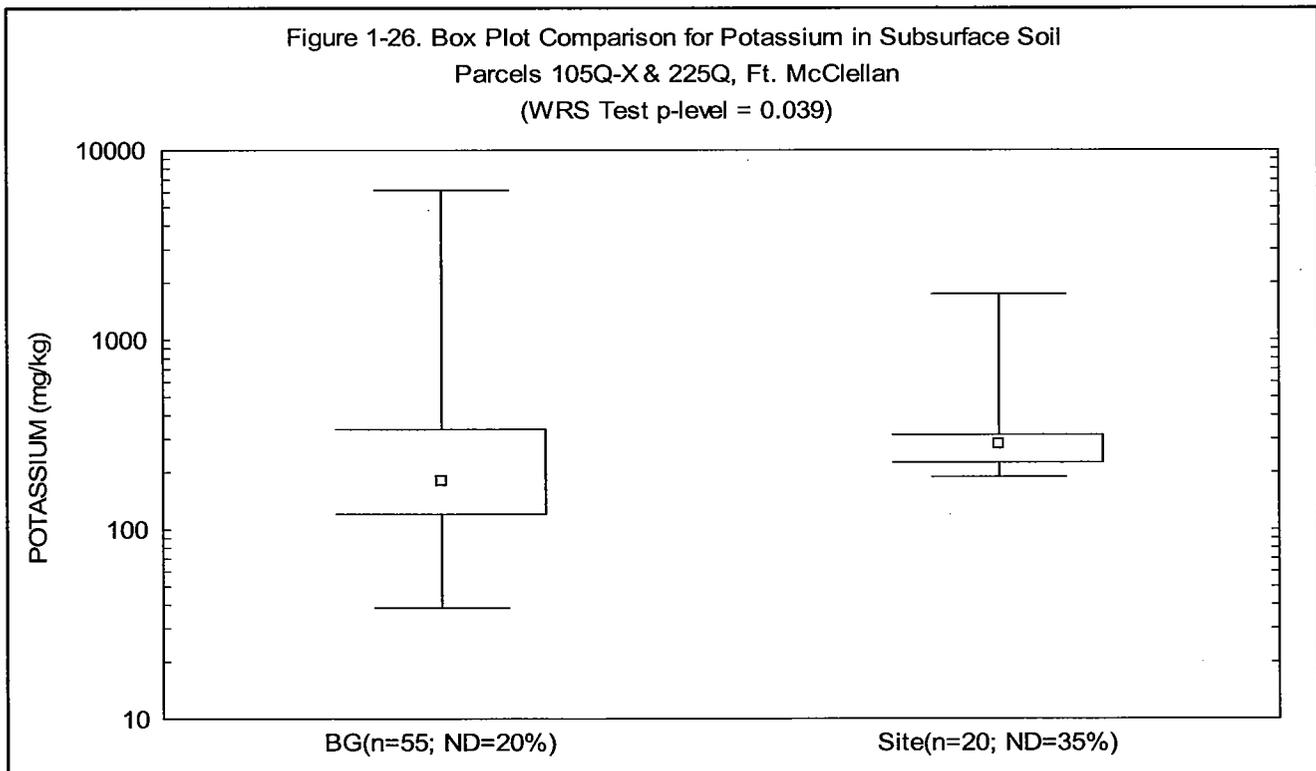
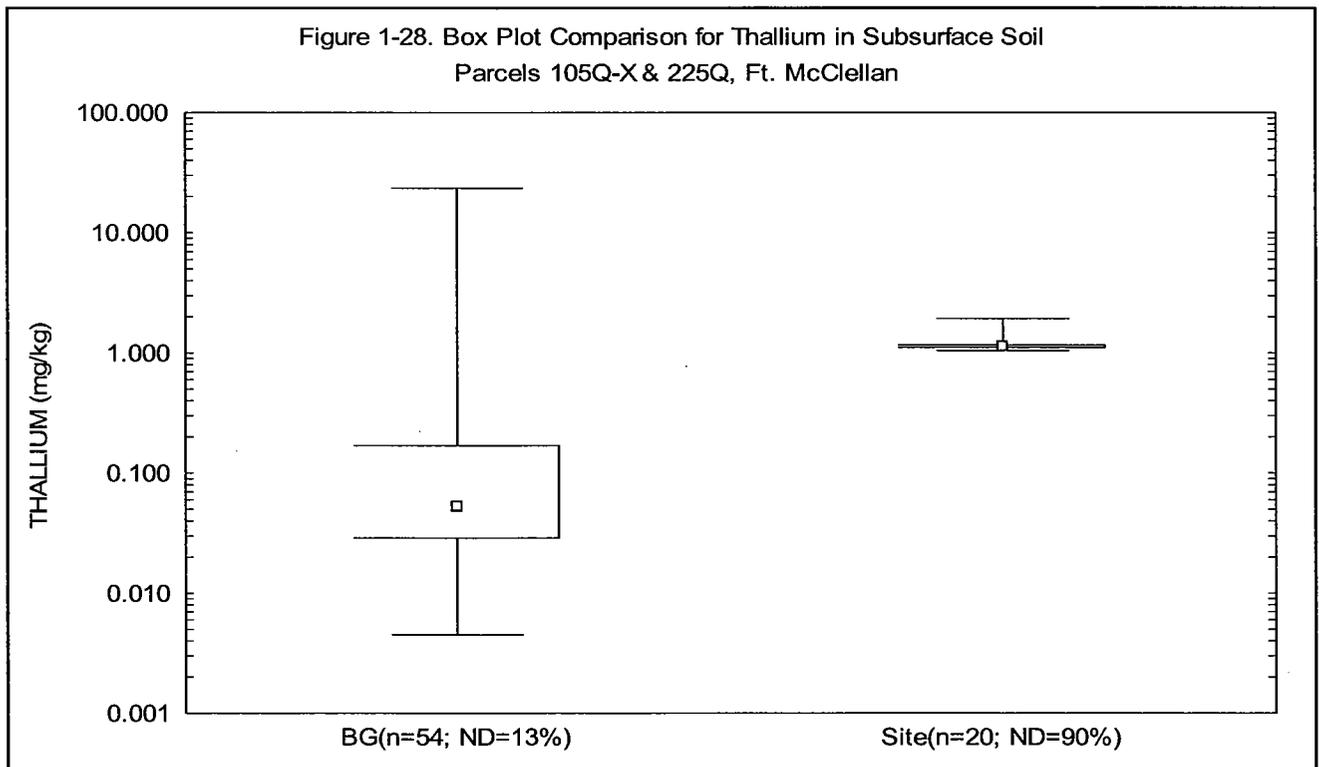
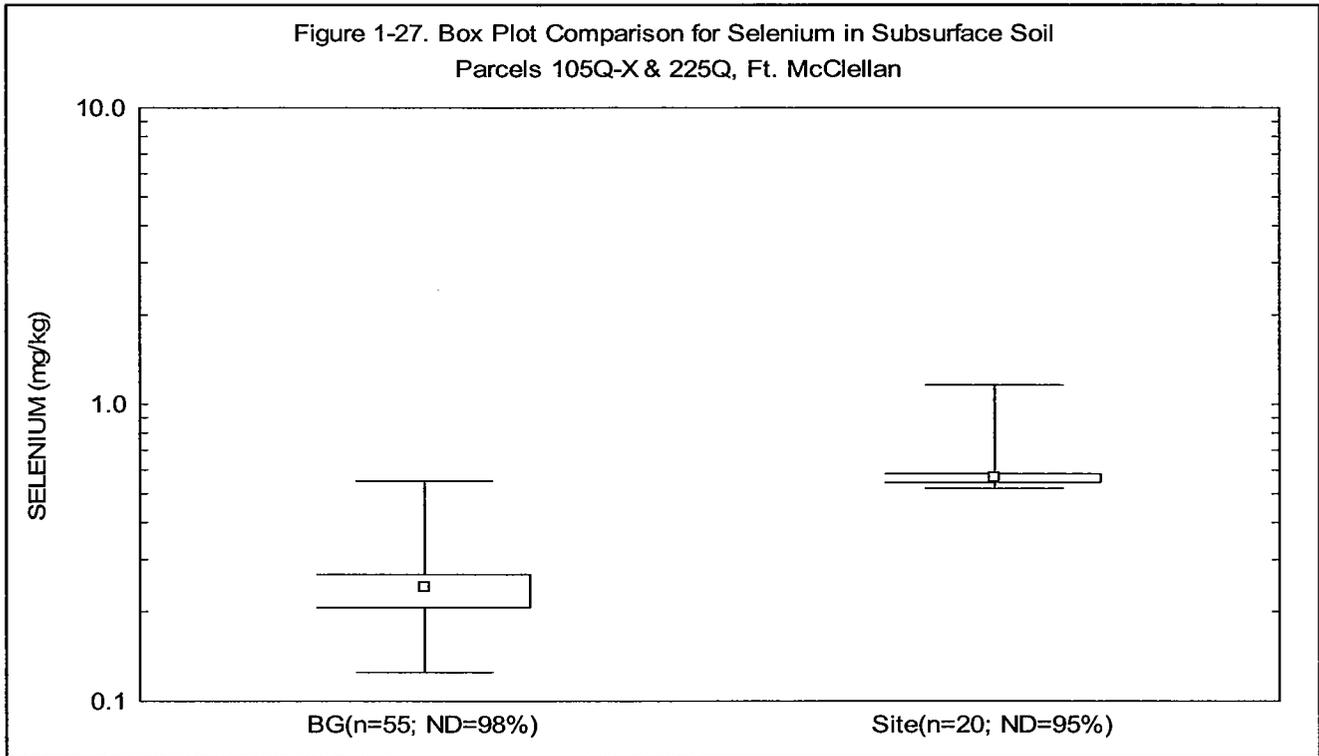


Figure 1-26. Box Plot Comparison for Potassium in Subsurface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.039)



**Box Plots  
Parcels 105Q-X 225Q  
Fort McClellan, Alabama**



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**

Figure 1-29. Box Plot Comparison for Vanadium in Subsurface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.084)

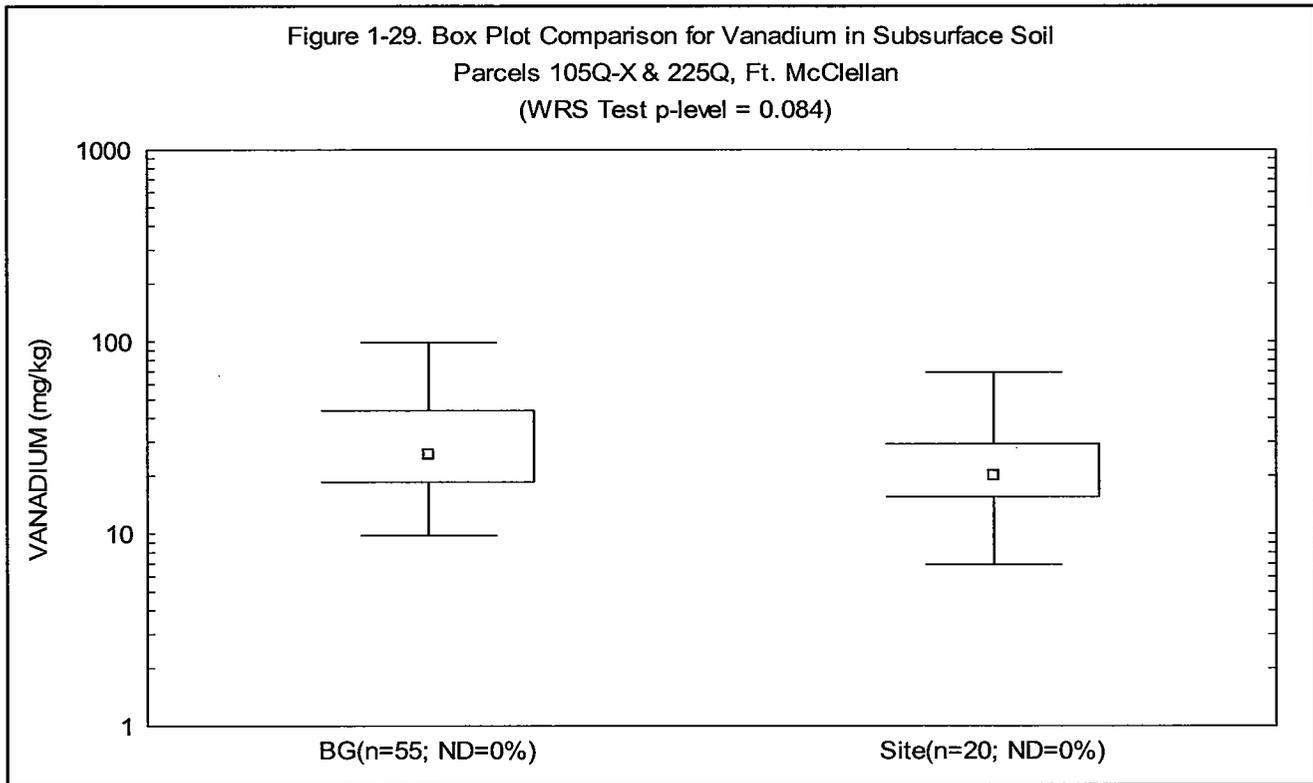
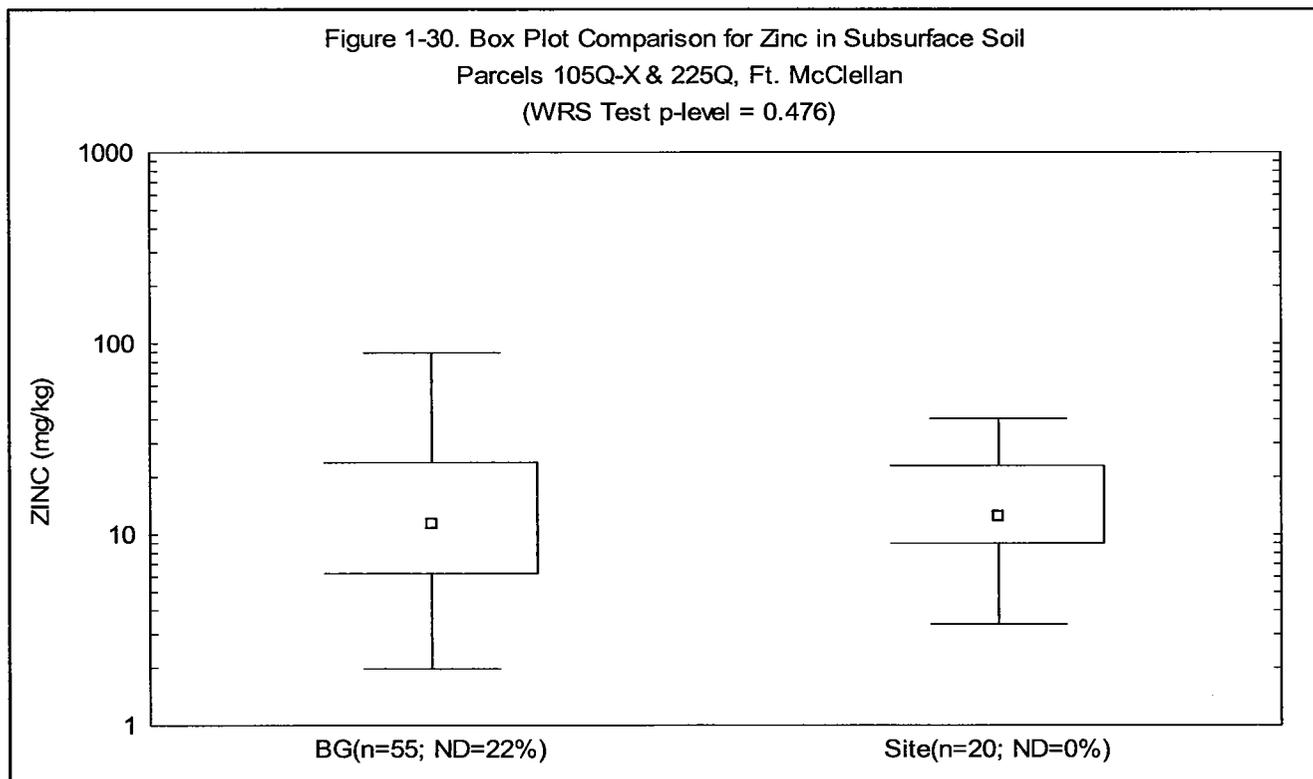
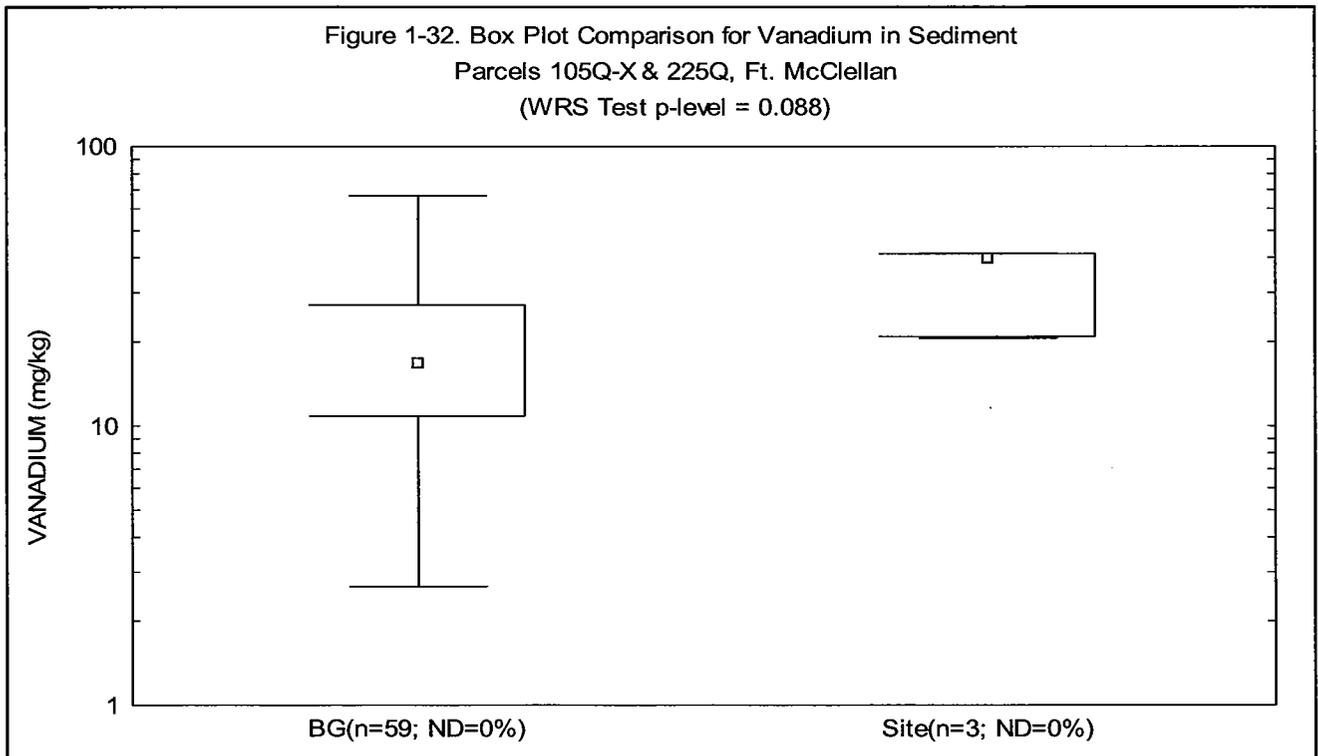
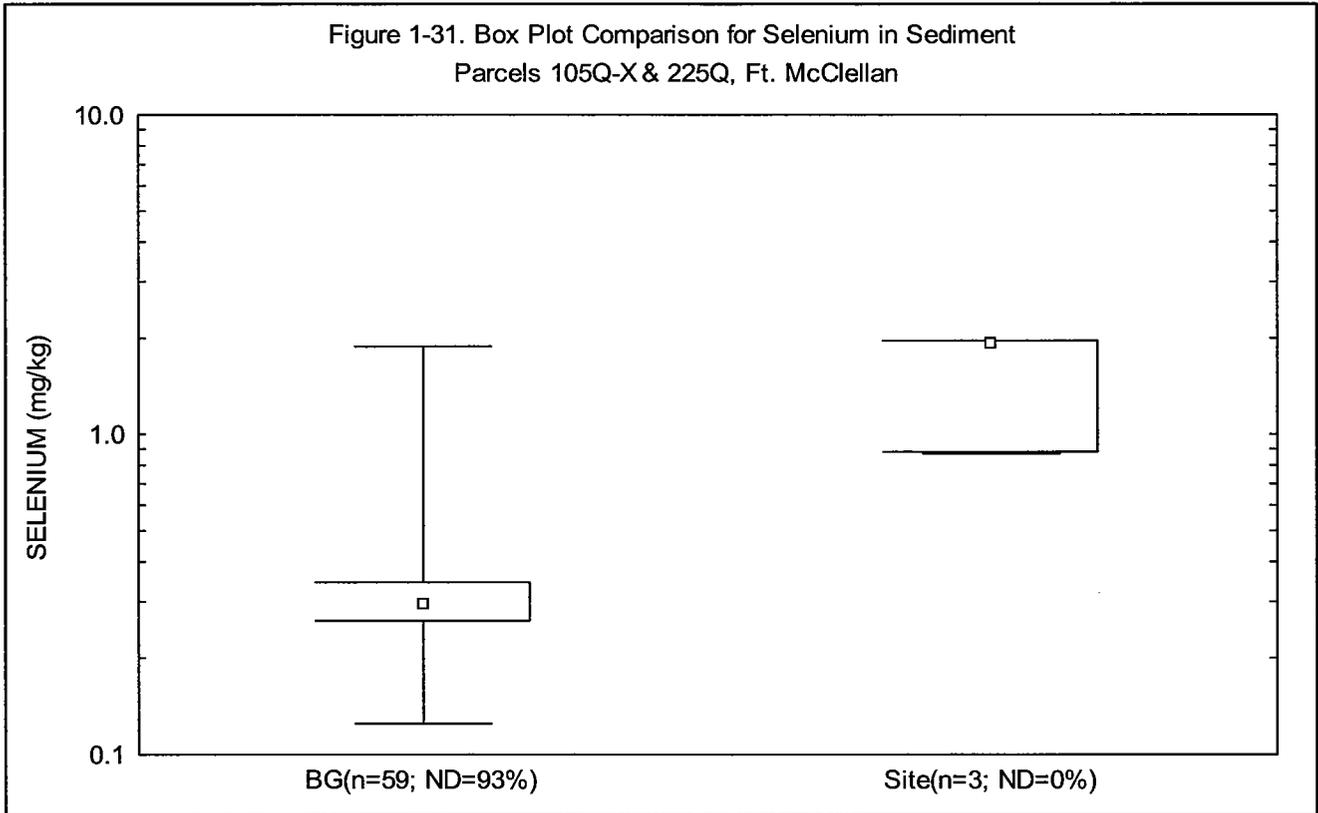


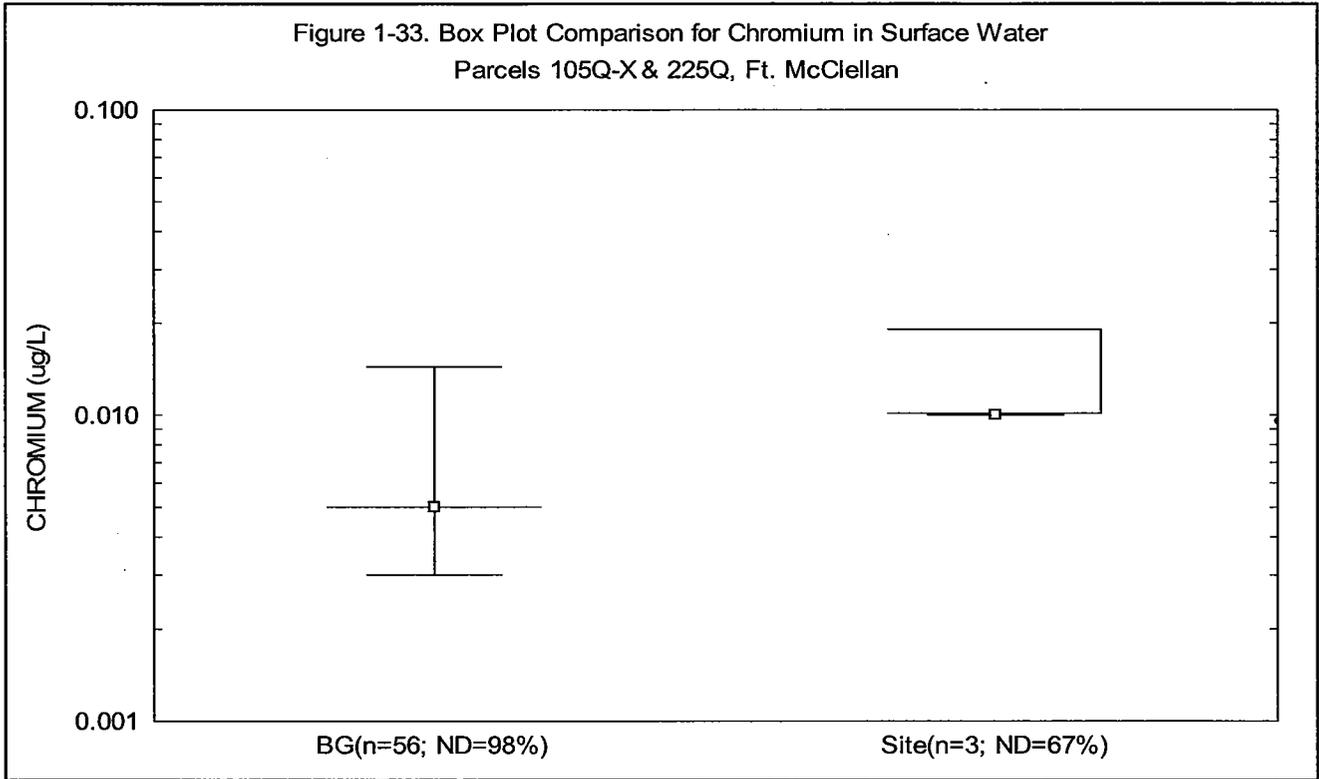
Figure 1-30. Box Plot Comparison for Zinc in Subsurface Soil  
Parcels 105Q-X & 225Q, Ft. McClellan  
(WRS Test p-level = 0.476)



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**



**Box Plots**  
**Parcels 105Q-X 225Q**  
**Fort McClellan, Alabama**



## **GEOCHEMICAL (TIER 3)**

# **Geochemical Evaluation of Metals in Site Media Former Mortar Firing Point, Parcel 105Q-X, and Former Defendam Range (Eastern), Parcel 225Q Fort McClellan, Alabama**

## ***1.0 Introduction***

This report provides the results of a geochemical evaluation of inorganic constituents in soil, sediment, and surface water samples from the Former Mortar Firing Point, Parcel 105Q-X, and Former Defendam Range (Eastern), Parcel 225Q, located at Fort McClellan in Calhoun County, Alabama. Ten elements in soil, two elements in sediment, 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 evaluation consist of 23 surface and depositional soil samples (obtained from depths of 0 to 0.5 or 0 to 1 foot below ground surface [bgs]) and 20 subsurface soil samples (obtained from various depths ranging from 1 to 4 feet bgs) collected in July and September 2002. In addition, three sediment samples and three surface water samples were collected in July 2002. All of the site samples were analyzed for the full suite of 23 target analyte list (TAL) metals. Installation-wide background data for TAL metals in soil, sediment, and surface water are provided in the background study report (Science Applications International Corporation, 1998) and are used in the following evaluation.

## ***2.0 Geochemical Evaluation Methodology***

Statistical site-to-background comparisons for trace elements in soil commonly have high false-positive error rates. A large number of background samples is required to adequately characterize the upper tails of most trace element distributions, which are typically right-skewed and span a wide range of concentrations, but such a large background data set is not always feasible. There are also concerns regarding the statistical validity of comparing site data from a small parcel with facility-wide background data that typically display higher variance than the site data. Higher false-positive error rates are expected if the site sample size is greater than the background sample size. The presence of estimated concentrations and nondetects with differing reporting limits can also cause statistical comparison tests to fail.

Statistical tests consider only the absolute concentrations of individual elements, and they disregard the interdependence of element concentrations and the geochemical mechanisms controlling element behavior. However, it is well established that trace elements are naturally associated with specific soil-forming minerals, and the preferential enrichment of a sample with these minerals will result in elevated trace element concentrations. It is thus important to be able to identify these naturally high concentrations and distinguish them from potential contamination.

If an analyte fails statistical comparison to background as described in the “Statistical Comparison of Site and Background Data for the Former Mortar Firing Point, Parcel 105Q-X, and Former Defendamm Range, Parcel 225Q,” then a geochemical evaluation is performed to determine if the elevated concentrations are caused by natural processes. Recent publications indicate that geochemical evaluations are assuming a larger role in environmental investigations (e.g., U.S. Environmental Protection Agency, 1995; Barclift, *et al.*, 2000; U.S. Navy, 2002 and 2003; Myers and Thorbjornsen, 2004). A properly executed geochemical evaluation can distinguish between naturally high element concentrations versus contamination, and it can identify the specific samples that may contain some component of site-related contamination. This section describes the geochemical evaluation techniques that were employed in the site-to-background comparison for Parcels 105Q-X and 225Q. Additional supporting information on these techniques is provided in the installation-wide work plan (IT Corporation, 2002) and the technical memorandum dated March 14, 2005 (Shaw Environmental, Inc., 2005).

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

Geochemical evaluation of inorganic data is not a new concept, and it is based in part on the well-established principles of trace element adsorption that are described in the literature (e.g., Gullledge and O'Connor, 1973; McKenzie, 1980; Electric Power Research Institute [EPRI], 1984; Hem, 1985; EPRI, 1986; Belzile and Tessier, 1990; Bowell, 1994; Manceau, 1995; Stumm

and Morgan, 1996; Sullivan and Aller, 1996; Drever, 1997; Belzile *et al.*, 2000; Nickson *et al.*, 2000; Kabata-Pendias, 2001; Lai and Chen, 2001; Emmanuel and Erel, 2002; Munk *et al.*, 2002; Roddick-Lanzilotta *et al.*, 2002; Smedley and Kinniburgh, 2002; Cornell and Schwertmann, 2003; Welch and Stollenwerk, 2003). These papers and monographs provide the technical basis for the geochemical evaluations performed for the Fort McClellan project. This fundamental research has been applied in numerous peer-reviewed papers that employ correlation plots of trace elements versus specific major elements. The aims of these applied-science papers are to determine the likely mechanisms controlling element concentrations and identify potentially contaminated samples (e.g., Windom *et al.*, 1989; Hanson *et al.*, 1993; Daskalakis and O'Connor, 1995; Schiff and Weisberg, 1997; Barclift *et al.*, 2000; Kuss *et al.*, 2001; Chen *et al.*, 2002; El Bilali *et al.*, 2002; Mostafa *et al.*, 2004). In most cases, these papers use the same types of analytical data that are obtained during the Fort McClellan investigations and typical CERCLA investigations at other sites.

## **2.1 Soil and Sediment**

Trace elements naturally associate with specific soil-forming minerals, and geochemical evaluations are predicated on these known associations. For example, in most uncontaminated oxic soils, arsenic exhibits an almost exclusive association with iron oxide minerals (Bowell, 1994; Schiff and Weisberg, 1997). Arsenic exists in oxic soil pore fluid as oxyanions such as  $\text{HAsO}_4^{-2}$  and  $\text{H}_2\text{AsO}_4^-$  (Brookins, 1988), and these negatively charged species have a strong affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge (EPRI, 1986). (In this report, the term "iron oxide" encompasses oxides, hydroxides, oxyhydroxides, and hydrous oxides of iron.) This association is expressed as a positive correlation between arsenic concentrations and iron concentrations for uncontaminated samples: soil samples with a low percentage of iron oxides will contain proportionally lower arsenic concentrations, and soil samples that are enriched in iron oxides will contain proportionally higher arsenic concentrations. Although there is variability in the absolute concentrations of arsenic and iron in soil at a site, the As/Fe ratios of the samples will be relatively constant if no contamination is present (Daskalakis and O'Connor, 1995). Samples that contain excess arsenic from a contaminant source (e.g., arsenic-bearing compounds such as the chemical warfare agent lewisite or certain herbicides) will exhibit anomalously high As/Fe ratios compared to the uncontaminated samples.

To perform the geochemical evaluation, correlation plots are constructed to explore the elemental associations and identify potentially contaminated samples. The detected concentrations of the trace element of interest (dependent variable) are plotted against the

detected concentrations of the reference element (independent variable), which represents the mineral to which the trace element may be adsorbed. In the case of arsenic, the arsenic concentrations for a given set of samples would be plotted on the y-axis, and the corresponding iron concentrations would be plotted on the x-axis. If no contamination is present, then the samples will exhibit a generally linear trend, and the samples with the highest arsenic concentrations will lie on this trend. This indicates that the elevated arsenic is due to the preferential enrichment of iron oxides in those samples, and that the arsenic has a natural source. If, however, the samples with high arsenic concentrations have low or moderate iron concentrations (anomalously high As/Fe ratios), then they will lie above the linear trend established by the other samples. This would indicate that the anomalous samples contain excess arsenic beyond that which can be explained by the natural iron oxide content, and such samples may contain a component of contamination.

The reference elements against which trace elements are evaluated reflect the affinity that the trace elements have for specific minerals. The concentrations of iron, aluminum, and manganese serve as qualitative indicators of the amounts of iron oxide, clay, and manganese oxide minerals in the soil samples. Along with arsenic, selenium and vanadium are present in oxic soil pore fluid as anions and have an affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge. Concentrations of arsenic, selenium, or vanadium in a set of samples can be evaluated through comparison to the corresponding iron concentrations. Barium, cadmium, lead, and zinc are typically present in soil as divalent cations and have an affinity to adsorb on clay minerals, which tend to maintain a net negative surface charge. Concentrations of barium, cadmium, lead, or zinc can be evaluated through comparison to the corresponding aluminum concentrations. Manganese oxides have a strong affinity to adsorb barium, cobalt, and lead (Kabata-Pendias, 2001), so concentrations of these elements can be compared to the corresponding manganese concentrations, as long as there is enough manganese present in the soil to form discrete manganese oxides.

Over a limited range of concentrations, the adsorption of a trace element on a mineral surface can usually be described by a linear isotherm. Over a wider range of concentrations, a two-parameter curved fit (such as a Freundlich or Langmuir isotherm) may be more appropriate for some trace elements. In this report, the elemental correlations are referred to as “linear trends,” although though there may be some degree of curvature to the natural relationship.

It is important to note that some trace elements have very strong affinities for a particular type of mineral, whereas other elements will partition themselves between several minerals. For

instance, vanadium has a particularly strong affinity for iron oxides, so correlation coefficients for vanadium versus iron in uncontaminated samples are usually very high, and this is expressed on a correlation plot as a highly linear trend. In contrast, chromium forms several coexisting aqueous species with different charges [ $\text{Cr}(\text{OH})_2^+$ ,  $\text{Cr}(\text{OH})_3^0$ , and  $\text{Cr}(\text{OH})_4^-$ ] that will adsorb on several different types of minerals, including clays and iron oxides. This behavior will yield lower correlation coefficients for chromium versus iron or chromium versus aluminum relative to the coefficients observed for vanadium versus iron, and more scatter may be observed on the correlation plots. Some elements are more selective than others with respect to adsorption on specific mineral surfaces, and this selectivity is dependent on site-specific conditions, including soil pH, redox conditions, and concentrations of competing elements.

**Ratio Plots.** Site samples with a trace element present as a contaminant will exhibit anomalously high trace-versus-major element ratios compared to background trace-versus-major element ratios. These elevated ratios may not always be apparent in log-log correlation plots, especially at the upper range of concentrations. Therefore, ratio plots, which depict trace element concentrations on the y-axis and trace/major element ratios on the x-axis, are employed in conjunction with correlation plots in those cases where it is not immediately apparent which site samples have anomalously high elemental ratios on the correlation plots. The ratio plots permit easy identification of samples with anomalously high elemental ratios relative to background, and they have high resolution over the entire concentration range. The presence of an anomalously high elemental ratio is not definitive proof of site-related contamination; however, such samples are discussed in the text and, unless otherwise noted, are flagged as representing potential site-related contamination. This is a conservative approach.

It is also important to note that there is natural variability, as well as analytical uncertainty, in the elemental ratios of uncontaminated soil and sediment samples. Trace/major element ratios are calculated from two uncertain analytical results, so the resulting uncertainties in the ratios can produce some scatter in the points on a ratio plot. This is especially true when estimated (“J”-qualified) analytical results are used. This can be seen on many of the plots that show more scatter of the points at the lower concentration range, where analytical uncertainties are higher and analytical results are reported with fewer significant figures.

On ratio plots, vertical trends should be expected only in those cases where the trace element adsorption is a linear process and where the trace element concentrations are controlled exclusively by adsorption on a given mineral type. Nonvertical trends are much more common in ratio plots, however, because adsorption processes often are not linear and because trace

elements often have affinities for more than one type of sorptive surface. Nonlinear adsorption of a trace element on mineral surfaces will manifest itself as a curve rather than a straight line on a correlation plot and as a nonvertical trend on a ratio plot. In addition, the presence of competing ions in soil or sediment and differences in pH and redox conditions among the sample locations can add to the natural variability of elemental ratios.

Ratio plots may also be prepared for the major elements (e.g., aluminum versus Al/Fe ratios). However, adsorption is not the dominant process controlling major element concentrations. For example, aluminum and iron concentrations covary largely because they are controlled by the abundance of fine-grained minerals in the samples. The plots thus reflect physical effects rather than chemical effects such as adsorption. Linearity is often not observed in major-versus-major element correlation plots and associated ratio plots.

## **2.2 Groundwater and Surface Water**

Trace element behavior in groundwater is more complex than in soil and sediment because it is subject to a wider range of pH and redox conditions, and trace elements are more sensitive to the presence of natural complexing ligands (chloride, hydroxyl, sulfate, phosphate, etc.) and organic contaminants in aqueous systems. Although there are more dimensions to interpretation of the data, more parameters are available to aid in the interpretation. These additional parameters include pH, dissolved oxygen (DO), oxidation-reduction potential (ORP), filtered/unfiltered ratios, turbidity, total dissolved solids, total suspended solids (TSS), specific conductivity, anion concentrations, volatile organic compound and semivolatile organic compound concentrations, etc.

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. The effects of suspended particulates and reductive dissolution are discussed below.

**Effects of Suspended Particulates.** Under natural conditions, metals concentrations are commonly controlled through adsorption on suspended particulates. The most common suspended particulates in groundwater samples are clay minerals, hydrous aluminum oxides ( $\text{Al}_2\text{O}_3 \cdot n\text{H}_2\text{O}$ ), and aluminum hydroxides [ $\text{Al}(\text{OH})_3$ ], hereafter referred to as “clays”; and iron oxide ( $\text{Fe}_2\text{O}_3$ ), hydrous iron oxide, iron hydroxide [ $\text{Fe}(\text{OH})_3$ ], and iron oxyhydroxide ( $\text{FeO} \cdot \text{OH}$ ) minerals, hereafter referred to as “iron oxides.” Aluminum is a primary component of all clay minerals, which have low solubilities over the neutral pH range (6 to 8). Measured

concentrations of aluminum greater than approximately 1 milligram per liter (mg/L) indicate the presence of suspended clay minerals (Hem, 1985; Stumm and Morgan, 1996); the higher the aluminum concentration, the greater the mass of suspended clay minerals in the sample. Iron oxides also have very low solubilities under neutral pH conditions, as long as the redox conditions are moderate to oxidizing. Measured iron concentrations above approximately 1 mg/L under neutral-pH, moderate to oxidizing redox conditions, indicate the presence of suspended iron oxides (Hem, 1985).

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). Divalent cations such as barium, lead, and zinc have an affinity to adsorb on clay surfaces, which tend to maintain a net negative charge (EPRI, 1984; Brookins, 1988). Concentrations of barium, lead, or zinc in a set of samples can be evaluated through comparison to the corresponding aluminum concentrations. Under oxidizing conditions, elements such as arsenic, selenium, and vanadium are usually present as oxyanions and have a strong affinity to adsorb on iron oxide surfaces, which tend to maintain a net positive charge (Pourbaix, 1974; Hem, 1985; Brookins, 1988; Bowell, 1994). Concentrations of arsenic, selenium, or vanadium can be evaluated through comparison to the corresponding iron concentrations. Chromium can exist as a mixture of aqueous species with different charges [ $\text{Cr}(\text{OH})_2^+$ ,  $\text{Cr}(\text{OH})_3^0$ , and  $\text{Cr}(\text{OH})_4^-$ ], depending on pH (EPRI, 1984), so it can be distributed on several different types of sorptive surfaces, including clay and iron oxide minerals.

In an example geochemical evaluation for groundwater or surface water, the detected concentrations of zinc are plotted on the y-axis, and the corresponding detected concentrations of aluminum are plotted on the x-axis. A linear trend with a positive slope (positive correlation) indicates that the zinc in those samples is associated with suspended clay minerals at a relatively constant ratio and that the zinc is natural. A sample that plots above the linear trend contains excess zinc beyond that which can be explained by the suspended clay content and may contain a component of contamination. Ratio plots (described in Section 2.1) are also a useful tool for interpreting the relationship between trace and major elements and for identifying anomalous samples that may contain a component of contamination. However, ratio plots must be used with care when depicting aqueous data and should only be used for samples from oxidizing

waters. For samples from low-redox areas, redox-sensitive elements (such as arsenic, iron, and manganese) are expected to display a higher degree of scatter on correlation plots and, hence, a wider range of ratios on ratio plots. Plots of trace element concentrations versus redox indicators such as DO, ORP, ferrous iron, sulfide, Fe/Al ratios, or sums of organic contaminants are also useful to evaluate the effects of local redox conditions on trace elements.

Over a limited range of concentrations, the adsorption of a trace element on a mineral surface can usually be described by a linear isotherm. Over a wider range of concentrations, a two-parameter curved fit (such as a Freundlich or Langmuir isotherm) may be more appropriate for some trace elements. In this report the elemental correlations are referred to as “linear trends,” although there may be some degree of curvature to the natural relationship.

In addition to the evaluation of trace-versus-major element correlations, the effects of suspended particulates can be assessed via the evaluation of element-versus-turbidity correlations, element-versus-TSS correlations, and the comparison of the concentrations of filtered versus unfiltered splits. Evaluations of turbidity and TSS measurements provide additional lines of evidence that support the conclusions drawn from the evaluation of trace-versus-major element correlations. However, turbidity and TSS measurements are qualitative and cannot distinguish between suspended iron oxides, clay minerals, and natural organic material. Consequently, they do not provide the mechanistic information afforded by the correlations of trace elements versus aluminum or trace elements versus iron. Comparisons of filtered versus unfiltered splits of samples are highly informative and independently support the geochemical evaluation by identifying elements that are present as suspended particulates versus those that are present as colloids or are in true solution. However, filtered-versus-unfiltered comparisons cannot be performed for this report because filtered splits were not obtained for the site groundwater and surface water samples.

***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 jet fuel, gasoline, or chlorinated solvents can establish local reducing environments caused by 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 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). It should also be noted that natural reducing conditions can exist in groundwaters and surface waters that are associated with swamp or wetland environments.

Evidence for reductive dissolution includes low Al/Fe ratios and 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 ORP or 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 of Metals in Soil**

Aluminum, barium, cobalt, lead, and selenium in the site surface soil data set failed statistical comparison to background, as did aluminum, barium, copper, iron, lead, magnesium, mercury, potassium, and selenium in the subsurface soil data set. The results of the geochemical evaluation of these ten elements are provided below. Correlation plots are provided in Attachment 1.

#### **Aluminum**

Aluminum is the second most abundant of the 23 elements analyzed in the site soil samples, with a mean concentration of 9,790 mg/kg (approximately 1 weight percent). Aluminum is a primary component of common soil-forming minerals such as clays, feldspars, and micas. Aluminum also substitutes for ferric iron in iron oxide minerals, and it can adsorb on iron oxide surfaces (Cornell and Schwertmann, 2003). The site soil boring logs note that the predominant grain sizes range from clay to medium sand, depending on the sampled interval, and that clay is present as at least a minor component in over half the samples. The soil colors are primarily light brown, medium brown, reddish brown, or yellowish orange. Iron is the most abundant element analyzed in the site soil samples (mean concentration of 14,100 mg/kg, or 1.4 weight percent) and is dominantly present as iron oxides. Iron oxides are common soil-forming minerals, and they occur as discrete mineral grains or as coatings on silicate minerals (Cornell

and Schwertmann, 2003). The red and orange colors of the site soils are imparted by the iron oxides, which are highly pigmented.

Clays and iron oxides tend to exist as very fine particles, so both aluminum and iron are enriched in samples with finer grain sizes. A plot of aluminum versus iron concentrations provides a qualitative indicator of the relative abundance of clay and iron oxide minerals in site soil (Figure 1). Installation-wide background soil samples are represented by circles (BG), site subsurface (deep) soil samples are represented by filled triangles (Site DS), and site surface soil samples are represented by open triangles (Site SS). The site and background samples form a common, generally linear trend with a positive slope in Figure 1. The site samples with the highest aluminum concentrations also contain proportionally higher iron content and lie on the background trend.

The site samples exhibit Al/Fe ratios that are consistent with those of the background samples. This indicates a natural source for the elevated aluminum concentrations in the site samples. It is important to note that clay and iron oxide minerals adsorb specific trace elements (as discussed in Section 2.1), so the samples that plot on the upper end of the trends 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**

Manganese oxides are naturally occurring minerals in soil, and they are present as discrete mineral grains or as coatings on other minerals (Post, 1999). Manganese oxides have a strong affinity to adsorb divalent cations (such as  $Ba^{2+}$ ,  $Co^{2+}$ , and  $Pb^{2+}$ ), due to the large surface area and high negative surface charges of these minerals. If a soil sample contains a high proportion of manganese oxides, then it is expected to contain naturally high concentrations of manganese and associated trace elements such as barium. A plot of barium versus manganese reveals a common, generally linear trend with a positive slope for the background samples and most of the site samples (Figure 2). The site samples with high barium concentrations also contain proportionally higher manganese content, and they lie on the background trend. These site samples exhibit Ba/Mn ratios that are consistent with those of the background samples, indicating a natural source for their barium concentrations.

One surface sample (111 mg/kg Ba) and one subsurface sample (54.9 mg/kg Ba) have slightly elevated Ba/Mn ratios and lie above the background trend in Figure 2. It should be noted that these concentrations are well below their respective background 95<sup>th</sup> upper tolerance limits (193.8 mg/kg and 320 for surface and subsurface soil, respectively). In addition to its affinity to adsorb on manganese oxides, barium ( $Ba^{2+}$ ) is often associated with magnesium ( $Mg^{2+}$ ) in minerals, most likely due to similarities in electronegativity parameters and ionic size (Kabata-Pendias, 2001). A plot of barium versus magnesium is provided in Figure 3. The site samples are positively correlated ( $R^2 = 0.58$  and  $0.55$  for the surface and subsurface intervals), and they all exhibit Ba/Mg ratios that are within the background range. This suggests that the barium detected in the site samples is naturally occurring.

### Conclusion

Barium detected in the site soil samples is naturally occurring.

### **Cobalt**

Manganese oxides are naturally occurring minerals in soil, and they are present as discrete mineral grains or as coatings on other minerals (Post, 1999). Manganese oxides have a strong affinity to adsorb divalent cations (such as  $\text{Ba}^{2+}$ ,  $\text{Co}^{2+}$ , and  $\text{Pb}^{2+}$ ), due to the large surface area and high negative surface charges of these minerals. If a soil sample contains a high proportion of manganese oxides, then it is expected to contain naturally high concentrations of manganese and associated trace elements such as cobalt. A plot of cobalt versus manganese reveals a collinear trend for the site and background samples ( $R^2 = 0.72$  and  $0.92$  for the site surface and subsurface intervals, respectively) (Figure 4). The site samples with the highest cobalt concentrations also contain proportionally higher manganese concentrations, and they lie on the trend established by the other samples. These observations suggest that cobalt in the site samples is associated with manganese oxides at ratios consistent with those of the background samples, and it is natural.

### Conclusion

Cobalt detected in the site soil samples is naturally occurring.

### **Copper**

Cations such as copper ( $\text{Cu}^{2+}$ ) and nickel ( $\text{Ni}^{2+}$ ) have an affinity to adsorb on the surfaces of iron oxides under the pH range of typical soils (5 to 8 standard units), with adsorption increasing as pH approaches neutrality (Cornell and Schwertmann, 2003). The cations bind to surface hydroxyl groups ( $\text{OH}^-$ ), giving rise to metal-surface complexes. Because of this affinity for cation adsorption, positive correlations are commonly observed for copper versus iron concentrations in uncontaminated soil samples. Samples that contain a high proportion of iron oxides are therefore expected to contain naturally high concentrations of cations such as copper. Figure 5 provides a plot of copper versus iron for the site and background samples. The background samples form a generally linear trend with a positive slope, and the site samples lie on this trend. This suggests that copper in the site samples is associated with iron oxides at ratios consistent with those of the background samples, and it is natural.

Another perspective on the data sets is provided in Figure 6, which depicts the copper concentrations versus their corresponding Cu/Fe ratios. If a site sample contained excess copper from a contaminant source, it would exhibit an anomalously high Cu/Fe ratio relative to background and would plot to the right of the background samples in Figure 6 [see also the associated ratio-plot discussion in Section 2.1]. However, all of the site samples exhibit Cu/Fe ratios that are within the background range.

### Conclusion

Copper detected in the site soil samples is naturally occurring.

### **Iron**

Iron is the most abundant element analyzed in the site soil samples, with a mean concentration of 14,100 mg/kg (1.4 weight percent). The site soil boring logs note that the predominant grain

sizes range from clay to medium sand, depending on the sampled interval, and that clay is present as at least a minor component in over half the samples. The soil colors are primarily light brown, medium brown, reddish brown, or yellowish orange. The iron in the samples is dominantly present as iron oxides, which are highly pigmented and impart the red color to the site soils. Iron oxides are common soil-forming minerals, and they occur as discrete mineral grains or as coatings on silicate minerals (Cornell and Schwertmann, 2003).

As explained in the aluminum evaluation, a plot of aluminum versus iron can be used to qualitatively assess the relative abundance of clays and iron oxides in site soils (Figure 1). The site and background samples form a common, generally linear trend with a positive slope in Figure 1. The site samples with the highest iron concentrations also contain proportionally higher aluminum content and lie on the background trend.

The site samples exhibit Fe/Al ratios that are consistent with those of the background samples. This indicates a natural source for the elevated iron concentrations in the site samples. Clay and iron oxide minerals adsorb specific trace elements (as discussed in Section 2.1), so the samples that plot on the upper end of the trend in Figure 1 — including many of the site samples — are expected to contain proportionally higher concentrations of trace elements.

#### Conclusion

Iron detected in the site soil samples is naturally occurring.

#### **Lead**

Manganese oxides are naturally occurring minerals in soil, and they are present as discrete mineral grains or as coatings on other minerals (Post, 1999). Manganese oxides have a strong affinity to adsorb divalent cations (such as  $Ba^{2+}$ ,  $Co^{2+}$ , and  $Pb^{2+}$ ), due to the large surface area and high negative surface charges of these minerals. 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 such as lead. A plot of lead versus manganese reveals a linear trend with a positive slope for the background samples and the majority of site samples (Figure 7). All of the site samples exhibit Pb/Mn ratios that are consistent with those of the background samples. This conclusion is supported by a comparison of lead concentrations versus the corresponding Pb/Mn ratios (Figure 8). If a site sample contained excess lead from a contaminant source, it would exhibit an anomalously high Pb/Mn ratio relative to background and would plot to the right of the background samples in Figure 8. However, all of the site samples exhibit Pb/Mn ratios that are within the background range. This suggests a natural source for the lead detected in the site samples.

#### Conclusion

Lead detected in the site soil samples is naturally occurring.

#### **Magnesium**

Magnesium ( $Mg^{2+}$ ) is a common component of soil-forming minerals such as clays, often occurring as part of the mineral structure and as loosely adsorbed cations. Clays are characterized by large surface-area-to-volume ratios and strong negative surface charges. As a result, the major cations, such as magnesium, are attracted to these mineral surfaces and take part

in cation exchange reactions. Positive correlations between magnesium and aluminum concentrations are thus typically observed for uncontaminated soil samples. A plot of magnesium versus aluminum reveals a common trend with a positive slope for the site samples and most of the background samples ( $R^2 = 0.78$  and  $0.50$  for the site surface and subsurface intervals, respectively) (Figure 9). The site samples with elevated magnesium concentrations also have high aluminum concentrations, and they lie on the trend established by the other samples. These observations indicate a natural source for the magnesium in the site samples.

#### Conclusion

Magnesium detected in the site soil samples is naturally occurring.

#### **Mercury**

Mercury in soil can adsorb on the surfaces of iron oxide and clay minerals, but its concentrations are commonly controlled through organic complex formation (Kabata-Pendias, 2001). As a result, weak correlations for mercury versus iron or mercury versus aluminum are often observed, even in uncontaminated soil samples. This is seen for the background samples in a plot of mercury versus aluminum ( $R^2 = 0.34$ ) (Figure 10). However, the site samples form a linear trend with a positive slope and exhibit comparatively strong correlation ( $R^2 = 0.53$  and  $0.77$  for the site surface and subsurface intervals, respectively). This suggests that mercury concentrations in the site samples may be controlled at least in part by adsorption on aluminum-bearing minerals such as clays. Site sample RM0008 contains the highest mercury concentration of the site samples (0.129 mg/kg), but it also has the highest aluminum concentration (30,300 mg/kg) and lies on the linear site trend. The site samples exhibit consistent Hg/Al ratios, and these ratios are within the range of background Hg/Al ratios. All of these observations indicate a natural source for the site mercury detections.

#### Conclusion

Mercury detected in the site soil samples is naturally occurring.

#### **Potassium**

Potassium ( $K^+$ ) and magnesium ( $Mg^{2+}$ ) are common components of soil-forming minerals such as clays, often occurring as part of the mineral structure and as loosely adsorbed cations. Potassium and magnesium concentrations often covary in uncontaminated soil samples. A plot of potassium versus magnesium reveals a common trend for the site samples and most of the background samples (Figure 11). The site samples with the highest potassium concentrations also have proportionally higher magnesium content, and they lie on the trend established by the other samples. This suggests a natural source for the potassium detected in the site samples.

#### Conclusion

Potassium detected in the site soil samples is naturally occurring.

#### **Selenium**

As noted in Section 2.1, selenium is typically present in oxic soil pore fluid as oxyanions ( $HSeO_3^-$ ,  $SeO_3^{2-}$ ) and has an affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge. Positive correlations between selenium and iron concentrations are thus commonly observed for uncontaminated soil samples. A plot of detected selenium versus iron

concentrations is provided in Figure 12. The site samples and one background sample form a common linear trend with a positive slope (i.e., they exhibit similar Se/Fe ratios). Site sample RM0009 has the highest selenium concentration (1.71 mg/kg), but it also has the highest iron concentration of the samples depicted in the plot (26,900 mg/kg). This sample most likely contains a high proportion of iron oxides, and hence it contains naturally high concentrations of associated trace elements such as selenium. All of these observations suggest a natural source for the selenium detected in the site samples.

#### Conclusion

Selenium detected in the site soil samples is naturally occurring.

### **4.0 Results of the Geochemical Evaluation of Selenium and Vanadium in Sediment**

This section presents the results of the geochemical evaluation of selenium and vanadium detected in the three sediment samples from Parcels 105Q-X and 225Q. Correlation plots are provided in Attachment 1.

Iron is the primary reference element used to evaluate selenium and vanadium concentrations in soil and sediment samples. Although iron did not fail statistical comparison to background for the site sediment data set, a geochemical evaluation of iron is provided to establish the absence of iron contamination and support its use as a reference element.

#### **Iron**

Iron is the most abundant element analyzed in the site sediment samples (mean concentration of 24,200 mg/kg, or 2.4 weight percent) and is dominantly present as iron oxides. Iron oxides are common minerals in soil and sediment, and they occur as discrete mineral grains or as coatings on silicate minerals (Cornell and Schwertmann, 2003). Aluminum is the second most abundant of the 23 elements analyzed in the site sediment samples, with a mean concentration of 5,310 mg/kg (0.5 weight percent). Aluminum is a primary component of common minerals such as clays, feldspars, and micas. Aluminum also substitutes for ferric iron in iron oxide minerals, and it can adsorb on iron oxide surfaces (Cornell and Schwertmann, 2003). A plot of iron versus aluminum concentrations provides a qualitative indicator of the relative abundance of these minerals in site sediment (Figure 13). Most of the background samples form a generally linear trend with a positive slope, and the site samples lie on this trend. The site samples exhibit Fe/Al ratios that are consistent with those of the background samples, which suggests that the site samples do not contain excess iron from a contaminant source.

#### Conclusion

Iron detected in the site sediment samples is naturally occurring.

## **Selenium**

As discussed in Section 2.1, selenium in oxic soils is commonly present as oxyanions ( $\text{HSeO}_3^-$ ,  $\text{SeO}_3^{2-}$ ) and has a strong affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge. Positive correlations between selenium and iron are typically observed for uncontaminated samples under those conditions. A plot of selenium versus iron is provided in Figure 14. The two site samples with elevated selenium concentrations also contain high iron, which suggests that these samples are naturally enriched in iron oxides and associated trace elements such as selenium (they also contain higher concentrations of vanadium, as discussed below). It is important to note that two of the three site selenium detections (0.87 J mg/kg in RM1001 and 1.96 J mg/kg in RM1004) are estimated (J-qualified) concentrations. The uncertainty associated with estimated values likely explains why a stronger correlation is not observed for the site samples in Figure 14.

### Conclusion

Selenium detected in the site sediment samples is naturally occurring.

## **Vanadium**

As discussed in Section 2.1, vanadium is present in oxic pore fluid as oxyanions ( $\text{H}_2\text{VO}_4^-$ ,  $\text{HVO}_4^{2-}$ ) and has a strong affinity to adsorb on iron oxides, which tend to maintain a net positive surface charge. Positive correlations between vanadium and iron concentrations are thus expected for uncontaminated samples under those conditions. A plot of vanadium versus iron reveals a common linear trend for the site and background samples (Figure 15). The V/Fe ratios of the site samples are consistent with those of the background samples. The site samples with the highest vanadium concentrations also contain higher iron, and they lie on the background trend. This suggests that these samples are naturally enriched in iron oxides and associated trace elements such as vanadium. These observations indicate a natural source for the vanadium detected in the site samples.

### Conclusion

Vanadium detected in the site sediment samples is naturally occurring.

## **5.0 Results of the Geochemical Evaluation of Chromium in Surface Water**

This section presents the results of the geochemical evaluation of chromium detected in the three unfiltered surface water samples from Parcels 105Q-X and 225Q. Correlation plots are provided in Attachment 1.

**Field Readings.** Field-measured pH readings for samples RM2001 (sample location HR-225Q-SW/SD01), RM2002 (HR-225Q-SW/SD02), and RM2003 (HR-225Q-SW/SD03) are 5.19, 5.79, and 5.60, respectively. These values indicate slightly acidic conditions at the sample locations. Turbidity measurements for the three samples are 5.7 nephelometric turbidity units

(NTU), 5.6 NTU, and 7.3 NTU, respectively. These readings suggest that the samples did not contain a significant mass of suspended particulates.

The DO readings for samples RM2001, RM2002, and RM2003 are 7.87 mg/L, 8.41 mg/L and 7.84 mg/L, respectively; and the ORP readings are +215 millivolts (mV), +190 mV, and +235 mV. These values suggest that redox conditions were moderate to oxidizing at the time of sample collection. Examination of the aluminum and iron concentrations in the site samples permits a qualitative assessment of the redox conditions, and it serves to verify the field redox measurements. It should be noted that field readings are not available for the background groundwater samples.

**Aluminum and Iron.** Aluminum was detected in all three site surface water samples, at concentrations of 0.107 J mg/L (RM2001), 0.274 mg/L (RM2002), and 0.183 J mg/L (RM2003). Detectable aluminum concentrations of approximately 1.0 mg/L or more in neutral-pH groundwater indicate the presence of suspended clays. Some fraction of detected aluminum will be present in solution at pH conditions below about 4 and above 10 (Drever, 1997), but all of the site pH readings are within this range (see the above discussion of field readings). Iron was also detected in all three samples, at concentrations of 0.22 J mg/L (RM2001), 0.575 J mg/L (RM2002), and 0.637 J mg/L (RM2003). Detectable iron concentrations of approximately 1.0 mg/L or higher in neutral-pH, moderate to oxidizing groundwater conditions indicate the presence of suspended iron oxides. Iron, unlike aluminum, is a redox-sensitive element, and its dissolved concentrations will increase under reducing conditions. Reducing conditions can be natural, or they can be induced by the microbial degradation of organic contaminants such as chlorinated solvents and fuels (see Section 2.2). Field readings for the site data set suggest moderate to oxidizing conditions at the sample locations. Iron in the site samples is thus expected to be present primarily in particulate form.

A plot of aluminum versus iron can be used as a qualitative indicator of the amount of suspended particulates in the surface water samples, as well as an indicator of the redox conditions at the sample locations (Figure 16). A linear trend with a positive slope is typically observed when the aluminum and iron concentrations are present in particulate form, and just such a trend is observed in Figure 16 for the site and background samples. The background samples with the highest aluminum concentrations exhibit proportionally higher iron and lie on the linear trend formed by the other samples. This suggests that the aluminum and iron concentrations are due to the presence of suspended particulates (such as clays and iron oxides) and that they have a natural source. All three site samples have lower aluminum and iron concentrations than most of

the background samples, and they lie on the linear particulate trend. Concentrations of these two elements in the site samples most likely reflect the presence of suspended clays and iron oxides. Suspended minerals have an affinity to adsorb trace elements such as chromium, as described in Section 2.2. Under circumneutral pH and moderate to oxidizing redox conditions, samples with detectable aluminum and iron are expected to contain detectable concentrations of associated trace elements.

## **Chromium**

Chromium was detected in only one of the three site surface water samples (RM2002; 0.0191 J mg/L). Chromium can be present in solution as Cr(VI) species under strongly oxidizing conditions or as Cr(III) species under oxidizing to reducing conditions (Brookins, 1988). Naturally occurring Cr(VI) species have been observed, but are not common, so the identification of Cr(VI) is generally considered to be an indicator of contamination. Chromium (VI) species are highly soluble and do not strongly adsorb, so they are not associated with suspended particulates. Chromium (III) species, in contrast, have low solubilities and strongly adsorb, so they usually are associated with suspended particulates. The degree of association with suspended particulates can thus be used to determine if the detected concentrations are natural or have a contaminant source. As noted in Section 2.2, chromium can adsorb on suspended clays or iron oxides, depending on pH. If a sample contains suspended clays or iron oxides, then it is expected to contain detectable concentrations of aluminum or iron and associated trace elements such as chromium.

Comparison to background is hindered by the high percentage of nondetects in the background data set. Site sample RM2002 has a slightly higher chromium concentration than the single background sample with detectable chromium (BG-W25-970717; 0.0144 mg/L). RM2002 has the highest aluminum concentration of the three site samples (0.274 mg/L) and the second highest iron (0.575 J mg/L). It lies on the linear particulate trend formed by the background samples in Figure 16, which suggests that the aluminum and iron in the sample are due to the presence of suspended clays and iron oxides. Given the pH and redox conditions at the time of sample collection, the chromium in sample RM2002 is most likely controlled by adsorption on these mineral surfaces and is most likely natural.

The difference between the site and background reporting limits has particular importance for this evaluation. The chromium reporting limit for the site samples is 0.02 mg/L, whereas the reporting limit for the background detection is 0.01 mg/L. The background detection is an unestimated value above its reporting limit, but the site detection is an estimated (J-qualified) concentration below its reporting limit. Such estimated values are highly uncertain. This uncertainty may explain why site sample RM2002 appears to have a higher chromium concentration relative to background sample BG-W25-970717.

## Conclusion

Chromium detected in site surface water sample RM2002 is most likely natural.

## 6.0 Summary

This section summarizes the results of the geochemical evaluation of selected metals in soil, sediment, and surface water samples from Parcels 105Q-X and 225Q.

**Surface Soil.** Aluminum, barium, cobalt, lead, and selenium in the site surface soil data set failed statistical comparison to background. Geochemical evaluation indicates that all detected concentrations of aluminum, barium, cobalt, lead, and selenium are naturally occurring.

**Subsurface Soil.** Aluminum, barium, copper, iron, lead, magnesium, mercury, potassium, and selenium in the site subsurface soil data set failed statistical comparison to background. Geochemical evaluation indicates that all detected concentrations of aluminum, barium, copper, iron, lead, magnesium, mercury, potassium, and selenium are naturally occurring.

**Sediment.** Selenium and vanadium were the only two elements in the site sediment data set that failed statistical comparison to background. Geochemical evaluation indicates that all detected concentrations of selenium and vanadium in the sediment samples are naturally occurring.

**Surface Water.** Chromium was the only element in the site surface water data set that failed statistical comparison to background. Geochemical evaluation indicates that the single detected concentration of this element in the site samples is most likely natural.

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**ATTACHMENT 1**

