# 4. CONTAMINANT DISTRIBUTION

This chapter presents the significant findings in the contaminant analyses on surface water, sediment, surface soils, subsurface soils, groundwater, and off-Site soil samples collected as part of the RI. A summary of analytical results is provided in Appendix H (in tabular format), along with the Data Validation Report. The complete set of analytical results is provided in Appendix I (as spreadsheet files on a compact disc).

This chapter is organized as follows:

- Water quality parameters in groundwater (Sect. 4.1);
- Non-radioactive inorganics, including metals, fluoride, cyanide, nitrate, chloride, and sulfate (Sect. 4.2);
- Radionuclides, including uranium, technetium-99 thorium, radium, neptunium, and plutonium (Sect. 4.3); and
- Organics, including VOCs, SVOCs, petroleum, pesticides, PCBs, and dioxins. (Sect. 4.4).

Each section is further subdivided into discussions regarding the contaminant analysis results in each type of environmental media sampled (i.e., surface water, sediment, etc.). Section 4.5 contains discussion of analytical findings with respect to each of the AOCs (listed in Sect. 1.6). It shoud be noted that samples of the waste material in the burial pits were not collected as part of this investigation due to various administrative and technical issues, therefore the description of pit contents presented in this Report is based on available contemporaneous information (i.e. the burial pit log books) and inferred from other information including data obtained from analysis of soil and overburden groundwater samples in the vicinity of the pits. This data is sufficient to define the nature and extent of contamination from this identified source area as presented in this RI Report.

The rationale behind the selection of target RCOPCs and CCOPCs for each environmental medium can be found in the RI/FS WP (Section 4 of LBG 2003), TSWP (SAIC 2004 (a through g) methods, and in Chapter 1 of this report. Details regarding sample collection and analysis methods were presented in Chapter 2. This section focuses on contaminant distributions based on the sample analytical results, while the integration of these contaminant distributions with the Site physical characteristics (presented in Chapter 3) to arrive at past and future mechanisms for transport are presented in Chapter 5. VOC contaminant distribution in subsurface soils and groundwater is presented and discussed in Chapter 5, because the distribution of VOCs was crucial in developing a conceptual model for contaminant transport at the Hematite Site.

The following should be noted regarding the use of minimum detection limits (MDL) and reporting limits in the analytical data reported by the laboratory that conducted all the laboratory analyses for this RI:

- The method detection limit (MDL) is defined as the minimum concentration of a substance that can be measured with 99% confidence that the analyte concentration is greater than zero (40 Code of Federal Regulations, Part 136, Appendix B). The laboratory followed prescribed procedures for establishing MDLs.
- The reporting limit (RL) is the lowest concentration that can be reliably quantified under routine laboratory operating conditions. The laboratory determines this using the lowest calibration standard that can be used such that the RL is higher than the MDL.

- In the data package, the laboratory provided MDLs for the radionuclides, and RLs for the rest of the analytes as part of the data package.

- For the organic and inorganic analytes, results that fall below the RL are flagged as "U" unless the analyte can be "J" qualified (i.e., the analyte level is above the MDL).

- For radionuclides, results that fall below the MDL are flagged as "U."

The laboratory also provided measurement errors associated with each radionuclide measurement. Uncertainties need to be evaluated when using the analytical results for quantitative calculations (e.g., baseline risk assessment). On the other hand, the qualitative assessment provided in this RI Report is not expected to be sensitive to these measurement errors; samples with "elevated activities" usually have activities that are sufficiently high such that the measurement error is only a small fraction of the measurement result.

## 4.1 WATER QUALITY PARAMETERS IN GROUNDWATER

Field parameters were measured in groundwater samples from wells in the overburden, Jefferson City, and Roubidoux Formations during the December 2004 round of sampling (Appendix H.1). Parameters included in this data set are:

- turbidity,
- specific conductance,
- pH,
- temperature,
- dissolved oxygen (DO),
- ORP,
- iron,
- sulfide, and
- alkalinity.

The following subsections describe the ranges of results for field parameters obtained from groundwater samples from overburden and bedrock. The discussions below categorize the analytical results in bedrock groundwater according to geologic formation (i.e., Jefferson City-Cotter and Roubidoux) rather than the HSUs presented in Sect. 3.3.3 (i.e., Jefferson City-Cotter, Jefferson City-Cotter/Roubidoux Contact Zone, Roubidoux). Most of the field parameters are not likely to be sensitive to a specific HSU but are more likely to be a function of the chemical characteristics of a geologic formation (e.g., pH and alkalinity).

### 4.1.1 Turbidity

Turbidity results for groundwater from the overburden and bedrock units at the Hematite Site are shown in the histogram on Fig. 4.1. Although most groundwater samples have a turbidity of less than 100 NTU, samples from overburden exhibit a much wider range of values. Overburden lithologies range from coarse to fine-grained and the presence of clay-size particulates entrained in groundwater is a reasonable expectation in this environment. The presence of clay particulates in the groundwater is also indicated by higher aluminum analysis results in unfiltered samples when compared to co-located filtered samples (Sect. 4.2.2.2). Turbidity also can be caused by oxidation and precipitation of some metals (e.g., iron and manganese) if samples are exposed to atmospheric oxygen either in the aquifer or prior to

stabilization during sample collection. Groundwater from bedrock typically is expected to have lower turbidity because the presence of unattached clay-size material in fractures is less likely and particulates gradually are filtered out with increasing flow distance through bedrock.

In Sect. 4.2.2.2, the impact of suspended solids is evaluated through a comparison of metals analysis results in filtered and unfiltered samples.

### 4.1.2 Specific Conductance

As for many chemical parameters at the Hematite Site, specific conductance values for groundwater from the bedrock units lie within a very restricted range when compared to specific conductance in the overburden wells (Fig. 4.2). Specific conductance is a measure of the quantity of dissolved ionic species in water, with higher values corresponding to a greater concentration of ions. Because the dolomite in bedrock exerts such a strong chemical buffering on groundwater, a relatively narrow range of specific conductance values is expected. In contrast, the overburden is subject to much less buffering and is more likely to reflect the impact of the addition of contaminants from the Hematite Facility, many of which will contribute ions in solution (e.g., strong acids, KOH, etc.) or will produce ions from biodegradation (e.g., chloride released from the breakdown of PCE and TCE). The contribution of chloride ions from the breakdown of chlorinated solvents can be significant where very high levels of dissolved chlorinated organics are associated with the presence of non-aqueous phase liquids.

### 4.1.3 pH

Measurement of pH values accompanied all field sampling activities for groundwater obtained in the vicinity of the Hematite Site. The principal objective of these measurements was to ensure that well purging had been adequate to allow the collection of representative groundwater samples, as evidenced by stable pH values. Two different approaches were used depending on the preference of the field team involved. One team used a pH meter that was calibrated to a single buffer solution (one point calibration). This procedure is effective for evaluating the stability of pH in purge water, but the measured values are accurate only if they are close to that of the buffer. This approach was used during this investigation for sampling all newly constructed wells.

Field measurements of pH in existing, older monitoring wells was done by a field team using a pH meter that had been calibrated against three buffer solutions (three point calibration), bracketing the anticipated range of pHs likely to be encountered in groundwater samples (pH =4, 7, and 10). This approach ensures accurate pH readings across this wide range of values and permits assessment of what factor(s) might account for the observed values of groundwater pH and how they might be impacted by activities associated with the Facility and its disposal sites. Fig. 4.3 shows a histogram of groundwater pH values in samples obtained from the three geologic units at the Hematite Site by this second approach.

Nearly all of the overburden wells represented in Fig. 4.3 are geographically proximal to the Facility and are located in association with various sites on the southern (Former Leach Field, Evaporation Ponds, Limestone Storage Area) and eastern (Burial Pits) sides of the Facility. Therefore, the pH in shallow groundwater in these wells may be affected by several factors. For example, shallow groundwater typically originates from recently recharged precipitation that has absorbed atmospheric $CO_2$. This process can depress pH values significantly below 7.0, although chemical interaction between newly recharged groundwater and soil will tend to change pH values in the opposite direction. In addition, the impact on pH (and water chemistry) of infiltrating precipitation migrating through the sites that involved surface and subsurface waste disposal might be significant.

In Fig. 4.3 it is possible to distinguish among groundwater from different geologic units based on their pH values. For example, over 80% of the groundwater samples from overburden have pH values less than 7.0 and nearly 30% have pH's below 6.0. It is assumed that the factors mentioned above probably are responsible for the low pH values. In contrast, although the Jefferson City-Cotter groundwater samples in Fig. 4.3 also typically come from the same geographic area as the overburden wells, all but one sample has pHs between 6.8 and 7.5. The outlying sample has an unusually high pH (9.3) with no definitive reason for its occurrence. However, this well is shallow and located close to the Burial Pits that is known to be significantly contaminated with chlorinated VOCs based on previous field investigations and data from the current RI (Sect. 4.4.5.6). The Roubidoux groundwaters illustrated in the histogram are more widely distributed geographically, but the pH range is very narrow (7.1 – 7.31). It is likely that the common, narrow range of pH values for most of the groundwater samples from the Jefferson City-Cotter and Roubidoux formations probably reflects: (1) a greater residence time in bedrock so that chemical reactions are more likely to reach equilibrium (i.e., a greater distance from the surface and sources of contamination to the screened intervals in the wells), and (2) strong chemical buffering of pH due to the interaction with the host carbonate bedrock.

### 4.1.4 Temperature

All groundwater temperatures measured in the overburden and bedrock wells at the Hematite Site are less than 20°C. These measurements were made in December 2004, with a few measurements associated with field sampling activities in August 2004 and January 2005. With rare exception, groundwater from the Jefferson City and Roubidoux wells exhibited a temperature range from 10 to 14$^{o}$C. For groundwater from overburden the temperature range was considerably wider (approximately 3 to 19ºC). Temperature measurements are made while groundwater purging is done prior to sample collection. Low flow purging methods are used and generally only a relatively small volume of water passes through the sampling tubing and measurement cell. Therefore, measured temperatures typically are not representative of thermal conditions prevailing in the aquifer. Temperatures associated with that of ambient groundwater, the initial conditions of the sample tubing and measurement cell, and ambient air all are factors that can affect measured temperatures during purging. The cumulative impact of the extraneous thermal factors tends to be more pronounced in shallow wells which probably accounts for the much wider range of temperatures encountered with overburden wells.

### 4.1.5 Oxidation Reduction Potential and Dissolved Oxygen

The oxidation-reduction (redox) state of aquifer systems is an important property that can help in gaining an understanding of the F&T of chemical species capable of being oxidized or reduced. Many inorganic and biochemical reactions (e.g., precipitation and/or sorption of radionuclide and metals; anaerobic degradation of many organic contaminants) can be affected by these conditions. For example, both uranium and technetium are much less soluble under reducing conditions. Reductive dechlorination of PCE and TCE also requires reducing conditions. In principle, the oxidation-reduction potential of water samples can be measured in the field with a platinum electrode in combination with a standard reference electrode. The measured potential (in millivolts) usually is referred to as the ORP and is meant to assess the state of equilibrium between oxidized and reduced species coexisting in solution. In practice, however, many uncertainties are associated with ORP measurements. For example:

- The solution contains a complex mixture of oxidants and reductants that are not all equally well sensed by the platinum electrode; in general, it is not known to what species the electrode is responding

- Not all redox couples [e.g., Tc(VII)-Tc(IV)] will be in equilibrium

- Some species in groundwater (e.g., $S^{2-}$) can coat the platinum electrode and interfere with measurements

An alternative (or complementary) approach to determining the redox state of groundwater is to measure directly various couples or indicators of redox conditions (e.g., $Fe^{2+}$ - $Fe^{3+}$, $S^{2-}$ - $SO_4^{2-}$, dissolved oxygen). The following sections (Sects. 4.1.6, 4.1.7, and 4.1.8) provide some information for the Hematite Site related to this approach.

Regardless of the limitations of field measurement of ORP, it is common practice to obtain this information and, in combination with other results, use it to provide insight into the redox state of the water.

Figure 4.4 presents results for ORP measurements obtained from groundwater samples from the three major geologic units at the Hematite Site. The ORP values were obtained using an Ag-AgCl reference electrode. The ORP measurements range from a low of -200 to +250mV, with only a few samples showing higher values. The range of values is somewhat wider for groundwater from overburden than from bedrock. If these measurements represent equilibrium values, then from an assessment of the appropriate Eh-pH diagrams for these elements one would expect $Fe^{2+}$ to predominate over $Fe^{3+}$, and $SO_4^{2-}$ to exceed $S^{2-}$ in solution (e.g., Stumm and Morgan 1981). A similar evaluation could be performed for other redox couples and would show that the predominant species present (oxidized or reduced) is couple-dependant. That is, a positive value of ORP does not necessarily mean that conditions are oxidizing for all redox couples.

Figure 4.5 presents the DO measurements for groundwater samples obtained from the Hematite Site. DO is one of the redox-sensitive species in Hematite Site groundwater. The other redox-sensitive species include iron (Sect. 4.1.6), and sulfide (Sect. 4.1.7). The DO values in the Jefferson City and Roubidoux tend to cluster within a rather narrow range from 1.5 to 3 mg/L, whereas in the overburden, the trend is toward a much wider range of values varying from 0 to 9.76 mg/L. Air-saturated water will support a DO of about 8 mg/L. It is reasonable that shallow, recently recharged groundwater will have elevated DO values. Consumption of DO with increasing residence time in the subsurface occurs where reducing conditions prevail. However, preventing contamination from atmospheric oxygen during field measurement is very difficult and is usually encountered to some extent in any large field sampling program. It is generally safe to say that any errors in readings provide values that are biased high. Nevertheless, the DO results suggest a reducing environment for most samples from each unit.

### 4.1.6 Iron

A histogram of ferrous ($Fe^{2+}$) iron concentrations measured in the field is shown on Fig. 4.6. There is a wide range of ferrous iron concentrations in the overburden, with ferrous iron concentrations greater than 10 mg/L in nine groundwater samples. The bedrock groundwater exhibited much lower ferrous iron levels, which reflects the predominantly dolomitic nature of the bedrock (Chapter 3). The ferrous iron field measurements are compared to total iron laboratory measurements in Sect. 4.2.2. The latter comparison is useful in assessing the nature of particulates found in the groundwater samples. In general, the conclusion from Fig. 4.6 and the discussion in Sect. 4.2.2.2 is that total iron equals dissolved iron (present as ferrous iron). This supports the inference that at least moderately reducing conditions exist in the groundwater.

### 4.1.7 Sulfide

Only four groundwater samples have a measurable amount of sulfide (BR-03-JC, BR-03-RB, BD-01, and DM-02); all other samples have a reported concentration of “0 ppm” by the field analytical method

used. None of the samples with detectable sulfide had a concentration exceeding 0.5 ppm. Sulfide concentrations similar to those observed in the four samples also support reducing conditions at these locations.

### 4.1.8 Alkalinity

A histogram of the alkalinity values for groundwater from the three geologic units at the Hematite Site is presented on Fig. 4.7. The alkalinity values for groundwater from the overburden range from less than 50 to nearly 300 mg/L.

In contrast, most Jefferson City-Cotter and Roubidoux groundwater samples tend to have higher alkalinity values that primarily are in a narrow range from 150 to 250 mg/L. This latter observation is consistent with the chemical buffering effect of dolomite on the dissolved inorganic carbon species and the narrow range of pHs of the bedrock groundwater illustrated on Fig. 4.3.

## 4.2 NON-RADIOACTIVE INORGANICS

The following subsections present contaminant assessments of inorganics in surface water (Sect. 4.2.1), groundwater (Sect. 4.2.2), sediment (Sect. 4.2.3), surface soils (Sect. 4.2.4), and subsurface soils (Sect. 4.2.5). Where appropriate, comparisons are made with off-Site sample results. Details regarding sample collection and analysis methods were given in Chapter 2, while the complete data set of inorganics can be found in Appendix H.

### 4.2.1 Non-radioactive Inorganics in Surface Water

This section reviews surface water data for the presence and distribution of inorganic species. The complete data set for inorganics in surface water can be found in Appendix H.2. In general, except for common ions such as sodium and potassium, the review process involved an examination of measured concentrations with respect to Site geochemical conditions (presented in Sect. 4.1) and to water quality standards (e.g., drinking water standards) where they exist. Overall, the conclusions of this section are consistent with the previous investigations (summarized in Sect. 1.5), which indicated no significant contamination with non-radioactive inorganics.

Twelve surface water samples were collected at the locations shown on Fig. 2.2. Samples labeled “US” were collected upstream to evaluate background conditions. Background values for the following inorganics in surface water were developed: aluminum (0.98 mg/L), barium (0.14 mg/L), iron (1 mg/L), and manganese (0.38 mg/L). The development of these background values is discussed in Appendix J. Several of the analytes were not detected in any of the samples:

- antimony (all less than the RL of ~0.02 mg/L),
- beryllium (all less than the RL of ~0.0026 mg/L),
- cadmium (all less than the RL of ~0.002 mg/L),
- selenium (all less than the RL of ~0.005 mg/L),
- silver (all less than the RL of ~0.01 mg/L),
- thallium (all less than the RL of ~0.01 mg/L),
- cyanide (all less than the RL of ~0.01 mg/L), and
- mercury (all less than the RL of ~0.0002 mg/L).

Aluminum, barium, calcium, iron, magnesium, manganese, potassium, and sodium were detected in the upstream (“US”) samples. The only Site surface water sample ("SW") suggesting contamination was

SW-01-SW (collected from the Site Pond; refer to Fig. 2.2 for the location), based on metals concentrations that are elevated relative to the other "US" and "SW" surface water samples. For example, vanadium was measured at 0.045 mg/L in SW-01-SW, whereas it was not detected above the RL (~0.01 mg/L) in the other surface water samples. However, even where detected, the measured element concentrations are below drinking water standards.

It is doubtful whether element concentrations in SW-01-SW represent dissolved species based on the elevated concentrations of aluminum (19 mg/L), iron (23 mg/L), and manganese (1.3 mg/L). The latter two elements only dissolve in high concentrations in surface water under acidic conditions such as acid mine drainage, whereas the pH of this sample was near neutral (6.9). Similarly, aluminum is an amphoteric element being soluble at a pH <6 and >8.5, but essentially insoluble in the pH range of 6.5 to 8.5 (Srinivasan et al. 1999). Furthermore, aluminum readily precipitates as $Al(OH)_3$. For this to occur, 0.5 mg/L of alkalinity (expressed as $CaCO_3$) must be consumed for every 1 mg/L of $Al_2(SO_4)$ (Srinivasan et al. 1999). Although not measured on this sample, an alkalinity too low to precipitate aluminum in the local environment would be remarkable.

The elements aluminum, iron, and manganese are particularly susceptible to measurements that are biased high because of the turbidity of a water sample. These elements are abundant in native rocks and soils. Similarly, many elements (e.g., arsenic, uranium, chromium, copper, nickel, etc.) are often reported in conjunction with high concentrations of aluminum, iron, and manganese because the hydrous oxides of the latter elements are highly efficient sorbents for other species.

Fluoride was only detected above the RL (0.5 mg/L) in SW-09-SW, which was collected from the Northeast Site Creek downstream of the Burial Pits (see Fig. 2.2 for location). All other elements in this sample were comparable to the "US" samples.

Measured concentrations in the Site surface water samples can be summarized as follows:

- aluminum, 19 mg/L in SW-01, all other samples 0.98 mg/L (Site background) or less;
- arsenic, 0.011 mg/L in SW-01, all other samples < RL 0.01 mg/L;
- barium, 0.63 mg/L in SW-01, all other samples 0.14 mg/L (Site background) or less;
- chromium, 0.026 mg/L in SW-01, all other samples < RL of 0.004 mg/L;
- fluoride, 0.67 mg/L in SW-09, all other samples <RL of 0. 5 mg/L;
- iron, 23 mg/L in SW-01, all other samples 1 mg/L (Site background) or less;
- lead, 0.068 mg/L in SW-01, all other samples <RL of 0.003 mg/L;
- manganese, 1.3 mg/L in SW-01, 0.38 mg/L (Site background) in US-04, all other samples 0.11 mg/L or less;
- nickel, 0.031 mg/L in SW-01, all other samples < RL of 0.005 mg/L;
- vanadium, 0.045 mg/L in SW-01, all other samples <RL of 0.01 mg/L; and
- zinc, 0.35 mg/L in SW-01, 0.012 mg/L in SW-08, 0.017 mg/L SW-02, all other samples <RL of 0.006 mg/L.

### 4.2.2 Non-radioactive Inorganics in Groundwater

Groundwater samples were collected site-wide during December 2004 (see Sect. 2.6 for a description of sampling and analysis). Groundwater sampling locations are shown on Figs. 2.6a and 2.6b, and the complete data set for this sampling effort is presented in Appendix H.3. Similar to surface water data, the review process for groundwater data involved an examination of measured constituent concentrations except for common ions such as sodium and potassium. Measured concentrations were evaluated with respect to Site geochemical conditions (presented in Sect. 4.1), Site background conditions (presented in Appendix J), and to water quality standards where they exist.

As will be shown in the discussions below, nitrate detections under the Evaporation Ponds and buildings suggest groundwater contamination from Site operations. No other significant contamination from inorganics is indicated.

#### 4.2.2.1 General observations regarding major cations and anions in groundwater

Inorganics in groundwater include constituents that are recognized as being of environmental concern (e.g., arsenic, lead), as well as some that are generally considered to be either non-toxic (e.g., sodium and calcium) or of secondary importance (sulfate and chloride). The more benign constituents comprise the major cations (sodium, potassium, calcium, and magnesium) and anions (chloride, sulfate, and carbonate species) dissolved in groundwater, and are discussed in this subsection. The rest of the inorganics (e.g., metals other than sodium, potassium, calcium and magnesium) are discussed element by element in Sect. 4.2.2.3.

The distribution of elevated amounts of some of the benign constituents in a number of the groundwater samples may be related to activities at the Hematite Facility. They also can provide useful information about geochemical processes taking place as a result of soil–water or rock–water interactions. Overburden wells show the most frequent occurrences of elevated concentrations of these constituents and most of the impacted wells are located immediately around or under the Hematite Facility. Elevated values of sodium, calcium, magnesium, and chloride (in comparison to what was measured in most other wells) are observed in most of the wells located within and next to the buildings ("BD"-labeled wells, refer to Fig. 2.6b for well locations). Other wells with elevated concentrations of common cations and/or anions clusters at various points around the Facility are mainly associated with AOCs (e.g., Evaporation Ponds and the Burial Pit).

There are many potential mechanisms by which groundwater at the Hematite Site might develop elevated concentrations of these constituents. Some occurrences can reasonably be attributed to processes occurring at the Hematite Facility and the chemicals that were used in them (e.g., Table 1.1). For example, releases of nitric and hydrochloric acids at the Hematite Facility will lead to elevated chloride and nitrate concentrations (and lower pH). Reaction between the acids and any dolomite ($CaMgCO_3$) fragments contained in the overburden soil will result in elevated values of calcium and magnesium. Microbial degradation of TCE and PCE will release chloride to groundwater but in quantities that are unlikely to cause a significant increase relative to natural chloride levels.

The occurrence of elevated concentrations of major cations and anions within groundwater in bedrock is significantly more limited than in overburden. None of the Roubidoux wells, and only two of the Jefferson City-Cotter wells (WS-30 and PZ-03), have elevated concentrations for any of these constituents relative to the levels measured in the other bedrock groundwater samples. For example, in comparison to all other groundwater samples from the Hematite Site, groundwater from WS-30 has an unusually high concentration of potassium (69 mg/L). It is interesting to note that this well also has a very high pH (9.3, Sect. 4.1.3).

The fact that groundwater from bedrock wells does not exhibit elevated concentrations of the major cations and anions is attributed to the following factors:

- If the constituents of concern were released in the overburden, these constituents can interact with the overburden soils (e.g., adsorption or precipitation) resulting in attenuation before the groundwater reaches the bedrock.

- The primary bedrock mineral (dolomite) is relatively soluble and has a strong chemical buffering effect on groundwater pH and the dissolved concentrations of calcium and magnesium (additional examples of buffering are described in Sect. 4.1.3).

#### 4.2.2.2 Comparison of unfiltered (total) versus filtered (dissolved) metals concentrations

The role of particulates in influencing measured metals concentrations in groundwater at the Hematite Site can be assessed by comparing metals concentrations in co-located filtered and unfiltered samples (Figs. 4.8a through 4.8d). As mentioned in Chapter 2, groundwater samples collected from all the wells were unfiltered prior to analyses, but filtered groundwater samples were also collected from a subset of wells. Figure 4.9 clearly shows that aluminum tends to be higher in the unfiltered samples, indicating the presence of clay particulates (aluminum is an element found in common clay minerals) that were filtered out by the 0.45-μm filter. High turbidity was measured in some of the samples that had elevated levels of aluminum (Fig. 4.8a); however, there were some groundwater samples where turbidity was low despite high aluminum concentrations (e.g., sample from well NB-54). Iron and manganese concentrations are comparable between unfiltered and filtered samples (Figs. 4.8b and 4.8c). Zinc appears to also be higher in unfiltered samples (Fig. 4.8d), suggesting that zinc is either associated with the clay particles, or is present in particulates larger than the filter size (0.45 μm). This observation indicates that iron and manganese oxyhydroxide particulates were not present in the groundwater samples selected for filtered/unfiltered sampling, or that these particulates are fine enough to pass through 0.45-μm filters.

The presence of iron oxyhydroxide particulates in groundwater at the Hematite Site cannot be completely ruled out for some samples, based on a comparison of total iron measured in the laboratory on unfiltered samples, and ferrous iron measured in the field (Sect. 4.1.6). Note that the total versus ferrous iron comparison can be made on more than 100 samples collected during the site-wide sampling event, in contrast to 16 unfiltered versus filtered comparisons shown on Fig. 4.8a through 4.8d. Fig. 4.8e shows that total iron tends to be higher than ferrous (dissolved) iron for some samples, indicating the possible presence of iron oxyhydroxide particulates in the groundwater. However, there is considerable scatter of data points around the total iron = ferrous iron line suggesting that for many samples most of the dissolved iron is in the ferrous state.

#### 4.2.2.3 Element-by-element discussion of key inorganic constituents in groundwater

Two considerations are important in evaluating the groundwater data. First, all of the samples were not filtered per EPA protocol (Puls et. al 1996) (filtered samples were also collected from a subset of wells; see the discussion in the previous subsection) and some had high turbidity (refer to Sect. 4.1.1, see Appendix H.1 for the complete set of field parameter values). The elements aluminum, iron, and manganese are particularly susceptible to forming particulates that are collected as part of a water sample because they are so abundant in native rocks and soils. Similarly, many elements (e.g., arsenic, uranium, chromium, copper, nickel, etc.) are often detected in conjunction with high concentrations of iron and manganese because the hydrous oxides of the latter elements are highly efficient sorbents for inorganic species.

In evaluating the groundwater data, the measured concentrations are compared against Site background criteria (presented in Appendix J) and drinking water standards primarily for reference. Groundwater from the overburden is not a drinking water source and, as such, comparing groundwater Site data with drinking water standards as a qualitative approach to evaluating environmental impact is likely conservative. A quantitative assessment of risk associated with these groundwater constituents is being performed in a baseline risk assessment and will be documented in a separate report.

The groundwater data are described below on an element-by-element basis.

**Aluminum—**This element, a major constituent in geologic materials, was present in a number of groundwater samples at mg/L levels (e.g., BD-03 = 3.5 mg/L, LF-08 = 5.6 mg/L, BD-13 = 6.8 mg/L, BD-02 = 6.8 mg/L, and WS-23 = 16 mg/L). The background level developed for aluminum in overburden groundwater was 1.1 mg/L. As described for surface water samples in Sect. 4.2.1, aluminum detections in groundwater are almost certainly derived from the collection of soil particulates as part of the groundwater samples. This is supported by the aluminum concentrations being higher in unfiltered samples when compared to filtered samples (Fig. 4.8a; Sect. 4.2.2.2).

**Antimony—**This element was not detected above the RL of ~0.02 mg/L in any of the samples. For reference, the drinking water standard for antimony is 0.006 mg/L.

**Arsenic—**This element was not detected above the RL in most of the samples, with the RL of ~0.01 mg/L (Table 4.1). The drinking water standard for arsenic (0.05 mg/L) is exceeded in samples from deep overburden wells WS-23 and WS-25. The wells are in close proximity northeast of the buildings (see Fig. 2.6b for well locations), but are not located near surface soil samples containing elevated arsenic (see Sect. 4.2.4). Moreover, none of the subsurface soil samples contained elevated arsenic (see Sect. 4.2.5).

The elevated arsenic concentrations in these samples are associated with mg/L levels of iron (see iron concentrations in Appendix H.3). These data suggest the arsenic may be naturally occurring. The phenomenon of arsenic occurring in reducing groundwater zones, often in conjunction with iron-bearing zones, has been demonstrated elsewhere in Missouri and throughout the Midwestern United States. (Aggett and Kriegman 1988, Holm and Curtiss 1988, Korte 1991, Korte and Fernando 1991). An additional possibility is that colloidal iron oxide particles were collected as part of the water sample. The latter is supported by the comparison of total iron and ferrous iron discussed in Sect. 4.2.2.2. As described in the surface water section above, this phenomenon commonly results in detections of other naturally occurring elements.

**Barium—**This element is abundant naturally and was detected in every sample (range from 0.1 to 0.54 mg/L), with the highest results coinciding with the samples high in aluminum and iron. Thus, association with iron- and aluminum-based particulates is possible. The background values developed for barium in the groundwater of the overburden and the Jefferson City Formation were 0.39 mg/L and 0.54 mg/L, respectively. For reference, the drinking water standard for barium is 2 mg/L, which is not exceeded in any of the wells sampled.

**Beryllium—**This element was not detected above the RL (~0.0026 mg/L) in any of the samples. For reference, the drinking water standard for beryllium is 0.004 mg/L.

**Cadmium—**This element was only detected above the RL (~0.002 mg/L) in the groundwater sample from BD-02 (0.0035 mg/L). For reference, the drinking water standard for cadmium is 0.005 mg/L.

**Calcium—**This element is abundant naturally, especially at the Hematite Site where the underlying bedrock is dolomitic. Results varied from <10 to 260 mg/L. Several wells exceeded 100 mg/L

(BD-02 = 260 mg/L, BD-03 = 120 mg/L, BD-06 = 130 mg/L, BD-08 = 110 mg/L, BP-17 = 160 mg/L, CB-02 = 110 mg/L, DM-02 = 140 mg/L, EP-20 = 140 mg/L, OB-01 = 170 mg/L, WS-24 = 140 mg/L, and WS-27 = 110 mg/L).

**Chromium**—Most of the samples did not contain chromium above the RL of ~0.004 mg/L, except for the samples shown in Table 4.2. All of the results are from wells in the overburden. The samples with detectable chromium concentrations have mg/L concentrations of iron and/or aluminum, which in turn may be indicative of particulates present in the groundwater samples. As mentioned previously, naturally occurring elements tend to be detected in groundwater samples with suspended or colloidal particulates. For reference, the drinking water standard for chromium is 0.1 mg/L, which is not exceeded in any of samples in Table 4.2.

**Cobalt**—The maximum value reported for cobalt was 0.042 mg/L from GW-BD-03. The majority of the remaining samples were reported either as not detected (RL ~0.002 mg/L), or near the RL. The background values developed for cobalt in the groundwater of the overburden and the Jefferson City Formation were 0.0024 mg/L and 0.0022 mg/L, respectively. Well BD-03, located inside Building 240, contains 15 mg/L of iron and 3.5 mg/L of aluminum. Hence, colloidal soil particles may be a source of cobalt, a naturally occurring element in soil.

**Copper**—Most of the samples did not contain copper above the RL (~0.01 mg/L) (Table 4.3). All of the measured concentrations are in the overburden. The background value developed for copper in the overburden groundwater was 0.02 mg/L. For reference, the drinking water standard for copper is 1300 mg/L, which is not exceeded by any of the samples in Table 4.3. As with several other elements, all of the copper concentrations above the RL are associated with mg/L levels of iron.

**Iron**—Iron is not a toxic element, although there is a secondary drinking water standard for water supply systems (0.3 mg/L) because of its effects on color and taste. Iron is included here for specific discussion because of its implications regarding co-precipitation and/or sorption of elements and the redox status of the aquifer. Iron detections in Hematite Site groundwater are shown in Table 4.4. Except under acid conditions, iron is not soluble in oxidized water hence; the data in Table 4.4 indicate reducing conditions in groundwater or the collection of particulates as part of the water sample.

**Lead**—Most of the samples did not contain lead above the RL of ~ 0.003 mg/L (Table 4.5). The highest results (BD-02, BD-03, BD-13, WS-23, and WS-25) are once again associated with high iron results. Most of the anomalous lead in soil samples was associated with the Evaporation Ponds (Sects. 4.2.4 and 4.2.5), but monitoring wells WS-23 and WS-25 are located northeast of the plant near the Burial Pits. Thus, there is no logical connection between elevated lead in soil and in groundwater. For these reasons, the lead may be associated with iron oxyhydroxides naturally present in the soil and collected as part of the groundwater sample. In the unfiltered/filtered water samples, lead was only detected in the unfiltered sample from BP-20A (0.0043 mg/L); the associated filtered sample did not have lead above the RL; this is consistent with its possible association with particulates. The background value developed for lead in the overburden groundwater was 0.0082 mg/L. For reference, the drinking water action level for lead is 0.015 mg/L.

**Manganese**— Every groundwater sample had detectable manganese, with the highest value of 13 mg/L (BD-02) and many other results exceeding 1 mg/L. These data are consistent with the high iron values and indicate reducing conditions in the aquifer or the collection of particulates as part of the water sample. The background value developed for manganese in the overburden groundwater was 3.3 mg/L. For reference, there is no primary drinking water standard for manganese, although there is a secondary standard (for aesthetics and taste) of 0.05 mg/L.

**Mercury—**This element was not detected above the RL (~0.0002 mg/L) in any of the samples. For reference, the drinking water standard for mercury (inorganic) is 0.002 mg/L.

**Nickel—**This element was detected above the RL (~0.005 mg/L) in most samples, but only five reported concentrations exceeded 0.05 mg/L (Table 4.6). Wells with the highest nickel concentrations each contain mg/L levels of iron. The highest concentration of nickel was measured in BD-08 (0.15 mg/L), a well that is located inside a building (Fig. 2.6a for location). The background value developed for nickel in the overburden groundwater was 0.031 mg/L. There is no drinking water standard for nickel.

**Nitrate**—Many of the samples had detectable nitrate. Table 4.7 presents those samples with nitrate >1 mg/L. For reference, the drinking water standard for nitrate is 10 mg/L. This is only exceeded in samples from EP-20 and BD-02, associated with the Evaporation Ponds and soils under the buildings. Nitric acid was used at the Hematite Facility (see Table 1.3) and is a very mobile but highly biodegradable contaminant. Hence, the result at EP-20 and in wells in the Buildings (e.g., BD-02) is likely a result of Hematite Facility operations.

**Selenium**—Most of the samples did not contain selenium above the RL of ~0.005 mg/L (Table 4.8). For reference, the drinking water standard for selenium is 50 mg/L, which is not exceeded by any of the measured concentrations.

**Silver**—This element was not detected above the RL (~0.01 mg/L) in any of the samples. For reference, there is no primary drinking water standard for silver, but the secondary drinking water standard (for aesthetics and taste) is 0.1 mg/L, which is not exceeded in any groundwater samples from the Hematite Site.

**Sulfate**—Most of the results for sulfate were in the range of 20 to 60 mg/L, with the highest reported result at 170 mg/L. These results and the observed variability are not uncommon for natural waters and do not indicate contamination. For reference, there is no primary drinking water standard for sulfate, although there is a secondary drinking water standard of 250 mg/L. All the sulfate levels at the Hematite Site are below the secondary standard.

**Thallium**—Three groundwater samples (Table 4.9) exceeded the thallium RL of ~0.01 mg/L. For reference, the drinking water standard for thallium is 0.002 mg/L. Thallium was detected in two groundwater samples collected underneath buildings and from the Burial Pits.

**Vanadium**—Most of the samples did not contain vanadium above the RL of ~0.01 mg/L (Table 4.10). There is no drinking water standard for vanadium. It was not implicated as a soil contaminant (see Sects. 4.2.4 and 4.2.5) and is relatively abundant naturally. Each of the samples in Table 4.10 also contains high aluminum and iron, which suggests these measured concentrations are naturally occurring, as described previously.

**Zinc**—This element is naturally abundant and has a host of anthropogenic sources. Hence, it was detected in many of the groundwater samples. The background values developed for zinc in the groundwater of the overburden and the Jefferson City Formation were 0.210 mg/L and 0.069 mg/L, respectively. For reference, there is no drinking water standard for zinc although there is a secondary (for aesthetics and taste) drinking water standard (5 mg/L). None of the samples exceeded the secondary standard. Those samples with concentrations greater than 0.05 mg/L are shown in Table 4.11. NB-54 is located at the southwest corner of the buildings, in BD-03 in the center of the buildings, and in NB-32 east of the Evaporation Pond area. The two highest values, in WS-23 and WS-25, are located northwest of the Hematite Facility next to the Burial Pits. As with the other elements, zinc correlates more with high

iron than it does with known contamination sources. It was also higher in the unfiltered samples when compared to the filtered samples (see Sect. 4.2.2.2).

### 4.2.3 Non-radioactive Inorganics in Sediments

This section reviews sediment data for inorganic, non-radioactive species. Details of sediment sampling are presented in Sect. 2.1. Sampling locations for sediment were shown on Fig. 2.3. Sediment data for selected elements are presented in Table 4.12; the complete data set for inorganics in sediments can be found in Appendix H.4. Cyanide is not included in Table 4.12 because all results were below the RL of 0.96 mg/kg. Antimony is not included in the table because it was only detected in one sample (SW-07-SS, 1.9 mg/kg) at a concentration that was slightly greater than the reporting limit of 1.5 mg/kg.

Concentrations in the Site sediment samples are compared to levels measured in two upstream sediment samples, and to site-specific background concentrations determined from off-Site subsurface soil samples (Appendix J). The results in Table 4.12 show that some of the metals are elevated in a number of sediment samples from the Site Pond, Site Creek, and Northeast Site Creek. Highest concentrations were measured in SW-06-SS from the Site Pond. For example, this sample contained the highest mercury result (1.1 mg/kg); this sample also has the highest aluminum result (13,000 mg/kg) and is one of the two highest samples in iron and manganese (latter data not shown in Table 4.12, but can be found in Appendix H). These data suggest either an accumulation zone where oxyhydroxides of aluminum, iron, and manganese have scavenged metals from the surface water or where some metal scrap may be present.

With the exception of SW-15-SS, which was collected near the bridge on Joachim Creek (see Fig. 2.3), concentrations of inorganics in sediment samples from Joachim Creek are comparable to the upstream and site-specific background concentrations (Table 4.12). As mentioned in Sect. 2.8, anomalies were detected during a geophysical survey at the bridge across Joachim Creek, but the majority of the anomalies were due to visible surface metals scrap from use of the area as an adhoc household dumping site. The elevated metals in SW-15-SS may be due to the presence of the scrap metal.

### 4.2.4 Non-radioactive Inorganics in Surface Soil

This section reviews surface soil data for inorganic, non-radioactive species. Details of surface soil sampling are presented in Sect. 2.2, while the complete data set can be found in Appendix H.5. The primary conclusion of this section is that elevated data are localized and tend to be associated with previously identified AOCs (e.g., the Burial Pits, the Evaporation Ponds, process buildings, and the Site Pond sediments at the Hematite Site). The same conclusion was reached in the analysis of sediment (Sect. 4.2.3 above) and subsurface soils (Sect. 4.2.5).

#### 4.2.4.1 Review process for surface soil inorganics data

The review process for the surface soil and subsurface soil data was performed in the following steps.

- The distributions of the on-Site data were examined to determine whether multiple populations were present. This approach is commonly used as a means of separating results representing the naturally occurring population from that comprised by contaminants (Fleischhauer and Korte 1990, EPA 2002; Appendix J). The presence of multiple populations, however, does not automatically indicate contamination. Naturally occurring elements will have multiple populations when different soil or rock types are sampled or because of the presence of fill or urban particulates (atmospheric deposition). Hence, professional judgment remains part of the review process.

- Each population identified in the previous step was assessed by comparison to regional and international averages in the published literature, as well as to data from nearby sites. When Site characterization data are within the range of regional and international data compilations; it is unlikely to represent contamination. In this case, on-Site results were also compared to data from 15 off-Site soil locations (refer to Fig. 2.7 for locations, Appendix H.5a). Eight off-Site soil sampling locations representative of the terrace strata were located along Highway P, approximately 2.5 miles west of the Hematite Site. Seven soil sampling locations representative of the alluvial strata were located at the U.S. National Guard Armory Site, located east and north of the Hematite Site near the junction of State Road P and State Road A (Fig. 2.7). No distinction was made between terrace and alluvial samples in the following discussion because little if any contamination is indicated on-site. Site background concentrations were calculated (Appendix J); however, the Site background was just one of the factors considered when evaluating the data for contamination. Additional details of the off-Site sampling program, the background soil sampling locations, and data are presented in Appendix J.

- Analysis for inorganic constituents are subject to interferences. Thus, concentrations of metals are evaluated as a group because contamination with a single inorganic species rarely occurs unless a specific process producing only that contaminant has been identified. A sampling location where one element is elevated with no clearly identified cause usually indicates a sampling or analytical artifact.

- The analytical results for the Site samples are also compared with local, regional, and international data.

The review process is demonstrated for arsenic at the Hematite Site. Figure 4.9 shows a cumulative frequency plot of the arsenic results in surface soils. An examination of the figure demonstrates there are two distinct populations with the upper and lower ends of the two populations meeting at approximately 25 mg/kg. Local, regional, and international data and measurements in urban dust and house dust, as described below, indicate the upper range of background for arsenic from these sources ranges from approximately 10 to 50 mg/kg. Because the second population contains values exceeding 10 to 50 mg/kg, this group of results requires examination as potential Site contamination. Indeed, virtually all samples in this group are either associated with known disposal sites (e.g., Burial Pits) or were collected adjacent to buildings.

Figure 4.10 presents data for arsenic in subsurface soils (data discussed in Sect. 4.2.5). Once again, two distinct populations are present. However, in contrast to the surface soil data, the highest results in the second population are approximately equal to the upper range for arsenic reported as background in regional and international soils data. The three highest values (24, 20, and 17 mg/kg) are associated with the Burial Pits, the limestone storage area, and the Evaporation Ponds, respectively. Hence, although within many background averages, these data are probably evidence of impact from Site activities.

#### 4.2.4.2 General observations regarding inorganics in surface soils

Sampling locations for surface soils (including composite samples from the limestone storage/pile areas) are shown on Figs. 2.4a and 2.4b. The ten highest results are presented in Table 4.13. Table 4.13 does not include the elements generally considered to be non-hazardous major soil components such as aluminum, calcium, and iron, or elements such as barium and vanadium where results were comparable to the off-Site and regional values (Table 4.14).

Not all results in Table 4.13 are suggestive of contamination. For example, most of the cobalt results cannot be distinguished from background, as shown by the cumulative frequency plot in Appendix J. Similarly, selenium results up to approximately 2 mg/kg in Table 4.13 are probably part of a background

distribution with a greater range because the on-Site sample population size is ten times larger than the off-Site sample population. Finally, more than ten results are elevated for the metals mercury, thallium, and zinc, although results not shown on Table 4.13 are within regional and international background ranges, as shown in Table 4.14.

Descriptive statistics for the entire surface soil data set are compared to local, regional, and international averages, as well as to common urban values in Table 4.14. (Cyanide results are not included because none were detected above the RL (0.7 mg/kg) in surface soils.) The Illinois data (IEPA 1994) used in Table 4.14 are from a program to determine state-wide background concentrations and represent a comprehensive regional data set. The data for shale, clay, sandstone, sand, carbonates, soil, and loess are from a comprehensive program performed by the USGS (Connor and Shacklette 1975) and were listed as "Missouri region" in the original text. The regional Illinois data set is included in this evaluation because it is more recent and is based on more up-to-date methods when compared to the USGS Missouri regional data. The Missouri data from Tidball (1984) may include some of the USGS Missouri data. The compilation by Lindsay (1973) is another classical accumulation of soils data. Finally, the results for urban road dust and house dust (Fergusson and Kim 1991) provide perspective regarding the ubiquity of metals in the environment.

The utility of including surface soil comparisons with urban road dust and house dust is demonstrated by reviewing the data for cobalt and zinc. Cobalt is not commonly used in industrial activities. Hence, little enrichment in road and house dust is expected. In such instances, the Hematite Site mean and the means for regional and international studies and for urban and house dusts should be similar because the primary source of cobalt in each case is soil. Indeed, the means for each of the data sets are quite similar. In contrast, zinc is added to the environment from many sources, including tire wear and roofing materials. Thus, the means for road and house dusts should be and are much higher than for background samples as reported by Lindsay (1973), the state of Illinois (1995) and USGS (Connor and Shacklett 1975).

#### 4.2.4.3 Element-by-element discussion of elevated surface soil results

Figure 4.11 shows a map of surface soils with elevated inorganic concentrations, based on the review process described earlier in Sect. 4.2.4.1. The following is an element-by-element discussion of the anomalous surface soil concentrations on Fig. 4.11, and the results shown in Table 4.13. Site background values developed for inorganics in surface soils are presented in Table 4.13 and Appendix J.

**Arsenic**—Elevated levels were identified by considering the cumulative frequency plot (presented in Fig. 4.9) for arsenic in surface soils and the regional data in Table 4.14. The highest arsenic values are clustered near the Evaporation Ponds (locations shown on Fig. 4.11, "EP"-labeled samples). Other elevated concentrations were mostly from samples collected near buildings (Fig. 4.11, data shown in Table 4.13, "BD"-labeled samples Operations at the Hematite plant involved the handling (e.g., cleaning, machining) of specialty alloys. The presence of heavy metals (e.g., arsenic, chromium, copper, and nickel) could indicate site-related releases from cleaning of specialty alloy metal parts.

**Antimony**—The elevated antimony values are clustered near the Evaporation Ponds (locations shown on Fig. 4.11, "EP"-labeled samples).

**Beryllium**—The elevated beryllium values are from samples collected near the Evaporation Ponds (locations shown on Fig. 4.11, data shown in Table 4.13, "EP"-labeled samples).

**Cadmium**—The elevated cadmium values are from samples collected near the Evaporation Ponds (locations shown on Fig. 4.11, data shown in Table 4.13, "EP"-labeled samples).

**Chromium**—The highest result (280 mg/kg, BD-10) is outside of common ranges for background and road and house dust, as shown in Table 4.14. Three of the samples listed in Table 4.13 are clustered near the Evaporation Ponds. The other high sample is from OA-08, a location next to a building in the middle of the Hematite Facility area with other elevated metal results.

**Cobalt**—The highest cobalt result (300 mg/kg, OA-23) is more than approximately ten times the common soil averages (see Table 4.14). The latter sample contains no other metal contaminants and is probably a sampling or analysis artifact. The few elevated results and their sporadic distribution do not indicate a cobalt contamination issue.

**Copper**—Only one copper result (1800 mg/kg, EP-02) is significantly elevated. Four of the highest reported values are associated with the Evaporation Ponds (Table 4.13). The other location, OA-08, contains other elevated elements (see chromium above).

**Fluoride**—The highest fluoride levels in the surface soil samples were measured in samples from the Evaporation Ponds area, Deul's Mountain area, next to the buildings and adjacent outdoor areas (EP, DM, BD, and OA-labeled samples in Appendix H.5). The highest fluoride result (170 mg/kg) is still below the geometric mean of regional values (270 mg/kg) reported by Tidball (1984).

**Lead**—Five of the highest six lead values (Table 4.13) are from samples that had no other anomalous metals. All the anomalous results, however, are near buildings or the Evaporation Ponds.

**Mercury**— Elevated mercury concentrations in some surface soils closely associated with the Evaporation Ponds ("EP"-labeled samples; Table 4.13, Fig. 4.11). Other samples with elevated results were collected north of the plant (OA-11 and OA-13) near the limestone storage area or next to Building 240 (BD-11). These samples also have elevated levels of otherwise contaminated with other metals and radionuclides.

**Nickel**—All of the elevated values are associated with the Evaporation Pond area.

**Selenium**—The highest selenium values are associated with Evaporation Pond samples contaminated with a variety of metals and solvents.

**Silver**—Silver results are only slightly elevated, with the two highest values (Table 4.13) reported near the Evaporation Ponds.

**Thallium**—The highest thallium values are associated with samples that contain other metals. These areas are contaminated with a variety of solvents as well.

**Zinc**—All of the high results except for NB-23 are clustered next to the Evaporation Ponds. NB-23 is east of the plant. Most zinc sources (automobiles, tire wear, and roofing materials) are sources of other metals. Because there are no other metals associated with NB-23, this result is probably a sampling or analysis artifact.

### 4.2.5 Non-radioactive Inorganics in Subsurface Soils

Sampling locations of subsurface soils were shown on Figs. 2.5a and 2.5b, while sampling and analysis methods were described in Sect. 2.3. The analytical data were reviewed according to the same process conducted on the surface soil sample results, as described in Sect. 4.2.4.1.

#### 4.2.5.1 General observations regarding inorganics in subsurface soils

The ten highest results for subsurface soil samples and selected elements are shown in Table 4.15, and elevated data are presented on Fig. 4.12. Moreover, for some elements, all results were less than the site-specific background concentration and were not included in Table 4.15. These elements were: aluminum, barium, calcium, iron, magnesium, manganese, potassium, silver, sodium, and vanadium. All of the analytical results are provided in Appendix H.6, and descriptive statistics for all of the elements and data are presented in Table 4.16. (Cyanide results are not included because none were detected above the RL of ~0. 96 mg/kg in subsurface soils.)

#### 4.2.5.2 Element-by-element discussion of anomalous subsurface soil results

The element-by-element discussions under surface soils (Sect. 4.2.4.3) can be reviewed for brief mention of potential sources of inorganic/metal constituents. These are not repeated here because of the few elevated subsurface soil trace element results. The element-by-element descriptions provided below are guided in part by the cumulative frequency plots in Appendix J. Site background values developed for inorganics in subsurface soils are presented in Table 4.15 and Appendix J. Indications of contamination appear to be highly localized (e.g., SW-02 and BD-05 samples collected from boreholes near the Site Pond, and under Bldg. 240, respectively) and low-level. Fig. 4.12 shows the locations of samples with anomalous concentrations (refer to Figs. 2.5a and 2.5b for locations of all boreholes from which subsurface samples were collected).

**Arsenic**—The highest arsenic value in the subsurface was 24 mg/kg. Moreover, there is no apparent correlation among locations or multiple indications of contamination in a single borehole. For example, BP-18, from which the 24-mg/kg sample was collected, had four other arsenic samples that were collected above and below the sample having the elevated concentration and all other samples had concentrations that were <10 mg/kg. Consequently, the highest arsenic values in subsurface soils are most likely natural occurrences.

**Beryllium**—The highest beryllium values are mostly SW samples (collected near the Site Pond), particularly samples collected from borehole SW-02 (2.8 mg/kg at a depth of 1 ft), which accounts for three of the highest values. The cumulative frequency plot (Appendix J), however, indicates that only two of the results are truly elevated.

**Antimony**—The highest antimony values are sporadically distributed and low-level (<2 mg/kg).

**Cadmium**—Three of the highest cadmium values were measured in samples collected from borehole SW-02, thus suggesting low-level contamination with metals at this location. The measured cadmium levels in the subsurface soil samples are all significantly less than the CALM standard of 110 mg/kg. This indicates there is not a contamination problem with cadmium.

**Chromium**—The highest chromium result (49 mg/kg) is from borehole BD-05—a location that accounts for several of the high values from subsurface soils. Nevertheless, the majority of the data does not correlate to specific locations, thus indicating there is not a significant contamination problem with chromium.

**Cobalt**—Most of the highest cobalt results are "BD" samples (collected under or near buildings), thus suggesting that elevated levels are from Site operations in these areas. As noted previously, there are no suspected cobalt sources at the Site.

**Copper**—The highest copper result (38 mg/kg) is from BD-05, which is a location responsible for several other of the highest values reported in subsurface soils.

**Fluoride** —The highest fluoride results were measured in the Evaporation Ponds, under the buildings and near Deul's Mountain (EP, BD, BLD, and DM-labeled samples in Appendix H.6). However, even the highest fluoride level (190 mg/kg in EP-13-06-SL) is below the geometric mean of regional values (270 mg/kg) reported by Tidball (1984).

**Lead**—Only one lead result (680 mg/kg, NB-75 at 19 ft) is elevated with respect to background, as can be observed from the cumulative frequency plot (Appendix J). This location and depth do not correlate to other contamination. Hence, there is no evidence of a significant contamination problem with lead and this result is probably an analytical or sampling artifact.

**Mercury**—SW-02 and EP-18 are the locations with the highest values for mercury. SW-02 has already been identified as having low-level metal contamination (e.g., berryllium, see preceding discussion in this subsection) and the Evaporation Ponds area has already been identified as a significant contamination source based on elevated metals concentrations in surface soil samples (refer to Sect. 4.2.4).

**Nickel**—The highest nickel result is 97 mg/kg, NB-85, which is outside of regional and international ranges. Another of the high samples is from BD-05, again implicating the latter location with low-level contamination. Nonetheless, the high results are sporadically distributed and relatively low level, thus indicating there is not a significant contamination problem with nickel.

**Selenium**—The highest selenium values are not significantly elevated (all <3 mg/kg) and are sporadically distributed. The cumulative frequency plot (Appendix J) suggests two distinct populations of roughly equal size. Hence, the higher values are most likely a consequence of two natural populations.

**Silver**—Silver data are not provided in Table 4.15 because only one result (0.85 mg/kg) appeared to be elevated with respect to background. This highest result, however, is from SW-02, the same location where several other metals are somewhat elevated.

**Thallium**—Thallium results, much like selenium, are separated into two large, distinct populations, thus indicating most of the higher values are naturally occurring. The highest result, however, is from BD-05, which is a location already implicated with low-level metal contamination.

**Zinc**—Zinc is relatively abundant naturally. Thus, only a few of the highest results suggest contamination. The locations for the highest zinc results, however, are sporadically distributed, thus indicating there is not a significant contamination problem.

In summary, locations SW-02 and BD-05 appear to have low-level element contamination in the subsurface. Most of the remainder of the highest results was sporadically distributed and not indicative of significant contamination. For example, the following locations had multiple occurrences of the higher results: NB-36-15-SL, cobalt = 54 mg/kg and nickel = 60 mg/kg; NB-42-05-SL, lead = 98 mg/kg and zinc = 380 mg/kg; NB-63-05-SL lead = 120 mg/kg and zinc = 850 mg/kg. However, overlying surface soil samples in these areas are not contaminated with these elements, nor are water samples from these or adjacent wells (refer to Sect. 4.2.2.3 for discussion of groundwater data). Thus, although there is no ready explanation for the latter results, all facts taken together, Site evidence indicates the contamination is both low-level and highly localized. Indeed, several of the higher results may represent natural outliers (considering the small % of elevated results).

## 4.3 RADIONUCLIDES

Information from the historical Site assessment and previous investigations indicated $^{234}U$, $^{235}U$, $^{238}U$, $^{99}Tc$, $^{232}Th$ and progeny were the most likely radioactive contaminants at the Hematite Site (Sect. 1.5). Radioactive contamination had been investigated as early as 1982 (RMC 1982). Subsequently, certain contaminated locations were identified. For example, a partial removal of contaminated soils and sediments from the Evaporation Ponds occurred in 1992 (Sect. 1.5.3). Similarly, groundwater contamination with $^{99}Tc$ in the central Hematite Facility area—between the limestone storage area near Deul's Mountain and the Hematite Facility buildings was documented in 1996 (GEA 1996, summarized in Sect. 1.5). In addition, groundwater contamination with $^{99}Tc$ in six deep (to 20 ft) and seven shallow boreholes in the Evaporation Ponds demonstrated radioactive contamination in soil (GEA 1997, also summarized in Sect. 1.5). Subsequent studies confirmed the $^{99}Tc$ groundwater contamination, thus suggesting that its extent was localized to a few previously identified areas (summarized in Sect. 1.5).

Isotopic uranium analyses were performed in the current study because the uranium used may have varied from depleted- to natural- to highly enriched. Thorium-232 analyses were performed because it was used in limited investigations regarding possible involvement in the fuel cycle.

The potential for transuranics and $^{99}Tc$ (contaminants in uranium reprocessed from spent fuel) to be present at the Hematite Site was also examined. According to the U.S. Department of Energy (DOE) (Project Overview and Field Site Reports entitled "A Preliminary Review of the Flow and Characteristics of Recycled Uranium throughout the DOE Complex 1951-1999"), most of the fission products and transuranic isotopes were disposed of as high-level waste during reprocessing by fuel recycling facilities (fuel recycling was not performed at the Hematite Facility; Sect. 1.3). However, traces of transuranics and $^{99}Tc$ remained with recovered uranium. DOE indicated $^{99}Tc$ would be the predominant recycled uranium contaminant followed by $^{241}Am$ and $^{237}Np$ at significantly lower concentrations. $^{237}Np$ is a potential contaminant due to its presence in $UF_6$ feedstock that was historically sent to the Facility.

### 4.3.1 Radionuclides in Surface Water

Details of surface water sampling are presented in Sect. 2.1.2 and the complete data set is presented in Appendix H.7.

Surface water samples were submitted for determination of isotopic uranium, isotopic thorium, and $^{99}Tc$. Neither thorium isotopes nor $^{99}Tc$ were detected in any of the samples. Data for uranium are presented in Table 4.17, which also includes uranium activities in surface water samples from locations upstream of the Facility ("US" samples). Background levels for uranium radionuclides are developed in Appendix J. These background levels in surface water are as follows: $^{234}U$ = 0.76 pCi/L, $^{235}U$ = 0.10 pCi/L, and $^{238}U$ = 0.82 pCi/L.

SW-01-SW (collected from the Site Pond, refer to Fig. 2.2 for location) has the highest uranium activities ($^{234}U$ = 29.6 ± 4.7 pCi/L; $^{235}U$ = 1.24 ± 0.273 pCi/L; $^{238}U$ = 4.77 ± 0.821 pCi/L). Clearly, uranium activities in SW-01-SW are elevated relative to the upstream sample (US-03-SW). Some or all of the uranium is likely sorbed to particulates (recall the elevated aluminum concentration (19.1 mg/L) in this surface water sample; refer to Sect. 4.2.1) and not migrating as a dissolved species. Activities in SW-02-SW (from the Site Creek) are lower relative to the Site Pond, but are still elevated relative to the relevant upstream sample (SW-15-SW). Sample SW-09-SW collected from the Northeast Site Creek also has slightly elevated activities relative to the upstream sample, although the difference is not significantly larger than the measurement errors (~0.5 pCi/L for $^{234}U$). Note that the activities in the upstream samples are relatively low and measurement errors are a large percentage of the actual results in these samples. Thus, there is some uncertainty when a Site sample is deemed to be comparable to upstream samples.

However, in the samples with high levels of uranium (e.g., SW-01-SW), the measurement errors in the results for this sample should not affect the inference that this sample contains uranium at levels higher than upstream values.

Samples in secular equilibrium would have a $^{234}U/^{238}U$ ratio near 1. The $^{234}U/^{238}U$ ratio for SW-01 is approximately 6 and sufficiently out of secular equilibrium that some of the measured uranium probably originated from the Hematite Facility operations. This is not surprising given that some release of radiologic compounds is allowed by the NPDES permit for the outfalls that discharge into the Site Pond.

In summary, the surface water data indicate the presence of radioactive contaminants at concentrations above upstream surface water. However, combined with the data for metals and other inorganic constituents, it is possible that some of the uranium measured in the samples indicating contamination from Hematite Site processes is associated with particulates.

### 4.3.2 Radionuclides in Groundwater

Groundwater samples were collected for radionuclide analysis during the site-wide sampling program performed in December 2004. Sampling and analysis methods were presented in Sect. 2.6 of this report. Locations of groundwater monitoring wells sampled during this event are shown on Figs. 2.6a and 2.6b. All groundwater samples collected were analyzed for isotopic uranium and thorium, $^{99}Tc$, gross alpha, and gross beta. A select number of wells was also sampled for transuranic analyses ($^{241}Am$, $^{237}Np$, and isotopic plutonium). Twenty of the locations analyzed for transuranics were generated randomly and the remaining ten were selected to ensure that known source areas were adequately represented in the data set. The radionuclide-specific analyses are discussed in the following sections while the gross alpha and beta measurements can be found in Appendix H.8, which is a complete listing of all the groundwater radionuclide data collected during the RI. Since the sources for alpha and beta emissions at the Site are reasonably well established (i.e., uranium and technetium, respectively), it was deemed more appropriate to do a thorough evaluation of the analyte-specific data and to use the gross emissions measurements as a supplementary data set.

In summary, the radionuclide data indicates only $^{99}Tc$ has entered the groundwater at numerous locations (Sect. 4.3.2.4). Uranium contamination may also be present (Sect. 4.3.2.1), but the extent is limited. In general, the conclusions of this section are consistent with the previous investigations (summarized in Sect. 1.5) that indicated limited contamination with uranium, and somewhat more, although still localized, contamination with $^{99}Tc$. For example, groundwater contamination with $^{99}Tc$ in the central Hematite Facility area, between the limestone storage area and the main buildings, was documented in 1996 (GEA 1996) and subsequently confirmed with the suggestion that extent was localized to these areas (LBG 1999).

#### 4.3.2.1 Uranium in groundwater

Uranium detected in groundwater by alpha spectrometry is shown in Table 4.18. Uranium in groundwater can be evaluated by comparing the results to the 30-μg/L EPA drinking water standard for uranium. The uranium mass concentration in each groundwater sample was estimated as the sum of $^{234}U$, $^{235}U$, and $^{238}U$ mass concentrations which were, in turn, calculated from the measured activities (e.g., data in Table 4.18) using published specific activities ($^{234}U$: $6.1906 \times 10^{-3}$ Ci/g, $^{235}U$: $2.1616 \times 10^{-6}$ Ci/g, $^{238}U$: $3.362 \times 10^{-7}$ Ci/g). The EPA standard is exceeded in DM-02 (175 μg/L; a deep overburden well next to Deul's Mountain), WS-24 (82.6 μg/L; a shallow overburden well in the Burial Pits area), and WS-26 (32.7 μg/L; a shallow overburden well in the Burial Pits area). Uranium concentrations in WS-07 (a shallow overburden well near the evaporation ponds), BD-03 and BD-16 (deep overburden wells near the buildings) are 6, 6.5 and 23.6 μg/L, respectively. Uranium mass concentrations in the rest of the

groundwater samples from the overburden and bedrock wells were less than 5 μg/L. Measurement errors in the samples with elevated uranium activities (e.g., DM-02) are a relatively small fraction of the actual result. As such, these measurement errors are not expected to affect the mass concentration calculations and subsequent comparison with drinking water standards.

The sample from BD-03 also contained 15 mg/L of iron and 3.5 mg/L of aluminum, hence the uranium in this sample may be explained as natural and/or sorbed to particulates, although the location of the well in the central Hematite Facility area near a location contaminated with chlorinated solvents (Sect. 4.4) suggests contamination from Hematite Facility operations is also possible. In contrast, the other wells containing uranium over the groundwater standard have low levels of iron and manganese indicating a greater probability the uranium is dissolved. The latter is also indicated on Figs. 4.13 and 4.14, which show virtually no difference between $^{234}U$ and $^{238}U$ activities in filtered (<0.45 μm) and unfiltered samples. A similar comparison for $^{235}U$ is not shown because most of the samples in the subset of filtered/unfiltered samples had non-detectable $^{235}U$ activities. Uranium associated with iron oxyhydroxide particulates cannot be completely ruled out based on the presence of these particles inferred from a comparison of total and ferrous iron in more than 100 samples (Sect. 4.2.2.2 and Fig. 4.8e). Figs. 4.13 and 4.14 were based on a much smaller number of co-located filtered and unfiltered samples. Natural occurrences of uranium should also be considered. For example, uranium and its daughter products are associated with some dolomitic and limestone formations in the Midwest (Gilkeston et al. 1983, Sasman et al. 1982, Luczaj 1998).

The groundwater sample from BR-12-RB collected as part of the site-wide groundwater sampling event contained an isotopic activity of $^{234}U$ (12.5 pCi/L) that appeared to be elevated with respect to other bedrock wells. A groundwater sample was collected from BR-12-RB in June 2005, and the measured $^{234}U$ activity in this sample is comparable to $^{234}U$ activities measured in the other bedrock wells (refer Table 4.18) The elevated $^{234}U$ isotopic activity in BR-12-RB sample collected in December 2004 as part of the RI is inconsistent with the overall observation that elevated uranium concentrations in groundwater is limited to the immediate vicinity of known waste areas (e.g., the Burial Pits, the Evaporation Ponds, and under buildings). Other than the December 2004 groundwater sample from BR-12-RB, there is no indication of uranium contamination in the bedrock groundwater. Contaminant transport modeling using a site-specific Kd factor supported the limited mobility of uranium at the Hematite Site (Sect. 5.6). On the other hand, PCE and TCE have spread into the underlying shallow bedrock, and have been detected in a number of the bedrock wells (Sect. 4.4). Thus, uranium contamination without PCE or TCE contamination in the December 2004 sample from BR-12-RB is difficult to reconcile with (1) the more widespread contamination from PCE and TCE, and (2) other evidence for the limited mobility of uranium when compared to PCE and TCE at the Hematite Site. The June 2005 groundwater sample from BR-12-RB is more consistent with previously measured isotopic activities in the other bedrock groundwater samples. It is likely that the elevated $^{234}U$ activity in the December 2004 sample is due to sampling or analytical errors.

#### 4.3.2.2 Thorium in groundwater

Isotopic thorium data are shown in Table 4.19. The values for thorium isotopes are all relatively low, with only four samples (BD-02, BD-03, BD-16, and BR-01-JC) exceeding total isotopic thorium of 1 pCi/L. Moreover, each of these samples contains mg/L levels of iron. A filtered and unfiltered sample were collected and analyzed for BR-01-JC, and thorium isotopes were not detected in the filtered sample. Detection limits of 0.132, 0.149, and 0.018 pCi/L for $^{228}Th$, $^{230}Th$, and $^{232}Th$, respectively, were recorded. Thus, it is clear that the thorium detected in BR-01-JC is a result of particulates collected as part of the groundwater sample; this is also probable in BD-02 and BD-03. Appendix K contains a report on thorium (and radium) isotopes at the Hematite Site.

#### 4.3.2.3 Radium in groundwater

Three samples contained $^{226}$Ra above the MDL (~0.5 pCi/L): BR-12-JC (1.38 pCi/L), BR-01-JC (1.03 pCi/L), and BR-09-JC (1.62 pCi/L); for reference, the drinking water standard $^{226}$Ra of 5 pCi/L. Radium-228 was reported above the MDL (~0.5 pCi/L) in BR-09-JC (1.29 pCi/L). All of these samples are from the Jefferson City Dolomite. In a national survey of 96 groundwater public water supply systems, a USGS study (Focazio et al. 2001) found that 30, 33, and 26% of the samples collected were reported above the MDL of 1 pCi/L [the contractual minimal detectable concentration (MDC)] for $^{224}$Ra, $^{226}$Ra, and $^{228}$Ra, respectively. Thus, the radium activities detected in the Jefferson City wells are not unusual and probably represent natural occurrences. In addition, uranium and its daughter products (i.e., $^{226}$Ra) are associated with some dolomitic and limestone formations in the Midwest (Gilkeston et al. 1983, Sasman et al. 1982, Luczaj 1998). Appendix K contains a report on radium (and thorium) isotopes at the Hematite Site.

#### 4.3.2.4 Technetium-99 in groundwater

Data for $^{99}$Tc are shown in Table 4.20. Clearly, measurable $^{99}$Tc activity is more areally extensive compared to any other inorganic or radiochemical species, but is still limited compared to the extent of VOC migration (refer to Sect. 4.4.5.6 and Chapter 5). Figure 4.15 demonstrates $^{99}$Tc's association with previously identified contamination sources, such as the process buildings and the Evaporation Ponds, and that detectable $^{99}$Tc activity (MDL ~10 pCi/L) is limited to within the Hematite Facility. For reference, the drinking water standard for beta emitters is 4 mrem/yr, which is equal to ~500 pCi/L of $^{99}$Tc. $^{99}$Tc activities are greater than this reference standard in several of the wells shown in Table 4.20.

#### 4.3.2.5 Transuranics in groundwater

Plutonium isotopes were not detected in any groundwater samples. One sample, NB-64 (south-southeast of the Hematite Facility towards Joachim Creek) reportedly contained $^{241}$Am (0.0294 pCi/L), but the result was qualified with "LT" [result was below the requested MDC but higher than the sample-specific MDC]. One sample (BD-16, near buildings) reportedly contained $^{237}$Np at 0.0175 pCi/L, but it was also qualified with an "LT." DOE has established derived concentration guides (DCG) for $^{241}$Am and $^{237}$Np of 30 pCi/L. The reported values are well below the DOE-DCG (DOE 1991).

#### 4.3.2.6 Gross Alpha and Gross Beta in Groundwater

Gross alpha and beta activities in groundwater can be found in Table H.8 of Appendix H. Elevated gross alpha activities were measured in DM-02 (301 pCi/L) WS-24 (132 pCi/L), BD-16 (47.1 pCi/L), BD-02 (26.9 pCi/L), BR-07-RB (19 pCi/L), BD-03 (18.1 pCi/L), WS-26 (18 pCi/L) and BR-10-RB (15.7 pCi/L). The rest of the groundwater samples have gross alpha activities less than 15 pCi/L. For reference, the drinking water standard for gross alpha excluding uranium and radium is 15 pCi/L. The total isotopic uranium activities for the aforementioned samples are: DM-02: 387.8 pCi/L, WS-24: 206.2 pCi/L, BD-16: 19.5 pCi/L, BD-02: 10.0 pCi/L, BR-07-RB: 5.7 pCi/L, BD-03: 16.3 pCi/L, WS-26: 30.6 pCi/L, BR-10-RB: 4.8 pCi/L. After the gross alpha activities are corrected for the U activities, only groundwater samples from BD-16 and BD-02 slightly exceed the drinking water standard.

Gross beta activities were very well correlated with $^{99}$Tc activities in the groundwater samples (i.e., plot for gross beta versus $^{99}$Tc activity results in a straight line, graph not shown). For reference the drinking water standard for beta emitters is 4 mrem/yr, which for $^{99}$Tc is approximately 500 pCi/L.

### 4.3.3 Radionuclides in Sediments

Sediment samples were collected from several locations around the Hematite Site (see Fig. 2.3) and were analyzed for radionuclides, as described in Sect. 2.1.3. Major findings and discussions of the results are presented in this subsection, while the complete data set can be found in Appendix H.9. The review process is essentially the same as that described previously for inorganics (Sect. 4.1.3). An evaluation of disequilibrium was included for samples with anomalous uranium activities.

#### 4.3.3.1 Uranium in sediments

Off-site/background soil samples collected near the Hematite Site (refer to Fig. 2.7 for locations) yielded background values of 0.92 pCi/g for $^{234}U$, a mean of 0.99 pCi/g for $^{238}U$, and a mean of 0.08 pCi/g for $^{235}U$. Development of these background values is discussed in Appendix J. In uranium that is neither enriched nor depleted, the activity of $^{234}U$ and $^{238}U$ are roughly equal and the activity of $^{235}U$ is roughly 5% of the others. These activity ratios are within experimental error of those found in the off-Site samples.

Hence, the activity ratios in conjunction with the off-Site values are useful for examining the origin of uranium at the Hematite Site. Additional perspective may be gained by comparison to regional data. Using the 690-pCi/mg conversion factor described previously, Tidball (1984) reports a geometric mean of 2.6 pCi/g with a range of 0.759 to 10 pCi/g. Hence, locally determined off-Site values are at the lower end of the range reported for Missouri soils.

In addition, to provide further perspective on uranium activities in sediment and soil samples from the Hematite Site, these may be compared to background values used at the Paducah Gaseous Diffusion Plant (PGDP) (DOE 1997). The Paducah site is a reprocessing facility for uranium located approximately 200 miles southeast of the Hematite Site. Background values for isotopic uranium at Paducah are: $^{234}U$ = 2.5 pCi/g, $^{235}U$ = 0.14 pCi/g, and, $^{238}U$ = 1.2 pCi/g (DOE 1997).

Reviewing the data in Table 4.21 in comparison with the off-Site data and activity ratios described above indicates that samples SW-01-SS through SW-07-SS, and possibly SW-11-SS and SW-12-SS, can be distinguished from background based on total activity. SW-01 through SW-07 are located in the Site Pond or the Site Creek (see Fig. 2.3 for locations). SW-11-SS and SW-12-SS are adjacent to the Burial Pit area. Hence, all of these samples are from known contaminated areas where solvents and other radiological contaminants were found. Uranium activities in sediment samples taken directly from Joachim Creek (SW-15, SW-14, SW-08 and SW-16) are comparable to background.

#### 4.3.3.2 Technetium-99 in sediments

Technetium-99 is a man-made isotope that would only be present as a result of human activity (e.g., Hematite Facility operations). Table 4.22 shows that sediment sampling locations SW-01-SS, SW-06-SS, and SW-07-SS (refer to Fig. 2.3 for locations), as with uranium, have measurable $^{99}Tc$ activities. These samples were collected from the Site Pond. A smaller amount of $^{99}Tc$ was reported from SW-12-SS, which was collected next to the Burial Pits.

#### 4.3.3.3 Thorium in sediments

Following the same approach used for uranium (Sect. 4.3.3.1), thorium activities in sediment samples were evaluated through a comparison with activities measured in the off-Site samples collected as part of this RI (see Fig. 2.7 for locations), and with background values from PGDP (DOE 1997). The background values developed from off-Site soil samples for $^{228}Th$ was 1.33 pCi/g, $^{230}Th$ was 1.30 pCi/g,

and $^{232}$Th was 1.32 pCi/g. Development of these background values is discussed in Appendix J. For additional perspective, background values used at PDGP for isotopic thorium were: $^{228}$Th = 1.6 pCi/g, $^{230}$Th = 1.5 pCi/g, and $^{232}$Th = 1.5 pCi/g (DOE 1997).

Thorium was analyzed in sediment samples SW-02-SS through SW-06-SS (refer to Fig. 2.3 for sample locations). Only SW-06-SS shows elevated thorium with respect to the off-Site and PGDP activities, with $^{228}$Th and $^{232}$Th activities both at approximately 5 pCi/g and $^{230}$Th approximately 3 pCi/g. SW-06-SS (collected in the Site Pond, Fig. 2.3) also contained the highest value for uranium (Table 4.21) and $^{99}$Tc (Table 4.22) in sediments. Note that $^{230}$Th comes from $^{238}$U decay chain whereas $^{228}$Th and $^{232}$Th come from the $^{232}$Th decay chain.

#### 4.3.3.4 Transuranics in sediments

$^{237}$Np, $^{238}$Pu, and $^{239/240}$Pu were not detected above their MDLs in the four samples that were selected for transuranics analysis (SW-01, SW-02, SW-07, and SW-13, refer to Fig. 2.3 for sediment sample locations).

### 4.3.4 Radionuclides in Surface Soils

Surface soils samples were collected from locations around the Hematite Site (see Figs. 2.4a and 2.4b), and were analyzed for radionuclides as described in Sect. 2.2. Major findings and discussions of the results are presented in this subsection, while the complete data set can be found in Appendix H.10. The review process is essentially the same as that for inorganics (Sect. 4.2.4.1). An evaluation of disequilibrium was included for samples with anomalous uranium activities.

#### 4.3.4.1 Uranium in surface soils

A gamma survey (SAIC 2003a) performed in 2003 was used to guide the selection of surface soil sampling locations. The coincidence of gamma survey anomalies and surface soil samples potentially containing elevated uranium, as described below, is shown on Fig. 4.16.

Following the approach used for uranium in sediments (Sect. 4.3.3.1), the uranium activities in surface soils are evaluated relative to the measured activities in the off-Site samples collected from locations shown in Fig. 2.7. The background criteria developed from off-Site surface soil sample results are: 0.97 pCi/g for $^{234}$U, 1 pCi/g for $^{238}$U, and 0.07 pCi/g for $^{235}$U. To provide additional perspective, the measured activities in the surface soils are also compared with the background values used for isotopic uranium at PGDP (DOE 1997): $^{234}$U = 2.5 pCi/g, $^{235}$U = 0.14 pCi/g, and $^{238}$U = 1.2 pCi/g (DOE 1997).

Isotopic uranium activities from alpha spectroscopy analysis show that OA-08 (in the center of the Facility area), EP-11 (near the Evaporation Ponds), and NB-14 (in or near the drainage from the Site Pond) are contaminated, with $^{234}$U activities of 472, 103, and 52.3 pCi/g, respectively (other isotopes are shown in Table 4.23). Note that these activities are more than an order of magnitude higher than the background $^{234}$U of 2.5-pCi/g activity used at PGDP. Using a $^{235}$U activity of 0.14 pCi/g, which is the background activity used in PGDP, other data from alpha spectrometry and gamma spectroscopy show a majority of the samples in Table 4.23 are contaminated with uranium. Almost all the potentially contaminated surface samples were collected from areas that were previously suspected of uranium contamination, including the Burial Pits, the Evaporation Ponds, Deul's Mountain, and process buildings.

#### 4.3.4.2 Technetium-99 in surface soil

Technetium-99 is a man-made isotope that could only be present in significant quantities from Hematite Site operations. Table 4.24 shows the $^{99}$Tc detections (MDL ~1 pCi/g) in surface soil samples, while sample locations with detected $^{99}$Tc activities are shown on Fig. 4.17. Several samples collected adjacent to buildings are elevated, most notably at BD-12 (574 pCi/g). However, the samples with the highest $^{99}$Tc activities were collected near the Evaporation Ponds where sample EP-10 exceeded 17,000 pCi/g and EP-08 exceeded 3,000 pCi/g. $^{99}$Tc activities in the composite samples from limestone storage/fill areas ranged were 23 to 94 pCi/g. However, OA-21, adjacent to the limestone storage area, and OA-22, between the limestone storage area and the buildings, both exceeded 600 pCi/g.

#### 4.3.4.3 Thorium in surface soils

Thorium detections in surface soils are presented in Table 4.25. None of the surface soil sample results exceed the background values for the Hematite Site (1.35 pCi/g for $^{228}$Th, 1.39 pCi/g for $^{230}$Th, and 1.32 pCi/g for $^{232}$Th). In addition, none of the results exceed the background values from Paducah [$^{228Th}$ = 1.6 pCi/g, $^{230}$Th = 1.5 pCi/g, and $^{232}$Th = 1.5 pCi/g (DOE 1997)]. Hence, the use of $^{232}$Th at the Hematite Facility has apparently not resulted in impacts above background levels in sediments and soils. As mentioned previously, $^{230}$Th comes from $^{238}$U decay chain whereas $^{228}$Th and $^{232}$Th come from the $^{232}$Th decay chain.

#### 4.3.4.4 Neptunium-237 in surface soils

Samples collected as part of the off-Site background data set were all reported as not detected except for the following results: BG-06-00-SL at 0.0134LT pCi/g and BG-07-03-SL at 0.00923LT pCi/g (refer to Appendix H10a for off-Site radionuclide data set). The background value for $^{237}$Np developed from off-Site surface soil sample results was 0.01 pCi/g.

Several on-Site Hematite samples reportedly contained $^{237}$Np, but most of the data were qualified and only two results are distinguishable from the 0.1 pCi/g used at Paducah and both are surface soils from areas already identified as highly contaminated: EP-02 (0.584 pCi/g) and EP-01 (0.44 pCi/g).

#### 4.3.4.5 Americium-241 in surface soils

Americium-241 was reported only as qualified data in a few samples. The only results exceeding 0.01 pCi/g are the surface soil samples shown in Table 4.26. All results in Table 4.26 are qualified as having both a significant density difference from the laboratory control sample (G) and as having an uncertain identification (TI).

Other reasons to question the values in Table 4.26 are the lack of results intermediate between these and background (<0.01 pCi/g, DOE 1980) and the lack (or low-levels) of $^{237}$Np, which co-occurs with $^{241}$Am. These and the qualifiers suggest these results cannot be considered as confirmed concentrations.

The sample locations in Table 4.26 were reviewed as a further check regarding the value of the data. The Deul's Mountain samples are surface soils collected adjacent to Deul's Mountain. These same Deul's Mountain samples contained elevated $^{99}$Tc and uranium. Similarly, the Evaporation Ponds samples also contained elevated $^{99}$Tc and uranium. Hence, the uncertainty regarding the $^{241}$Am content of these samples is not an issue because there are other important risk drivers that will require further consideration of these locations.

#### 4.3.4.6 Plutonium-238 and plutonium-239/plutonium-240 in surface soils

The background criterion developed from off-Site surface soils results is 0.02 pCi/g for $^{240}$Pu. A relevant background value for $^{238}$Pu is 0.073 pCi/g and for $^{239}$Pu is 0.025 pCi/g (DOE 1997). These values were determined at the Paducah Plant where uranium enrichment was performed and is consistent with the two reported values (both qualified) from the off-Site samples (0.0224 pCi/g LT and 0.0181 pCi/g LT). Only one on-Site $^{238}$Pu result is within an order of magnitude of the Paducah values and that is the surface soil at EP-02 (0.0222 pCi/g). The value is qualified LT and the location is already known to be highly contaminated. Several on-Site samples reportedly contained $^{239}$Pu near the background values (Table 4.27), but all were qualified LT (LT = result is < than MDC but > than sample-specific MDC). Moreover, irrespective of the qualifiers, none of the surface results are distinguishable from the background value determined at Paducah.

### 4.3.5 Radionuclides in Subsurface Soils

Subsurface soil samples were collected from locations around the Hematite Site (see Fig. 2.5a and 2.5b), and were analyzed for radionuclides as described in Sect. 2.3. Major findings and discussions of the results are presented in this subsection, while the complete data set can be found in Appendix H.11. The review process is essentially as that for inorganics (Sect. 4.2.4.1). An evaluation of disequilibrium was included for samples with anomalous uranium activities.

Uranium, technetium, thorium, and plutonium data in subsurface soil samples are presented and discussed in Sects. 4.3.5.1, 4.3.5.2, 4.3.5.3, and 4.3.5.4, respectively.

#### 4.3.5.1 Uranium in subsurface soils

Following the approach used for surface soils, the activities measured in the subsurface soils were evaluated relative to the measured activities in the off-Site samples collected from locations shown in Fig. 2.7. The background criteria developed from the off-Site subsurface soil sample results are: 0.92 pCi/g for $^{234}$U, 0.99 pCi/g for $^{238}$U, and 0.08 for $^{235}$U. To provide additional perspective, the measured activities in the surface soils are also compared with the background values used for isotopic uranium at Paducah (DOE 1997): $^{234}$U = 2.5 pCi/g, $^{235}$U = 0.14 pCi/g, and $^{238}$U = 1.2 pCi/g (DOE 1997).

Subsurface soil data (Table 4.28) indicate that shallow samples associated with the process buildings ("BD"- labeled samples) are contaminated. Likewise, SW-02, located in a low-lying area where drainage from the Hematite Facility collects, and DM-02 collected at Deul's Mountain show significant uranium contamination. A few other samples are potentially elevated above background (BD-16, CB-02, EP-16, EP-17, LF-06, NB-71, and PL-04), but are not significantly contaminated. Except for DM-02-22 (sample collected from 22 ft BGS) the elevated results are from the top 5 ft or less. Moreover, these results coincide with the already-identified contaminated areas. Figure 4.18 shows the subsurface sample locations in Table 4.28.

#### 4.3.5.2 Technetium-99 in subsurface soils

Table 4.29 shows that $^{99}$Tc activities detected in a number of subsurface soils were generally lower than concentrations found in surface soils (Table 4.24). EP-13-30 (30 ft depth, Evaporation Ponds) contained 131 pCi/g of $^{99}$Tc; the rest of the activities were below 30 pCi/g. There are a number of samples containing approximately 10-30 pCi/g and these are all associated with either the Evaporation Ponds or Deul's Mountain. The significantly lower concentrations in the subsurface suggest that although downward migration of $^{99}$Tc is occurring, most of the mass is retained in the surface soils. This is

consistent with the distribution coefficient ($K_d$) measured on samples collected from the Hematite Site (SAIC 2003c) that was relatively high when compared to published literature values.

#### 4.3.5.3 Thorium in subsurface soils

Thorium detections in subsurface soils are presented in Table 4.30. With the exception of SW-02-01 (collected near the Site Pond at 1 ft BGS), and DM-02-22 (collected near Deul's Mountain at 22 ft BGS), none of the results exceed the background values from Paducah [$^{228}$Th = 1.6 pCi/g, $^{230}$Th = 1.5 pCi/g, and $^{232}$Th = 1.5 pCi/g (DOE 1997)]. Hence, the use of $^{232}$Th at the Hematite Facility has apparently not cuased widespread impact to sediments and soils.

#### 4.3.5.4 Plutonium-238 and plutonium-239/plutonium-240 in subsurface soils

Following the approach used for surface soils (Sect. 4.3.4.6), the isotopic plutonium activities measured in the subsurface soils are compared to the relevant background value for $^{238}$Pu, which is 0.073 pCi/g, and for $^{239}$Pu, which is 0.025 pCi/g (DOE 1997). These values are consistent with the two reported values (both qualified) from the off-Site background samples (0.0224 pCi/g LT and 0.0181 pCi/g LT for $^{238}$Pu and $^{239}$Pu, respectively, Appendix H.10a).

Subsurface results (Table 4.31) are all less than the Paducah background sample by approximately an order of magnitude. Hence, it is concluded that neither $^{238}$Pu nor $^{239}$Pu are relevant contaminants at the Hematite Site.

## 4.4 ORGANICS

Samples of surface water, sediments, surface and subsurface soils, and groundwater from the Hematite Site were collected and analyzed for a wide variety of organic contaminants. Sampling and analyses methods were presented in Chapter 2, and the complete data set can be found in Appendices H.12 through H.16. A majority of the organic analytes were not detected above the MDL, or were detected but were below the estimated quantitation limits. Table 4.32 is a similar summary for organic analytes that were detected in at least one sample of sediment, surface, or subsurface soil. Table 4.33 presents a summary of the organic analytes that were detected in at least one sample of surface water and groundwater. The organic analytes are grouped into the following categories: base-neutral-acid extractable organics (BNAs), polynuclear aromatic hydrocarbons (PAHs), dioxins, pesticides, PCBs, petroleum, and VOCs. The BNAs and PAHs comprise the SVOCs that were analyzed using EPA SW-846 8270. Note that not all environmental media samples were analyzed for all the organic compounds; justification for the target analytes selected for each environmental media was described in Chapter 2.

Some of the detections represented in Tables 4.32 and 4.33 are likely to be "false positives." A common cause for false positive results is contamination of samples with common laboratory contaminants during collection, handling, shipping, or analysis. Among the VOCs, methylene chloride, acetone, 2-butanone, and cyclohexane are regarded as laboratory contaminants and frequently are detected in both method blanks and samples alike. For this RI, most of these contaminants were detected in many method blanks and are so noted in the data tables by appropriate validation codes. Among the BNA group of analytes, the common phthalates typically are detected in both samples and blanks. EPA recognizes these analytes as common laboratory contaminants and provides a protocol for screening analyses to avoid reporting false positive results (EPA 1999).

This screening process was not applied in this RI because it requires validation of 100% of the samples. However, it is likely that many of the detections of common laboratory contaminants (e.g., methylene chloride and acetone) in samples from the Hematite Site are false positives.

This RI Report does not include a risk assessment; that evaluation is being provided separately. Consequently, no screening of sediments, soils, surface water, and groundwater analyses for human health or ecological risks related to organic constituents is possible at this time. Rather, Tables 4.32 and 4.33 provide summary level information regarding the analyses for organic analytes and is compared to background results where such information is available. However, it is advantageous to provide a comparison of analytical results against reference concentration values to focus attention on the magnitude and distribution of the more elevated concentrations of constituents observed within any class of compounds. The reference concentrations chosen for this comparison have been extracted from the CALM standards (MDNR 2001) and the preliminary remediation goals (PRGs) from EPA Region 9 (EPA 2004). It is recognized that these are risk-based standards for different media based on potential human health risks alone. However, for the analysis provided in this Report they are simply being applied as reference concentrations to streamline the evaluation of contaminant distributions; no connotation of risk should be associated with this evaluation approach. It is anticipated that once the baseline risk assessment has been completed a more focused risk-based screening can be completed.

The "Scenario A" CALM values or the PRG "Residential Soil" values were used for comparison with the RI sediment and soils data. For water, the CALM standards for "Groundwater" and the PRG entries for "Tap Water" were used as reference concentrations to evaluate the RI surface water and groundwater data. All detects represented in the table were compared against the more conservative of the CALM and PRG levels for each analyte.

The entries in Tables 4.32 and 4.33 are color-coded:

- Gray: media that were not collected and analyzed for a specific group of contaminants.
- Green: analyte not detected above the MDL. Non-detects ("U" qualifier) and "B" qualified results are included in this category.
- White: analyte detected in the sample (no qualifier or "J" qualified results).

For each media and class of constituents listed in Tables 4.32 and 4.33 the number of samples represented in the data set is listed. In addition, for those media/analytes with detectable concentrations the number of samples and maximum concentration observed is provided. The maximum concentration values are in parentheses. All samples with any detectable analytes were then compared to the reference concentrations listed in the tables and this subset of samples form the basis for the discussions of nature and distribution of organic constituents at the Hematite Site. These discussions are organized as follows: organics in surface water (Sect. 4.4.1), organics in sediment (Sect. 4.4.2), organics in surface soils (Sect. 4.4.3), organics in subsurface soils (Sect. 4.4.4), and organics in groundwater (Sect. 4.4.5).

In addition, this section includes other topics related to organic contamination at the Hematite Site. Section 4.4.6 presents a comparison of on- and off-Site laboratory analyses, conducted to validate the on-Site analyses, which was used for measuring VOCs from the discrete interval sampling tests (Sect. 2.4, results presented in Chapter 5). Section 4.4.7 presents a comparison of the MIP screening data with co-located laboratory analysis results. Section 4.4.8 provides a summary of previous studies where organic contamination was detected at the Hematite Site, and compares the results of the RI with these previous studies.

### 4.4.1 Organics in Surface Water

The surface water sampling locations were shown on Fig. 2.2, while sampling and analysis methods were described in Sect. 2.1.2. Surface water was collected both from on-Site and upstream locations. Upstream samples generally are expected to represent background conditions. A complete set of analyses is found in Appendix H.12.

#### 4.4.1.1 BNAs in surface water

There were no detections for BNAs from either on-Site or upstream locations.

#### 4.4.1.2 PAHs in surface water

There were no detections for PAHs from upstream locations and only one detection for on-Site surface water. One sample (SW-01-SW) from Site Pond had a very low-level detect for fluoranthene, a common contaminant associated with byproducts of combustion.

#### 4.4.1.3 Pesticides in surface water

There were no detections for pesticides from either on-Site or upstream locations.

#### 4.4.1.4 PCBs in surface water

There were no detections for PCBs from either on-Site or upstream locations.

#### 4.4.1.5 VOCs in surface water

One water sample from an upstream location had a detectable level of toluene, although it was not detected in any of the on-Site surface water samples. Three on-Site samples had detectable levels of methylene chloride; however the presence of methylene chloride in method blanks associated with these samples suggests these analysis results are from laboratory contamination and do not represent Site conditions. Several on-Site locations had detectable levels of PCE (SW-01, SW-02, and SW-09) and TCE (SW-09 and SW-16). All five of these samples exceeded the reference concentrations listed in Table 4.33. Two of these locations are closely associated with the Hematite Facility (SW-01, SW-09) while the other two samples (SW-02, SW-16) are from Joachim Creek (see Fig. 2.2 for locations)

### 4.4.2 Organics in Sediments

The sediment sampling locations were shown on Fig. 2.2, while sampling and analysis methods were described in Sect. 2.1.3 of this report. Sediment was collected both from on-Site and upstream locations. Upstream samples generally are expected to represent background conditions and may include anthropogenic effects. A complete set of analyses is found in Appendix H.13.

#### 4.4.2.1 BNAs in sediments

No BNA analytes were detected above their respective quantitation limits in upstream sediment samples. In contrast, three BNAs were detected at some on-Site sediment locations and include several phthalates (possible laboratory contaminants) and carbazole (a byproduct of combustion of coal and petroleum). All of these constituents were detected at concentrations below the respective reference standards listed in Table 4.32.

#### 4.4.2.2 PAHs in sediments

A variety of PAH compounds were detected in both sediment and soil samples collected for this RI. Most of the PAHs are known to be byproducts of combustion of coal and/or petroleum products. Vehicular traffic on Highway P located on the northern side of the Site, diesel locomotives traveling on the rail line that passes through the Site, and fallout of emissions from any nearby fossil fuel power plants are possible sources for surface deposition of PAHs in the vicinity of the Site.

Six different PAHs were detected in a small number of background sediment samples. The on-Site distribution of PAH analytes is widespread with thirteen compounds being detected in up to ten different sediment sampling locations.

Six different PAHs were observed at concentrations exceeding their respective reference values in as many as nine on-Site sampling sites (Table 4.35, Fig. 4.19). Among these sites, SW-12-SS is located in Northeast Site Creek and all of the remaining samples exceeding reference concentrations came from Site Pond, and Site Creek. No upstream sediment samples exceeded the reference concentrations. The frequent detection of PAHs above the reference values at on-Site locations suggests a localized source(s) that probably was associated with discharges into Site Pond/Site Creek.

#### 4.4.2.3 Pesticides in sediments

One on-Site sediment sample from Site Pond (SW-01-SS) had a low-level detection for the pesticide endrin, but it did not exceed the reference concentration. No other pesticides were detected in any other on-Site or background sediment locations.

#### 4.4.2.4 PCBs in sediments

Two on-Site sediment samples had detectable quantities of PCB-1260, but neither exceeded the reference values for that compound. Both samples (SW-01-SS and SW-07-SS) are from Site Pond. No background samples had detections for PCBs.

#### 4.4.2.5 VOCs in sediments

Acetone (a common laboratory contaminant) and toluene were each detected in one upstream sediment sample. No other VOCs were observed in the background locations. In contrast, eight different VOCs were detected in on-Site sediment samples with acetone being the most frequently observed. Most of the detectable analytes were chlorinated compounds (PCE, TCE, *cis*-1,2-dichloroethylene (DCE), *trans*-1,2-DCE, and vinyl chloride) that are found in subsurface soils and groundwater at the Hematite Site (see Sects. 4.4.4 and 4.4.5). It is reasonable to infer that discharges to on-Site streams from runoff, wastewater outfalls, and groundwater may deliver these VOCs to surface water where subsequently they can become adsorbed onto organic materials associated with the sediments. None of the detected VOC constituents exceeded their respective reference concentrations in any sediment samples.

### 4.4.3 Organics in Surface Soils

Surface soil samples from the Hematite Site and several off-Site locations were collected and analyzed as part of the RI. Sampling and analysis methods for surface soil samples were described in Chapter 2 of this report. Off-Site locations are shown on Fig. 2.7, whereas on-Site locations are illustrated on Figs. 2.5a and 2.5b. Sect. 3.2.3 describes the soil types associated with the Site (USDA 2003).

The soil survey for Jefferson County indicates that off-Site soil samples collected from the location to the east of the Hematite Site (south of the National Guard armory – Fig. 2.7) are linked to the occurrence of the Kaintuck, Horsecreek, and, possibly, the Wilbur soil series. These soils are well-drained, coarse- to silty-alluvium associated with terrace and flood plain deposits. Although Wilbur soils are not found within the Hematite Site, they are closely similar to the Kaintuck, Horsecreek and other terrace flood plain soils mapped on the Hematite Site.

Off-Site surface soil samples also were collected approximately 3 miles southwest of the Hematite Site adjacent to Highway P (Fig. 2.7). Soils in this area belong to the Useful and Freeburg soil series, both of which are found on the Hematite Site.

From this brief assessment, it is apparent that surface soil samples from both background locations are from a group of soil series also found on the Hematite Site or, in the case of Wilbur soils, closely related to soils found on-site. Therefore, analytical results for contaminants in background soils should provide a valid basis for comparison with similar data obtained from Site soils.

On-Site samples were analyzed for the full suite of analytes whereas VOCs were the only organics for which background samples were analyzed. A complete set of analyses is found in Appendix H.14; analysis results for the off-Site samples are provided in Appendix H.14a.

Surface soil samples from background locations were not analyzed for BNAs, PAHs, pesticides, and petroleum analytes. Consequently, no comparison with results from on-Site surface soil samples is possible for these constituents.

#### 4.4.3.1 BNAs in surface soils

A range of BNA compounds were detected in on-Site surface soil samples. Four phthalates (regarded as common laboratory contaminants) constitute the most frequently detected analytes. In addition, carbazole (a common product of combustion) was detected in about 17% of the samples. With the exception of di-n-octyl-phthalate in one surface soil sample (DM-02-00, near Duel's Mountain: refer to Fig. 2.5b for location), none of the detected BNAs exceeded their respective reference concentrations.

#### 4.4.3.2 Dioxins in surface soils

The process used to compare the measured concentrations of dioxins in samples to a reference concentration follows guidance in EPA (1989). Toxicity Equivalence Factors (TEF) for each dioxin cogener are multiplied by the observed concentrations for the respective cogeners and the results are then summed to produce a Toxicity Equivalent Concentration (TEQ) for the sample. The sample TEQs are compared to the PRG reference values for 2,3,7,8-TCDD for the appropriate media (soil or tap water) to determine any exceedances.

The dioxins 1,2,3,4,6,7,8-HPCDD; 2,3,7,8-TCDF; OCDD; and OCDF were detected at one on-Site location (one sample and one field duplicate) where samples were collected for this analysis (Table 4.36). Location CB-01 is at the Cistern Burn Pit AOC and past activities at this location may account for the presence of low levels of dioxins in surface soil. Dioxin levels (TEQs) in both the sample and duplicate exceed the reference concentration for soil.

#### 4.4.3.3 PAHs in surface soils

Thirteen different PAH compounds were detected in on-Site surface soil samples and some of them (e.g., various anthracenes, pyrenes, fluoranthenes, and chrysene) were found in nearly 80% of samples analyzed.

In comparison to their respective reference concentrations, 41 on-Site samples had exceedances for benzo(*a*)pyrene. Four other PAHs also exceeded their reference concentrations in at least one of these samples (Table 4.37). Samples with PAH contamination above reference level concentrations are illustrated on Figs 4.20a and 4.20b. Most of these locations surround the Hematite Facility and include most AOCs in the immediate vicinity of the buildings. Burning of gasoline (automobiles), diesel fuel (trucks, train locomotives, generators, and residential/commercial heating), wood (home heating and controlled forest burns), and coal (power plants) all produce copious quantities of PAHs that can occur as fallout. Runoff from asphalt pavement (e.g., roads, parking lots) can also be a significant source of PAHs. The location of the Hematite Facility next to a state highway and railroad may point to these sites as likely sources of PAHs, although other local sources may be important as well. Surface soils and stream sediments are most susceptible to contamination because most PAHs have limited solubility.

#### 4.4.3.4 Pesticides in surface soils

All but one of the pesticides listed in Table 4.32 was detected in at least one on-Site surface soil sample. DDT, endrin, and endosulfan II were most frequently observed. It is likely that periodic use of pesticides on or near the Hematite Facility can account for small residues being found in surface soil samples. In addition, prior to construction of the Hematite Facility, the land was farmed. It is possible that some pesticide residues date to that period of time. None of the pesticides were detected at a concentration above the corresponding reference concentration.

#### 4.4.3.5 PCBs in surface soils

No surface soil samples from background locations had detectable quantities of PCBs. However, both PCB-1254 and PCB-1260 were detected in 12% and 22% of the samples collected, respectively. Five surface soil samples (and one field duplicate) had a detection of PCB-1260 above the reference level (Table 4.38). In addition, one of these samples also had PCB-1254 above its reference level. All of these locations surround the Hematite Facility and are associated with recognized AOCs (refer to Figs. 2.4a and 2.4b for sample locations):

- Burial Pit – BP-07,
- Evaporation Ponds – EP-04,
- Limestone Fill Areas – LF-01,
- Outer Area – OA-08 (near the Burial Pit), and
- Red Room Roof Burial Area – RR-01.

#### 4.4.3.6 Petroleum in surface soils

Three of the six samples (collected from the former gas station north-northeast of the Hematite Facility on Highway P, Fig. 2.4a) tested for petroleum had no detectable amounts of either diesel fuel or gasoline. However, gasoline was detected in one sample, but only with an approximate concentration (J qualified). Three samples showed diesel contamination, although those compounds detected were in the heavier end of the retention time window and their pattern did not resemble those expected for common diesel fuel products and may be the result of weathering of the lighter components

through aging (Table 4.39). No samples exhibited petroleum concentrations in excess of a reference level for TPH (200 mg/kg).

#### 4.4.3.7 VOCs in surface soils

The only VOC compounds detected in surface soil samples from background locations were methylene chloride (a common laboratory contaminant) and toluene. Both analytes were frequently observed in these samples. For on-Site surface soil samples, acetone and methylene chloride (both common laboratory contaminants), toluene, PCE, and TCE were detected. Both PCE and TCE probably are related to activities at the Hematite Site. None of the on-Site samples with detectable VOCs exceeded their respective reference concentrations.

### 4.4.4 Organics in Subsurface Soils

The subsurface soil sampling locations are shown on Figs. 2.5a and 2.5b. All locations are on the Hematite Site and all samples were analyzed for the complete suite of contaminant groups. A complete set of analyses is found in Appendix H.15.

#### 4.4.4.1 BNAs in subsurface soils

Seven different BNA compounds were detected in on-Site subsurface soil samples. The great majority of these detections were for bis(2-ethylhexyl) phthalate and other phthalate analytes. However, phthalates often are associated with laboratory contamination and there presence in the soils may not be significant. None of the BNA constituents detected in these soils exceeded their respective reference concentrations.

#### 4.4.4.2 Dioxins in subsurface soils

Two dioxin compounds, 1,2,3,4,7,8-HxCDD and 1,2,3,6,7,8-HxCDD, were detected in three subsurface soil samples (including one sample and its field duplicate) collected for dioxin analysis (limited to the Cistern Burn Pit Area) (Table 4.40). The samples came from three different depths within boring CB-02, which is located near the Cistern Burn Pit AOC and the detections were observed in samples taken from depths of 5 ft and 15 ft. The TEQs for these samples (and the duplicate) do not exceed the reference concentration for dioxins. Refer to Sect. 4.4.3.2 for a discussion of how the TEQ is determined.

#### 4.4.4.3 PAHs in subsurface soils

Similarities exist between on-Site surface and subsurface soils in regard to the spectrum of PAH compounds detected. For both groups of samples benzo(*a*)anthracene, benzo(*a*)pyrene, benzo(*b*)fluoranthene, and chrysene were most frequently detected, although a range of other PAHs also were observed. A major distinction between surface and subsurface soils is that PAHs were detected in only a small percentage (<10%) of the subsurface samples. The low solubility of PAHs in water probably accounts for their limited subsurface distribution. The likely sources of the PAHs are discussed in Sect. 4.4.3.3.

Ten subsurface soil samples (including one field duplicate) from eight locations (Fig. 4.19; Table 4.41) had detects for at least one PAH [benzo(*a*)pyrene] at concentrations above their respective reference levels. These sample locations are closely associated with the Hematite Facility and include the Limestone Fill and Burial Pit AOCs.

#### 4.4.4.4 Pesticides in subsurface soils

Rare detects of six different pesticides were observed in subsurface soil samples and the sample locations appear to be randomly distributed. No pesticides were detected at concentrations that exceed the reference values.

#### 4.4.4.5 PCBs in subsurface soils

There were no PCB analytes detected above the risk-based screening levels for any subsurface soil samples. However, there were detects for PCB-1254 in one sample and PCB-1260 in two other samples from the Hematite Site. These soil samples are associated with Building 253, the Leach Field, and the Evaporation Ponds.

#### 4.4.4.6 Petroleum in subsurface soils

There were no detects of diesel fuel or gasoline in any subsurface soil samples that were analyzed.

#### 4.4.4.7 VOCs in subsurface soils

A large number of VOC analytes were detected in subsurface soil samples at the Hematite Site. Among these were frequent occurrences of acetone, 2-butanone, and methylene chloride (common laboratory contaminants). However, a wide range of other VOCs were detected, including PCE, TCE, and their common degradation products. Twenty-five to 30% of the samples yielded detectable quantities of PCE and TCE.

Only four VOCs (methylene chloride, PCE, TCE, and 1,1-DCE) had concentrations that exceeded their respective reference levels (Table 4.42). PCE and TCE were detected above their reference concentration levels in 14 and 17 samples, respectively, whereas the other two analytes exceeded their reference levels in only a single sample (including a field duplicate). Locations of subsurface soil samples that exceed reference levels for PCE and TCE are illustrated on Fig. 4.21.

### 4.4.5 Organics in Groundwater

Groundwater samples were collected from on-Site wells and their locations are shown on Figs. 2.6a and 2.6b, while sample collection and analysis methods are presented in Sect. 2.6. A complete set of analyses is found in Appendix H.16.

#### 4.4.5.1 BNAs in groundwater

Three BNA analytes were detected in groundwater from the Hematite Site, including a phthalate, hexachloroethane, and phenol. Only two analytes (the phthalate and hexachloroethane) exceed their respective reference concentrations (Table 4.43). Bis(2-ethylhexyl)phthalate was observed at four locations and hexachloroethane was found in a single groundwater sample (BD-02) above their reference concentration levels. The phthalates are considered to be common laboratory contaminants and this may be the source of this compound in these samples. All of the locations are in close proximity to the Hematite Facility, so that a local source cannot be ruled out. AOCs encompassing these locations are: under the buildings, the Limestone Fill Areas, the Evaporation Ponds, and the Red Room Roof Burial Area (see Fig. 1.4 for AOCs and Figs. 2.6a and 2.6b for well locations). Note that all these wells are screened in the overburden.

#### 4.4.5.2 Dioxins in groundwater

Dioxins were analyzed in only one groundwater sample (CB-02, from the Cistern Burn Pit) and only 2,3,4,6,7,8-HxCDF was detected. The TEQ for this sample did not exceed the reference concentration for dioxins.

#### 4.4.5.3 PAHs in groundwater

There were no detections of PAHs in any groundwater samples that were analyzed.

#### 4.4.5.4 Pesticides in groundwater

There were no detections of pesticides in any groundwater samples that were analyzed.

#### 4.4.5.5 PCBs in groundwater

There were no detections of PCBs in any groundwater samples that were analyzed.

#### 4.4.5.6 VOCs in groundwater

Twenty VOC analytes were detected in groundwater samples from the Hematite Site. The contaminants fall into two groups. First, there are three constituents that are recognized as common laboratory contaminants:

- Acetone
- Methylene chloride
- 2-butanone

In addition, benzene, toluene, and xylenes were detected in some samples. These three compounds are constituents of fuels (e.g., gasoline) and that may be their source. Low levels of carbon disulfide were detected in four samples.

The second group includes only chlorinated compounds:

- Chloroethane;
- Chloroform;
- Chloromethane;
- 1,1-Dichloroethane;
- 1,2-Dichloroethane;
- 1,1-Dichloroethene;
- *cis*-1,2-DCE;
- *trans*-1,2-DCE;
- PCE;
- 1,1,1-Trichloroethane;
- 1,1,2-trichloroethane;
- TCE; and
- Vinyl chloride.

A total of 80 (including 6 field duplicates) samples contained 1 or more constituents that exceeded reference concentration levels (Table 4.44). The location of these samples is presented and discussed in

Chapter 5, and is associated with a detailed discussion of the principal contaminants and their F&T. With the exception of 2 samples in which methylene chloride is the sole VOC contaminant, the remaining 78 (including 6 field duplicates) samples each contain at least PCE or TCE, and usually both. This is a significant finding because it draws attention to the fact that PCE and TCE are the key chlorinated organic contaminants found in groundwater at the Hematite Site. The most common occurrences of chlorinated VOCs above reference concentrations among the groundwater samples are:

- PCE;
- TCE;
- 1,1-DCE;
- *cis*-1,2-DCE;
- *trans*-1,2-DCE; and
- Vinyl chloride.

The discussion in Chapter 5 provides information suggesting that these six contaminants may have a common origin, with PCE and TCE as parent contaminants widely used at the Hematite Facility, and the other constituents as potential degradation products of them as a result of microbial reductive dechlorination reactions.

Most of the remaining contaminants were detected in only a few samples. Their specific origin or source is more difficult to define because they are not cited as having been used or stored at the Hematite Facility (Table 1.3). More importantly, however, is the fact that their occurrence always coincides with the locations where the primary contaminants in groundwater (i.e., PCE, TCE, etc.) also are found. This coincidence permits the discussion to focus only on these primary contaminants, with the knowledge that these lesser constituents will be addressed simultaneously with them.

### 4.4.6 Comparison of Volatile Organic Compounds in Groundwater as Determined by Mobile and Off-Site Laboratories

During the summer of 2004, groundwater samples from six wells were analyzed by both an on-Site mobile laboratory and a fixed laboratory located remotely. Confirmation of the on-Site analyses with laboratory analysis was needed to validate on-Site mobile analyses of samples obtained during discrete interval sampling in the bedrock boreholes and domestic wells. The results of the discrete interval sampling are presented and discussed in Chapter 5.

Seven chlorinated VOC analytes were included in the comparison between the on-Site and fixed laboratory, and the results are provided in Table 4.45. In general, the results are comparable: 75% of the concentrations for specific constituents for sample splits from the same well agree within 15% of one another. The poorest agreement was for 1,1-DCE. The samples collected from PW-19 (207-227 ft BGS) account for most of the disagreement in results. The mobile laboratory tended to report lower concentrations than the off-Site laboratory for most analytes where disagreement was observed.

### 4.4.7 Comparison of MIP Results with Soil and Groundwater Sample Analyses

One of the more important tasks associated with this RI was developing an efficient method for selecting locations for collecting subsurface soil samples and for construction of monitoring wells from which groundwater samples could be obtained. One approach is to collect and analyze subsurface soil samples and to base future decisions on the results. However, the time between sample collection and receipt of analyses can be lengthy. As a result of this concern, a rapid field-based method that uses a MIP was used to facilitate selection of monitoring well locations.

As noted in Sect. 2.3.1, subsurface soil core material was collected by advancing split-spoon samples with a DPT probe. The core was scanned with a hand-held PID and selections were made of several 2-ft intervals of soil core for each location. These samples were sent to an off-Site laboratory for analysis. The results of these analyses are discussed in Sect. 4.4.4 and the results are tabulated in Appendix H.15.

In addition, at nearly all locations where soil and groundwater samples were collected, the Geoprobe™ was used to advance the MIP and to obtain screening-level data for selecting sampling sites and depths. The MIP consists of a membrane inserted in the wall of a tool that is attached to the Geoprobe™. When the membrane is heated electrically, it becomes permeable to volatile compounds in the soil and groundwater next to the probe. The heat helps mobilize the volatiles, which pass through the membrane and are conveyed to three different detectors, as listed below:

- PID,
- FID, and
- ECD.

These detectors respond to somewhat different compounds: the PID and ECD are more sensitive to chlorinated VOCs than the FID.

A complete set of results from the MIP is provided in Appendix B. Figures 4.22, 4.23, and 4.24 are examples of the response of these three detectors as a function of depth at three different sites:

- BD-02: soil highly contaminated with PCE (Fig. 4.22),
- OA-18: soil significantly contaminated with TCE (Fig. 4.23), and
- NB-50: soil with no detectable PCE or TCE (Fig. 4.24).

The detector responses are plotted with the same scale for each sample to simplify a comparison among them. These figures also contain the results of soil and groundwater analyses (where available) performed by the off-Site laboratory that are shown at the proper depth interval from which they were obtained.

Note that the ECD appears to respond best to the regions of known PCE and TCE contamination. The PID has a lesser response and the FID only shows a response in BD-02 (it is unclear if it is detecting PCE or another co-located VOC). Very little response was observed for any detector at NB-50, a result consistent with the absence of contamination. These detectors are not specific for any particular VOC, but the ECD appears to have the most reliable response to regions in the borehole that are known to be contaminated with PCE and TCE.

The results of the comparison of the MIP analysis with those from conventional soil analyses suggest that it is a useful tool for real-time screening of locations for contamination. The combination of detectors permits qualitative assessment of the presence of both chlorinated and non-chlorinated organics.

### 4.4.8 Organic Contamination Identified in Previous Investigations at the Hematite Site

Three prior investigations provide analyses for sediment, subsurface soil, surface water, and groundwater for selected locations at the Hematite Site (LBG 1999, 2002b). These studies only give results for VOC analytes. Table 4.46 is a summary of the types of media, sample locations, and those samples for which at least one VOC contaminant was detected. Wells were installed as part of these studies, and well locations of the pre-RI wells can be found on Figs. 1.2 and 1.3, but are also included on Figs. 2.6a and 2.6b.

Surface water was collected from four locations:

- Northeast Site Creek 15 ft above the confluence with Joachim Creek (SW-1),
- Lake Virginia/Site Creek Combined Tributary 150 ft south of the railroad bed (SW-3),
- within the banks of Joachim Creek midway between SW-1 and SW-3 (SW-2), and
- beneath the bridge over Joachim Creek in the town of Hematite (SW-4).

Sediment locations SS-1 and SS-2 correspond to surface water locations SW-1 and SW-2, respectively.

In general, the contaminants found in all media from these different investigations are limited to a few, key chlorinated compounds and include the following:

- TCE;
- PCE;
- *cis*-1,2-DCE (and total 1,2-DCE);
- Vinyl chloride; and
- 1,1-dichloroethane.

Most of the soil and groundwater samples included in the LBG (1999) investigations come from locations surrounding the Burial Pit, although several are distributed along the south side of the Hematite Facility. In addition, the LBG (2002b) study primarily focused on locations BR-1, BR-2, BR-3, and BR-4, which are more widely distributed across the site.

Results from the LBG (1999) report cannot be directly correlated with data from this RI, as groundwater from these wells and locations was not analyzed. In addition, wells WS-24 and WS-28 and soils from locations WS-27, WS-29, and WS-32 (LBG 1999) were not sampled during the study.

In general, the results for VOC analyses from these earlier investigations are consistent with contaminant data obtained during the RI. Not only is the areal distribution of contamination similar, but also the specific zone exhibiting contamination in BR-4 (95 to 105 ft BGS) reported by LBG (2002b, Table 5) agrees with results from the current study. Although the concentration of specific contaminants varies somewhat for samples from the same location among the different investigations, there is agreement in the general level of contamination. The major exceptions to this observation are for groundwater samples from WS-29, WS-30, and WS-31 where concentrations for the key VOC contaminants observed during the RI are significantly higher than reported by LBG (1999). Much lower concentrations of the VOCs were observed in groundwater from WS-32 during the RI than reported by LBG (1999). These observations suggest that the details of contaminant migration in groundwater in the vicinity of the Burial Pit may have changed over the past few years.

Detection of contaminants in surface water by LBG (1999) was confined to a very low concentration of PCE at a single location in Joachim Creek (SW-3). No contamination was detected in the upgradient sample, SW-4. During the RI, several low concentration detections of PCE; TCE; and *cis*-1,2-DCE were observed in the Lake Virginia/Site Creek Combined Tributary and Joachim Creek. Sampling of discharges from the wastewater treatment facility to Outfall No. 1 (located immediately downstream of the dam at Site Pond), as part of the NPDES program in 2004, yielded detectable amounts of both PCE and *cis*-1,2-DCE. This may account for some of the contamination observed in surface water samples analyzed as part of the RI.

## 4.5 SUMMARY OF FINDINGS IN AREAS OF CONCERN

The site-wide distributions of RCOPCs and CCOPCs based on the RI analytical data were presented in the previous subsections, with each subsection devoted to a major class of constituents (e.g., inorganics, radionuclides and organics). In this subsection, the analytical findings for the previously identified constituents of potential concern at each of the AOCs are summarized. As expected, elevated constituent concentrations or activities were present in various locations within the Site, however, the data also shows that some or all of the RCOPCs and/or CCOPCs were either not detected or were present at relatively low levels at a number of the AOCs. Note that a quantitative assessment of risk is being conducted and will be presented in a separate report.

### 4.5.1 AOC #1 Groundwater

The constituents of potential concern in AOC #1 Groundwater are chlorinated solvents (PCE, TCE and associated degradation products), fluoride, uranium isotopes ($^{238}U$, $^{235}U$, $^{234}U$) and $^{99}Tc$.

**Chlorinated solvents.** As mentioned previously (Sect. 4.4.5.6), VOC analyses of groundwater samples indicate that PCE and TCE are the key chlorinated organic contaminants found in groundwater at the Hematite Site (data in Table 4.44 and Appendix H.16f). These two constituents together with their degradation by-products (1,1-DCE, *cis*-1,2-DCE, *trans*-1,2-DCE, and vinyl chloride) are the most commonly occurring VOCs in the Site groundwater. A detailed discussion of PCE and TCE distribution in groundwater is presented in Chapter 5, where plumes in the overburden and bedrock hydrogeologic units are delineated based on the groundwater data. A conceptual model for PCE and TCE transport from the Facility is also presented in Chapter 5.

**Fluoride.** Subsurface soil samples, collected several months before the groundwater samples, were analyzed for fluoride, which was initially considered as a groundwater CCOPC (see Sect. 1.6). However, fluoride levels in the subsurface soil samples were mostly below or slightly above the reporting limit of ~7 mg/kg with the exception of a few samples from the Evaporation Ponds and under the buildings (Sect. 4.2.5.2). Thus, groundwater samples were not analyzed for fluoride.

**Uranium.** The RI groundwater data, presented and discussed in Sect. 4.3.2.1 and Table 4.18, suggest that uranium has not migrated to the same extent as the chlorinated VOCs, and the elevated activities are present in the overburden groundwater in localized areas within the Facility. These areas include: Deul's Mountain, the Burial Pits Area, the Evaporation Ponds and under the process buildings. The groundwater data from the bedrock wells do not indicate uranium contamination in the bedrock formations underlying the Hematite Site.

**Technetium-99.** $^{99}Tc$ activity was only detected in the overburden groundwater in localized areas in the Facility (Sect. 4.3.2.4 and Table 4.20), and similar to uranium, $^{99}Tc$ has not migrated in the groundwater to the same extent as the chlorinated solvents.

### 4.5.2 AOC #2 Surface Water Features

The constituents of potential concern in surface water features within the Hematite Site are chlorinated solvents (PCE, TCE and associated degradation products), fluoride, uranium ($^{238}U$, $^{235}U$, $^{234}U$), $^{99}Tc$, and $^{232}Th$. The surface water features included in this AOC are: the Site Pond and Creek, the Northeast Site Creek, and Joachim Creek. The following is a summary of findings for each of the surface water features that comprise AOC #2.

#### *4.5.2.1 Site Pond and Site Creek.*

The Site samples collected from the Site Pond and Creek are: surface water samples SW-01-SW and SW-02-SW, and sediment samples SW-01-SS through SW-07-SS (refer to Figs. 2.2 and 2.3 for sample locations).

**Chlorinated solvents.** Low levels of PCE and TCE were detected in the Site Pond and Site Creek surface water and sediments (Sects. 4.4.1.5 and 4.4.2.5; Table 4.34, and Appendix H.13e). These data indicate that the elevated levels of chlorinated VOCs in the subsurface soil underneath the Facility (refer to Table 4.42) have had minimal impacts on the Site Pond and Site Creek.

**Uranium.** Surface water and sediment data from the Site Pond (Sects. 4.3.1 and 4.3.3.1; Tables 4.17 and 4.21) indicate elevated uranium activity relative to upstream values. A limited amount of discharge into the Site Pond from the outfalls is allowed by the NPDES permit (refer to Figure 1.2 for outfall locations). The highest uranium activities in the surface water samples (Table 4.17) were measured in a sample from the Site Pond; this sample also contained a high aluminum concentration (likely from clay particles) suggesting that the uranium in the surface water may be sorbed onto suspended particulates. Uranium activities both in surface water and sediment decrease in the Site Creek downstream of the Site Pond dam.

**Technetium-99.** $^{99}$Tc was not detected in any of the surface water samples from the Site (Sect. 4.3.1). $^{99}$Tc was detected in the sediment samples from the Site Pond, but activities decreased significantly in the Site Creek sediments (Sect. 4.3.3.2, Table 4.22).

**Thorium.** $^{232}$Th was not detected in any of the surface water or sediment samples from the Site Pond and Site Creek (it was not detected in any of the surface water and sediment samples from the Site, Table H.7 and H.9).

**Fluoride.** Fluoride was not detected in any of the surface water samples from the Site Pond and Site Creek (Appendix H.2). It was detected in the sediment samples from the Site Pond (maximum of 28 mg/kg) but was not present in any of the sediment samples from the Site Creek (Appendix H.4).

#### *4.5.2.2 Northeast Site Creek*

The Site samples collected from the Northeast Site Creek are surface water sample SW-09-SW and sediment samples SW-10-SS through SW-13-SS (refer to Figs. 2.2 and 2.3 for sample locations).

**Chlorinated solvents.** PCE and TCE were detected at very low levels (i.e., below report limits of 5 μg/L) in the surface water and sediment samples from the Northeast Site Creek (Table H.12e and H.13e for data). These data suggest that any chlorinated solvents historically disposed of in the Burial Pits (Sect. 1.4) and elevated levels of chlorinated VOCs in subsurface soil underneath the Facility (Table 4.42) have had minimal impact on the Northeast Site Creek.

**Uranium.** Uranium activities in the surface water and sediment samples from the Northeast Site Creek are slightly elevated relative to the upstream samples (Appendix H.7 and H.9 for data). The data suggests that uranium known to be present in the Burial Pits based on disposal records (Sect. 1.4) has had a minimal impact on the Northeast Site Creek that runs adjacent to the Burial Pits area.

**Technitium-99.** $^{99}$Tc and thorium were not detected in any of the surface water or sediment samples from the Northeast Site Creek (Appendix H.7 and H.9 for data).

**Fluoride.** Fluoride was detected at a very low level (i.e., 0.67 mg/L slightly above the reporting limit of 0.5 mg/L) in the surface water sample from the Northeast Site Creek. Fluoride was also detected in some of the sediment samples from the Northeast Site Creek (maximum concentration of 10 mg/kg).

#### *4.5.2.3 Joachim Creek*

The Site samples collected from Joachim Creek are surface water samples SW-15-SW, SW-14-SW, SW-08-SW and SW-16-SW, and sediment samples SW-15-SS, SW-14-SS, SW-08-SS and SW-16-SS (refer to Figs. 2.2 and 2.3 for sample locations).

**Chlorinated solvents.** TCE and *cis*-1,2-DCE were detected in one surface water sample from Joachim Creek at a level below the reporting limit of 5 μg/L (data shown in Appendix H.12e).

**Uranium and Technetium-99.** Uranium activities in surface water and sediment samples from Joachim Creek are comparable to upstream values; $^{99}$Tc was not detected in any of the samples (data shown in Appendix H.7 and H.9). These data suggest that uranium and $^{99}$Tc known to be present in the Facility have not impacted Joachim Creek.

**Fluoride.** Fluoride in the surface water and sediment samples from Joachim Creek are comparable to upstream values (data shown in Table H.2 and H.4).

### 4.5.3 AOC #3 Burial Pits

The constituents of potential concern for soil and groundwater at AOC #3 Burial Pits are chlorinated solvents (PCE, TCE and associated degradation products), fluoride, uranium ($^{238}$U, $^{235}$U, $^{234}$U), $^{99}$Tc, and $^{232}$Th.

**Chlorinated solvents.** Maximum concentrations of PCE and TCE in soil samples collected from the boreholes within and around the periphery of the Burial Pits area are 170 μg/kg and 45 μg/kg, respectively. However, almost all groundwater samples collected from wells within the Burial Pit Area had detectable concentrations of TCE, PCE and their degradation products (Table 4.44). The Burial Pits area is identified as one of the zones of highest groundwater concentrations of PCE and TCE, and is a potential source zone for groundwater plumes in the overburden and bedrock (see Sect. 5.3).

**Uranium, Technitium, and Thorium.** The RI groundwater data confirmed the presence of uranium and $^{99}$Tc in overburden groundwater directly beneath the Burial Pits (e.g., refer to data for WS-24 and WS-26 in Table 4.18 and 4.20). $^{232}$Th was also detected in the groundwater samples from the Burial Pits (Table 4.19).

**Fluoride.** Fluoride was detected above the reporting limit of ~7 mg/kg in almost all the surface soil samples from and adjacent to the Burial Pits area (BP-labeled samples in Table H.5). The highest fluoride level in the surface soil samples from the Burial Pits (62 mg/kg) is well below the geometric mean of regional values reported by Tidball (1984). A majority of the fluoride results for the subsurface soil sample from this AOC are below the reporting limit (BP-labeled samples in Table H.6). The highest fluoride level in the subsurface soils from this AOC is 18 mg/kg.

### 4.5.4 AOC #4 Evaporation Ponds

The constituents of potential concern at AOC #4 Evaporation Ponds are chlorinated solvents (PCE, TCE and associated degradation products), fluoride, uranium ($^{238}$U, $^{235}$U, $^{234}$U), $^{99}$Tc, and $^{232}$Th.

**Chlorinated Solvents.** Similar to the Burial Pits, some of the highest concentrations of PCE and TCE in subsurface soil and groundwater at the Hematite Site were detected in the Evaporation Ponds area (Table 4.42 and 4.44, EP-labeled samples). This area is a potential source zone for PCE and TCE plumes in Site groundwater (discussed in Chapter 5).

**Uranium.** A number of surface and subsurface soil samples collected from the Evaporation Ponds are potentially contaminated with uranium (Table 4.23 and 4.28, discussion in Sects. 4.3.4.1 and 4.3.5.1). On the other hand, the overburden monitoring wells in the immediate vicinity of the Evaporation Ponds all have low U activities (data shown in Table H.8, EP-labeled samples). The highest $^{234}$U activity in the EP wells was 0.108 pCi/L. These data suggest that uranium present in the Evaporation Ponds is not migrating via groundwater away from this area.

**Technetium.** Several surface soil samples from the Evaporation Ponds had detectable levels of $^{99}$Tc (Table 4.24). The highest $^{99}$Tc surface soil activity at the Site was measured in a sample from Evaporation Ponds (EP-10-00-SL: 17,100 pCi/g). $^{99}$Tc was also detected in the overburden monitoring wells in the immediate vicinity of the Evaporation Ponds. One of the highest $^{99}$Tc activities at the Site was measured in monitoring well EP-20 (2080 pCi/L, see Table 4.20 for other $^{99}$Tc groundwater activity data). As mentioned previously, elevated $^{99}$Tc is present in the overburden groundwater but appears to be localized, and migration away from these localized areas did not occur to the same extent as for PCE and TCE.

**Thorium.** $^{232}$Th was detected in surface soil, subsurface soil and groundwater samples from the immediate vicinity of the Evaporation Ponds (Tables 4.19, 4.25, and 4.30). $^{232}$Th in the monitoring well EP-15 was measured at 0.007 pCi/L (Table 4.19).

**Fluoride.** Some of the highest fluoride levels in the surface and subsurface soil samples at the Site were measured in samples from the Evaporation Ponds area. However, as noted in Sects. 4.2.4.3 and 4.2.5.2, the highest fluoride level in these samples is still below the geometric mean of regional values reported by Tidball (1984).

**Metals.** Although metals were not included in the list of CCOPCs for the Evaporation Pond area, a number of metals (e.g., arsenic and mercury) were detected at elevated levels relative to Site and regional background values in surface soil samples from the the Evaporation Ponds area (Table 4.13 and Fig. 4.11). Only arsenic was detected above the range of local and regional background values in the subsurface soils (Table 4.15, Table 4.16, Fig. 4.12). Arsenic was not detected in any of the monitoring wells near the Evaporation Ponds (Appendix H.3).

### 4.5.5 AOC #5 Former Leach Field/Sanitary Sewer System

The potential constituents of concern at AOC #5 are: chlorinated solvents (PCE, TCE and associated degradation products), fluoride, uranium ($^{238}$U, $^{235}$U, $^{234}$U), $^{99}$Tc, and $^{232}$Th.

**Chlorinated Solvents.** PCE and TCE were detected in the subsurface soil samples from the Leach Field (maximum values are 80 and 19 μg/kg for PCE and TCE, respectively; Appendix H.15g). The concentrations of PCE and TCE in the LF-monitoring wells are in the upper range of values measured at the Site (e.g., PCE at LF-09 is 14,000 μg/L). The relatively low soil concentration, and high groundwater concentration in the LF-samples suggest that the chlorinated VOCs in the groundwater in the Leach Field area may be a result of migration from upgradient areas (e.g., the process buildings), and not from contaminated subsurface soils in the Leach Field area.

**Uranium.** None of the surface soils from the Leach Field (labeled "LF") contained $^{235}$U above the MDL (~0.5 pCi/g) (data shown in Appendix H.10). Elevated uranium activities were detected in only one

subsurface soil sample (LF-06-05-SL, Table 4.28, data in Appendix H.11); $^{235}U$ activity was not detected in any of the other subsurface samples from this AOC. Uranium activities in the Leach Field wells were low (i.e., less than 2 pCi/L; data in Appendix H.8).

**Technetium and Thorium**. $^{99}Tc$ was detected in one of the Leach Field groundwater wells (LF-08, 246 pCi/L) although none of the surface or subsurface soil samples from the Leach field area had detectable activities of $^{99}Tc$. The absence of $^{99}Tc$ in the subsurface and surface soils and the elevated activity in one of the LF field samples suggests that $^{99}Tc$ in the Leach Field may be a result of contaminant migration upstream of the Leach Field area (e.g., process buildings). $^{232}Th$ was 0.097 pCi/L in LF-08.

### 4.5.6 AOC #6 Soil Beneath Buildings

The potential constituents of concern for AOC #6 Soil Beneath Buildings are chlorinated solvents (PCE, TCE and associated degradation products), fluoride, uranium ($^{238}U$, $^{235}U$, $^{234}U$), $^{99}Tc$ abd $^{232}Th$.

**Chlorinated solvents.** The presence of dense, nonaqueous-phase liquids (DNAPLs) under at least one of the process buildings is indicated by the PCE concentration in a soil sample collected from under Bldg. 253 ($6.6 \times 10^6$ μg/kg in BLD253-02-21, Table 4.42, see also discussion in Sect. 5.4). PCE and TCE were detected in all the wells under and in the vicinity of the buildings, at concentrations ranging from 2.9 to 200,000 μg/L and 5.8 to 18,000 μg/L for PCE and TCE, respectively ("BD"-labeled samples in Table 4.44). Contaminated PCE and TCE soils underneath the building are the likely source of PCE and TCE plumes in the overburden and shallow groundwater (Chapter 5).

**Fluoride.** Detectable fluoride levels (RL ~7 mg/kg) in subsurface soil samples from under the buildings ranged from 6.8 to 190 mg/kg; however, fluoride was not detected in a majority of the subsurface soil samples from under the buildings (BD-labeled samples in Table H.6). Also, the highest concentration is lower than the geometric mean of regional values reported by Tidball (1984).

**Uranium.** Elevated uranium activities relative to the off-site/background samples were measured in shallow (< 5 ft depth) subsurface soil samples from under Bldg. 253 and 255 (e.g., $^{234}U$ = 604 pCi/g in BLD255-08-01, Table 4.28, see also Sect. 4.3.5.1). $^{234}U$ activities ranged from 8.0 to 13.8 pCi/L in the overburden monitoring wells installed under and in the vicinity of the process buildings (samples labeled "BD" in Table 4.18).

**Technetium-99.** $^{99}Tc$ was detected in two surface soil samples collected adjacent to Bldg. 240 and 255 (86.9 and 540 pCi/g; "BD" labeled samples in Table 4.24, and in two shallow (< 5 ft depth) subsurface soil samples collected underneath buildings (1.6 and 30.2 pCi/g, "BD" and "BLD" labeled samples in Table 4.29). $^{99}Tc$ activities in the overburden groundwater in and around the buildings ranged from non-detectable (MDL ~10 pCi/L) to 5100 pCi/L (detectable $^{99}Tc$ activities are shown in Table 4.20, "BD"-labeled samples).

**Thorium.** $^{232}Th$ activities above the MDL (~0.1 pCi/L) were measured in some of the overburden monitoring wells under the buildings (0.24 to 0.59 pCi/L; BD-labeled samples in Table 4.19). $^{232}Th$ was also measured in subsurface soil samples (0.4 to 1.2 pCi/g, BD-labeled samples in Table 4.30) but these activities were within the range of $^{232}Th$ activities in the off-site/background samples (0.7 to 1.3 pCi/g, Table H.10a).

### 4.5.7 AOC #7 Limestone Storage and Limestone Fill Areas

The potential constituents of concern for AOC #7 Limestone Storage and Limestone Fill Areas are uranium, ($^{238}$U, $^{235}$U, $^{234}$U), $^{99}$Tc, $^{232}$Th, and fluoride.

**Uranium and Technetium.** $^{235}$U was below the MDL (~1 pCi/g) in surface soil samples collected from the middle and edge of the Limestone Storage Area (OA-24-00-SL and OA-25-00-SL, refer to Fig. 2.4b for sample locations). Of the three samples collected from the limestone storage/fill areas, only the composite sample from the limestone fill in the Burial Pit Area contained detectable $^{235}$U activity (see Table 4.23 and Fig. 4.16). $^{99}$Tc activities in surface soil samples from the middle and edge of the Limestone Storage Area were measured at 13.1 and 87.5 pCi/g (Table 4.24). $^{99}$Tc activities in the limestone storage/fill area samples ranged from 22.7 to 94.1 pCi/g (Table 4.24, Fig. 4.17). $^{235}$U and $^{99}$Tc activities are higher in surrounding surface soil samples (e.g., see data for OA-23-00-SL in Table 4.23 and 4.24). The presence of uranium and $^{99}$Tc in surface soil sample OA-23-00 may be due to the Limestone Storage Area but may also be due to Deul's Mountain or other historical Facility activities in this area [e.g., the ring storage area was located east-northeast of Bldg. 252, as described in (GEA 1996) and summarized in Sect. 1.5.4].

**Thorium.** $^{232}$Th was not measured in the surface soil samples from the Limestone Storage Area. However, $^{232}$Th levels measured in surface soil samples from multiple locations within the Facility were within the range measured in the off-site/background samples (see discussion in Sect. 4.3.4.3).

**Fluoride.** Fluoride was detected above the reporting limit (RL ~7 mg/kg) in several surface soil samples collected in the vicinity of the Limestone Storage area and Deul's Mountain (OA-20-00-SL through OA-27-00-SL, refer to Fig. 2.4b for locations), ranging from 19 through 170 mg/kg (data in Table H.5). Fluoride was not detected in subsurface soil samples downgradient of the Limestone Storage Area (PL-04, N-39, NB-31 samples in Appendix H.6).

### 4.5.8 AOC #8 Outdoor and Shallow Surface Area

The constituents of potential concern in AOC #8 are chlorinated solvents (PCE, TCE and associated degradation products), fluoride, uranium ($^{238}$U, $^{235}$U, $^{234}$U), $^{99}$Tc, and $^{232}$Th. Surface and subsurface soil samples were collected from outdoor areas within the Facility ("OA"-labeled samples in Fig. 2.4a-b and 2.5a-b). Note that the samples collected in the immediate vicinity of the Limestone Storage Area (OA-24-00-SL and OA-25-00-SL) were discussed previously.

**Uranium, Technetium-99, Thorium and Fluoride.** The following summary of findings in the outdoor areas is broken down into sub-areas within the Facility:

*OA-01 through OA-5 next to Bldg 101 (Tile Barn) and Bldg. 120 (Wood Barn)* – The highest $^{235}$U and $^{99}$Tc activities in these surface soil samples were measured at 12.2 pCi/g and 10.3 pCi/g (Table 4.23 and 4.24). Fluoride was detected above the RL (~7 mg/kg) in one surface soil sample from this sub area (20 mg/kg).

*OA-07 through OA-11 next to process buildings* (e.g., Bldg 230, 240, 253, 254, etc., Fig. 2.4b for locations) - The highest $^{235}$U and $^{99}$Tc activities in these surface soil samples were measured at 472 pCi/g (measured using alpha spectroscopy in OA-08-00-SL, Table 4.23) and 58.3 pCi/g (Table 4.24), respectively. One surface soil sample contained 150 mg/kg of fluoride (OA-11-00-SL, data in Appendix H.5). Note that subsurface soil samples collected underneath the buildings contained fluoride in localized areas but fluoride levels were generally below the RL in most of the samples.

*OA-12 through OA-16, located east-northeast of Facility fenced area next to Burial Pits* (Fig. 2.4b for locations) - The highest $^{235}$U and $^{99}$Tc activities in these surface soil samples were measured at 3.6 pCi/g and 21.3 pCi/g (Table 4.23 and 4.24). The highest fluoride level in the surface soil samples from this sub-area is 57 mg/kg (Appendix H.5).

*OA-20 through OA-27 (surface soil sample locations near Limestone Storage Area and Deul's Mountain), OA-18 and OA-19 (subsurface soil sample locations near Limestone Storage Area and Deul's Mountain)* - The highest $^{235}$U and $^{99}$Tc activities in these surface soil samples were measured at 120 pCi/g (Table 4.23) and 691 pCi/g (Table 4.24), respectively. Only one subsurface soil sample from this sub-area contained detectable $^{235}$U (0.747 pCi/g OA-18-03-SL, Table 4.28). $^{99}$Tc was not detected in any of the subsurface soil samples from this sub-area. $^{234}$U in the groundwater sample from monitoring well OA-19 was 3.04 pCi/L (Table 4.18). As mentioned previously, fluoride was detected above the reporting limit (RL ~7 mg/kg) in several surface soil samples collected in the vicinity of the Limestone Storage area and Deul's Mountain (OA-20-00-SL through OA-27-00-SL, refer to Fig. 2.4b for locations), ranging from 19 through 170 mg/kg (data in Table H.5).

*OA-28 through OA-33 (Area north of Facility just outside fence- Fig. 2.4b for location)* – $^{235}$U and $^{99}$Tc were not detected in any of the surface soil samples from this sub-area. The data suggests that Facility activities have not had an impact on this outdoor area.

*OA-34 through OA-40 (East of Facility near the Northeast Site Creek, Fig. 2.4a and b for location)* - The highest $^{235}$U and $^{99}$Tc activities in these surface soil samples were measured at 1.9 pCi/g and 1.6 pCi/g, respectively (Table 4.23 and 4.24). $^{232}$Th was measured in one surface soil sample from the outdoor areas, and the sample was collected from this sub-area (OA-37-00-SL). The measured $^{232}$Th activity in this sample (1.1 pCi/g) is within the range of measured activities in the off-site/background samples.

**Chlorinated solvents.** TCE was measured at 4,000 µg/kg in a subsurface soil sample from OA-18 (OA-18-33-SL, Table 4.42). Given the depth of this sample (33 ft BGS) and the other OA-labeled samples with TCE (Table 4.42), it is likely that TCE in these boreholes is a result of migration from source areas upgradient of OA-18 and OA-19 (e.g., Bldg 255).

### 4.5.9 AOC #9 Former Gas Station

The constituents of potential concern in AOC #9 Former Gas Station are chlorinated solvents (PCE, TCE and associated degradation products), semivolatile organic compounds (SVOCs), total petroleum hydrocarbons, and metals.

**Chlorinated solvents.** PCE and TCE were not detected in any of the subsurface soil samples from this AOC (GS-labeled samples in Appendix H.15g). No VOCs were detected in the surface soils (GS-labeled samples in Appendix H.14g).

**Petroleum hydrocarbons.** Diesel range organics were detected in the soils from this AOC, ranging in concentration from 15 to 35 mg/kg. (Table H.14f).

**SVOCs.** Only benzo(*b*)fluoranthene and 4,4'-DDT were detected in the soil samples from this AOC (22J µg/kg, "J" qualified because level is below RL and 2.5 µg/kg, respectively).

**Metals.** A surface sample from this AOC (GS-04-00-SL) contained one of the highest selenium concentrations in the surface soil samples (1.7 mg/kg) but was comparable to selenium in offsite/background samples (see discussion in Sect. 4.2.4.3).

### 4.5.10 AOC #10 Gas Pipeline

The potential constituents of concern in AOC #10 Gas Pipeline are chlorinated solvents (PCE, TCE and associated degradation products), fluoride, $^{99}$Tc, and $^{232}$Th.

During the RI field investigation, excavations to expose the pipeline indicated that the pipeline depth ranged from 3 to 5 ft below ground surface, and was not buried in a gravel bed, but was surrounded by native soil (Sect. 1.4). Thus, the pipeline is buried in the fine-grained overburden layer (Sect. 3.2.4.1) based on the depth and location of the pipeline, the overburden cross-sections in Fig. 3.4 and 3.5, as well as the boring logs for the PL-04, PL-05 and PL-06. It is therefore unlikely that the pipeline is serving as a preferential pathway for any contamination originating from the Facility.

The following is a summary of results for samples collected from the immediate vicinity of the pipeline (PL-labeled samples).

**Chlorinated Solvents.** PCE and TCE were present in subsurface soil samples collected next to the gas pipeline, but at relatively low levels compared to the concentrations measured within the Facility under the buildings. PCE ranged from 15 to 74 μg/kg in soil samples from PL-06, while TCE was below the reporting limit of ~6 μg/kg (data in Appendix H.15g, "PL"-labeled samples). TCE and PCE were not detected above the reporting limit (~6 μg/kg) in any of the subsurface soil samples from PL-05. PCE and TCE were detected in monitoring well PL-04 (PCE 230 μg/L and TCE 1100 μg/L). PL-04 lies within the groundwater plume that originates from the Burial Pits area (see Chapter 5).

**Technetium-99.** $^{99}$Tc was detected in PL-06 (92.3 pCi/L, Table 4.20), but was below the MDL (10 pCi/g) in all of the subsurface soil samples collected from the pipeline (PL-labeled samples in Appendix H.11).

**Thorium.** $^{232}$Th was not detected (MDL ~0.1 pCi/L) in the monitoring wells in this AOC (data in Appendix H.8, PL-04 and PL-06). $^{232}$Th was not measured in the surface soil samples near the pipeline. However, $^{232}$Th levels measured in surface soil samples from multiple locations within the Facility were within the range measured in the off-site/background samples (see discussion in Sect. 4.3.4.3). $^{232}$Th in subsurface samples from this AOC were also within the range of off-site/background samples (PL-labeled samples in Table 4.30).

### 4.5.11 AOC #11 Red Room Roof Burial Area

The potential constituents of concern for AOC #11 are uranium ($^{238}$U, $^{235}$U, $^{234}$U), fluoride, and $^{232}$Th.

**Uranium.** One of the surface soil samples and one of the subsurface soil samples from the Red Room Roof Burial Area are potentially contaminated with uranium (RR-labeled samples in Table 4.23 and 4.28; discussions in Sects. 4.3.4.1 and 4.3.5.1). Uranium was detected in the overburden monitoring well in this AOC (RR-05) but at levels below the established background in the overburden ($^{234}$U = 1.68 pCi/L, Appendix J).

**Fluoride.** Fluoride was detected above the reporting limit of ~7 mg/kg in all 3 surface soil samples from this AOC, with a maximum value of 25 mg/kg (RR-labeled samples in Table H.6). Fluoride levels in the subsurface soil samples from this AOC are either below or slightly above the reporting limit of ~7 mg/kg (RR-labeled samples in Appendix H.6).

**Thorium.** $^{232}$Th activities in subsurface soil samples from this AOC were within the range of off-Site background values (RR-labeled samples in Table 4.30).

### 4.5.12 AOC #12 Domestic Well #3

The potential constituents of concern in AOC #12 Domestic Well # 3 are chlorinated solvents (PCE and TCE and associated degradation products).

Groundwater samples have been periodically collected from Domestic Well #3 and analyzed for VOCs. PCE and TCE have been detected in this well since sampling began in December 2001, although levels appear to have dropped relative to the historically highest values (340 and 520 μg/L TCE and PCE respectively) to less than 40 μg/L in the sample collected in February 2004 and during the packer testing performed in June 2004 as part of this RI. Monitoring data for Domestic Well #3 are available in a database maintained by Westinghouse.

Bedrock wells BR-05-JC and BR-05-RB were installed northeast of Domestic Well #3 (refer to Fig. 2.6a for location). No VOCs were detected in these wells (data in Table H.16f, reporting limit is 5 μg/L, detection limit is ~1/10th of the RL) in the samples collected as part of this RI.

### 4.5.13 AOC #13 Deul's Mountain

The constituents of potential concern in AOC #13 Deul's Mountain are uranium ($^{238}$U, $^{235}$U, $^{234}$U), $^{232}$Th, and fluoride. Note that the pile of soil referred to as Deul's Mountain has been removed from the Facility (Sect. 1.4).

**Uranium.** The highest uranium activities in groundwater, surface soil and subsurface soil were measured in this AOC (DM-labeled samples in Tables 4.18, 4.23 and 4.28).

**Thorium.** $^{232}$Th was not detected (MDC ~0.1 pCi/L) in the monitoring well in this AOC (DM-02). $^{232}$Th in subsurface soil samples from this AOC (DM-labeled samples, Table 4.30) are slightly above the range of $^{232}$Th activities measured in the off-Site background samples.

### 4.5.14 AOC #14 Cistern Burn Pit Area

The constituents of potential concern in AOC #14 are chlorinated solvents (PCE, TCE and associated degradation products), SVOCs, metals, dioxin, fluoride, uranium ($^{238}$U, $^{235}$U, $^{234}$U), and $^{232}$Th.

**Chlorinated solvents.** PCE, TCE and its daughter products were not detected in the groundwater sample from the overburden monitoring well in this AOC (CB-02, data in Appendix H.16f).

**SVOCs.** Benzo(*a*)pyrene was detected above the detection limit but below the reporting limit of ~420 mg/kg in the surface soil sample from this AOC (Table 4.37). No other SVOCs were detected above reference levels in the surface soils (see discussion in Sect. 4.4.3.3). No SVOCs were detected in the monitoring well at this AOC (CB-20, data in Appendix H.15).

**Dioxins.** Dioxins were reported in surface and subsurface soil samples from this AOC (Tables 4.36 and 4.40). The dioxin results in the subsurface soils are all "B" qualified, i.e., the analyte was also detected in the laboratory blank associated with the sample. Three dioxins were detected in the monitoring well in this AOC but all results were below reporting limits and/or "B" qualified (Appendix H.16b).

**Uranium and Technetium.** $^{235}$U was not detected (MDC ~0.4 pCi/g) in the surface sample from this AOC. One subsurface soil sample from this AOC (CB-02) contains $^{234}$U that is at the threshold used to determine contamination (Table 4.23, see also discussion in Sect. 4.3.5.1). The groundwater sample from CB-02 had uranium activities that were very low (<0.1 pCi/L, data in Appendix H.8). $^{99}$Tc was not

detected in the groundwater sample from CB-02 (MDC ~10 pCi/L); $^{99}$Tc was detected in the surface and subsurface soil samples from this AOC (CB-labeled samples in Table 4.24 and 4.29).

### 4.5.15 AOC #15 Joachim Creek Bridge.

This area was included as an AOC to investigate if third party materials were buried at this location. No sampling was planned for this AOC (LBG 2003). A geophysical survey was conducted to investigate this AOC (Geophex 2005), the results of which are summarized in Sect. 2.8.

# CHAPTER 4 FIGURES

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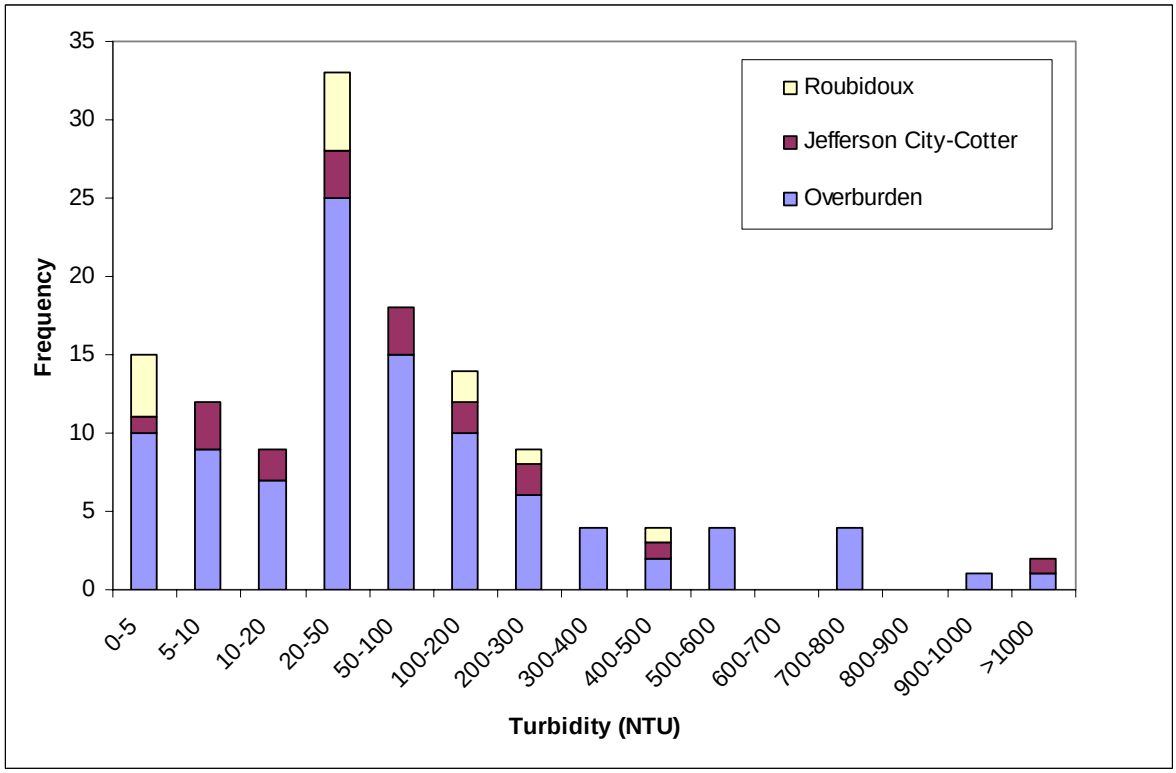


**Fig. 4.1. Histogram of turbidity.**

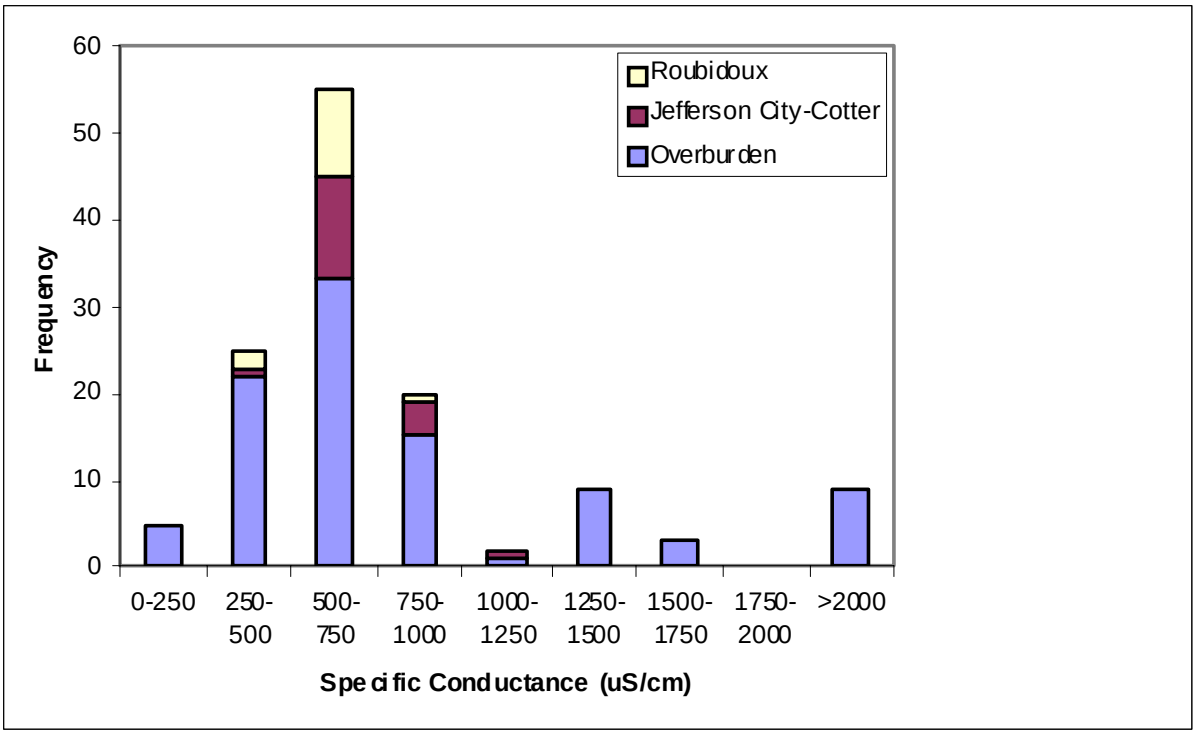


**Fig. 4.2. Histogram of specific conductance.**

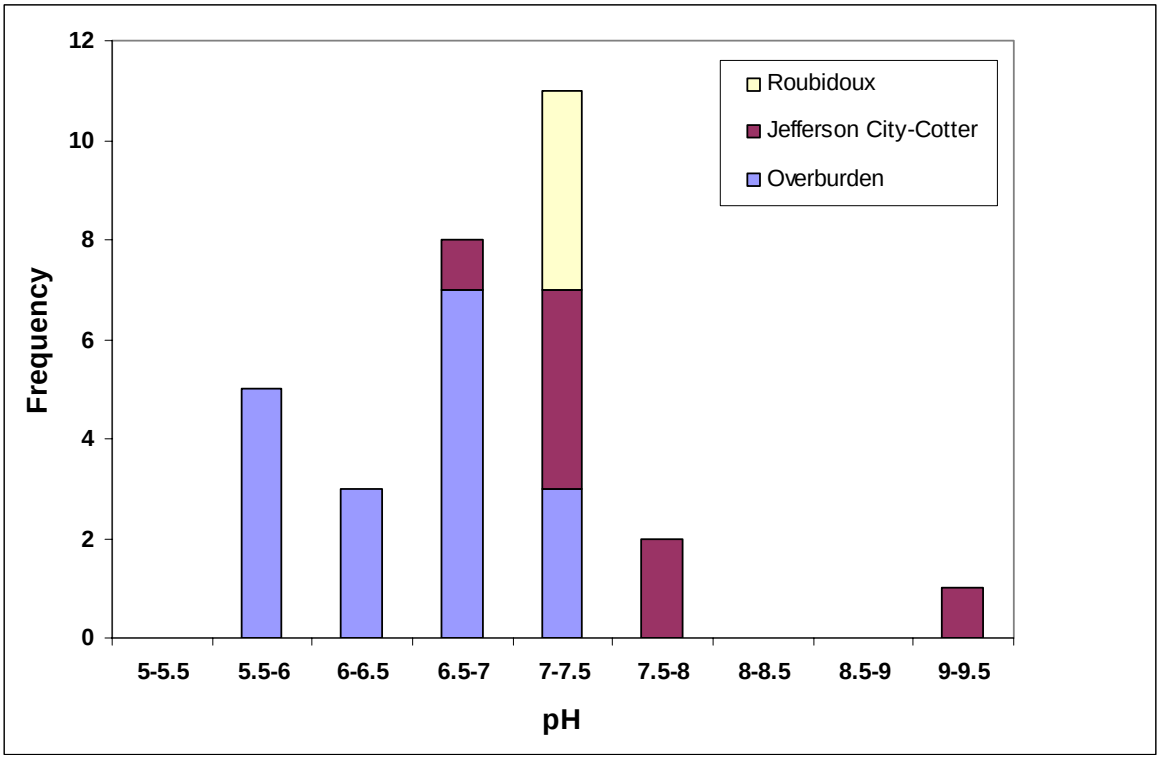


**Fig. 4.3. Histogram of groundwater pH.**

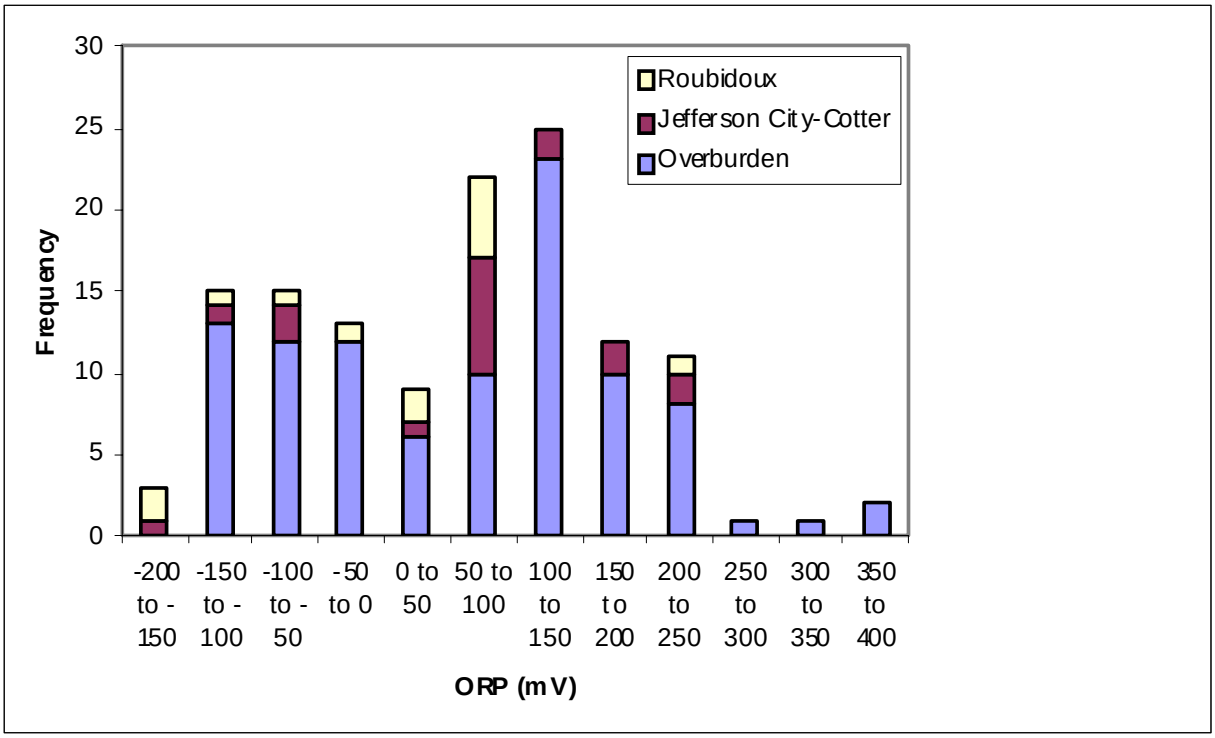


**Fig. 4.4. Histogram of groundwater oxidation-reduction potential.**

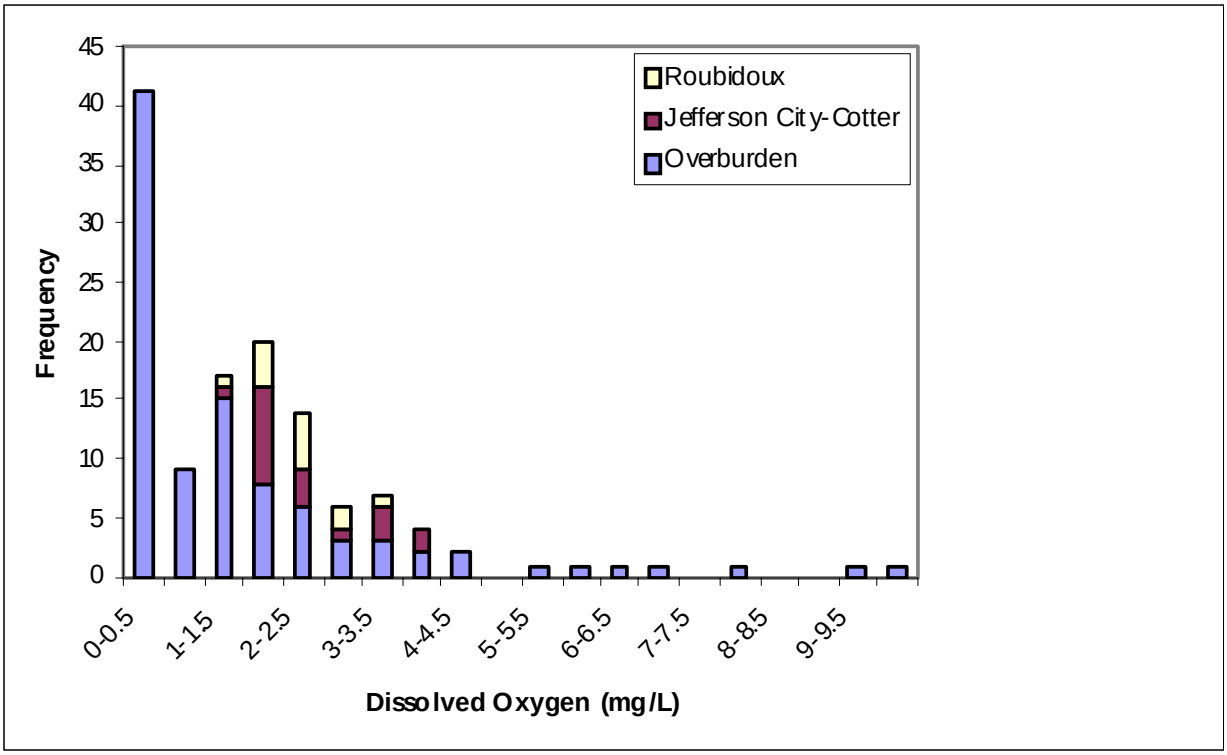


**Fig. 4.5. Histogram of groundwater dissolved oxygen.**

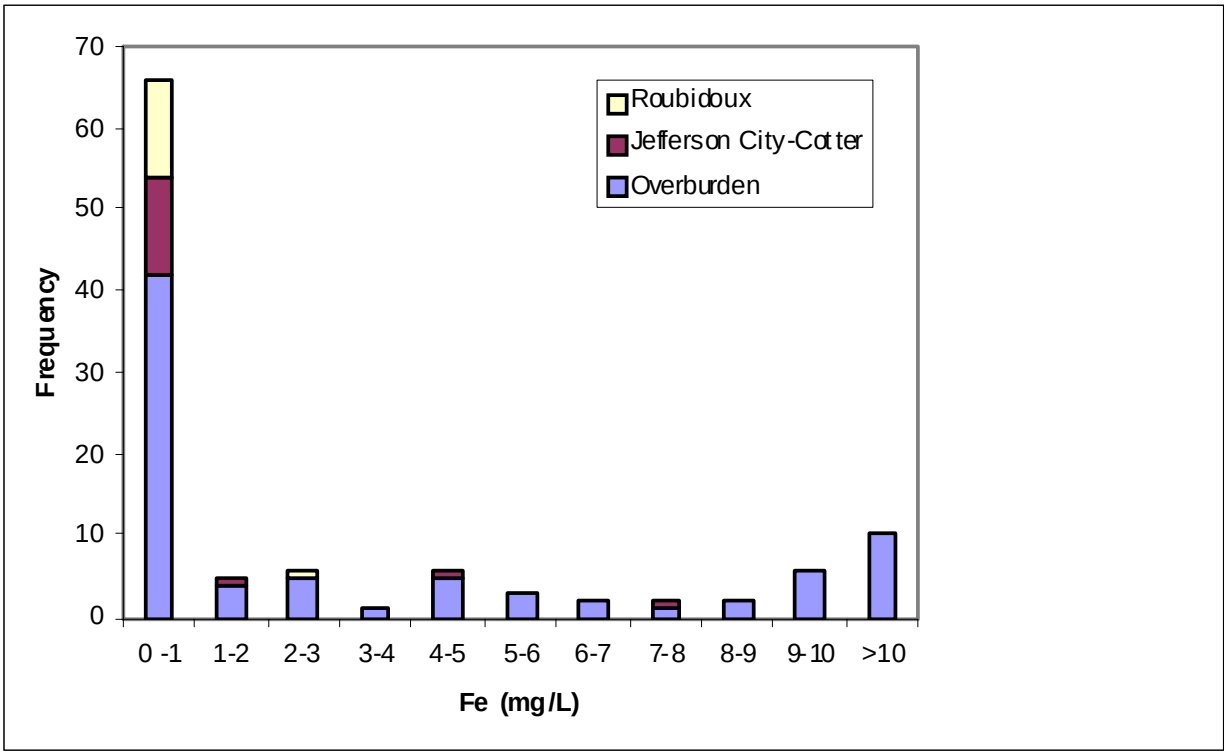


**Fig. 4.6. Histogram of ferrous iron concentrations in groundwater.**

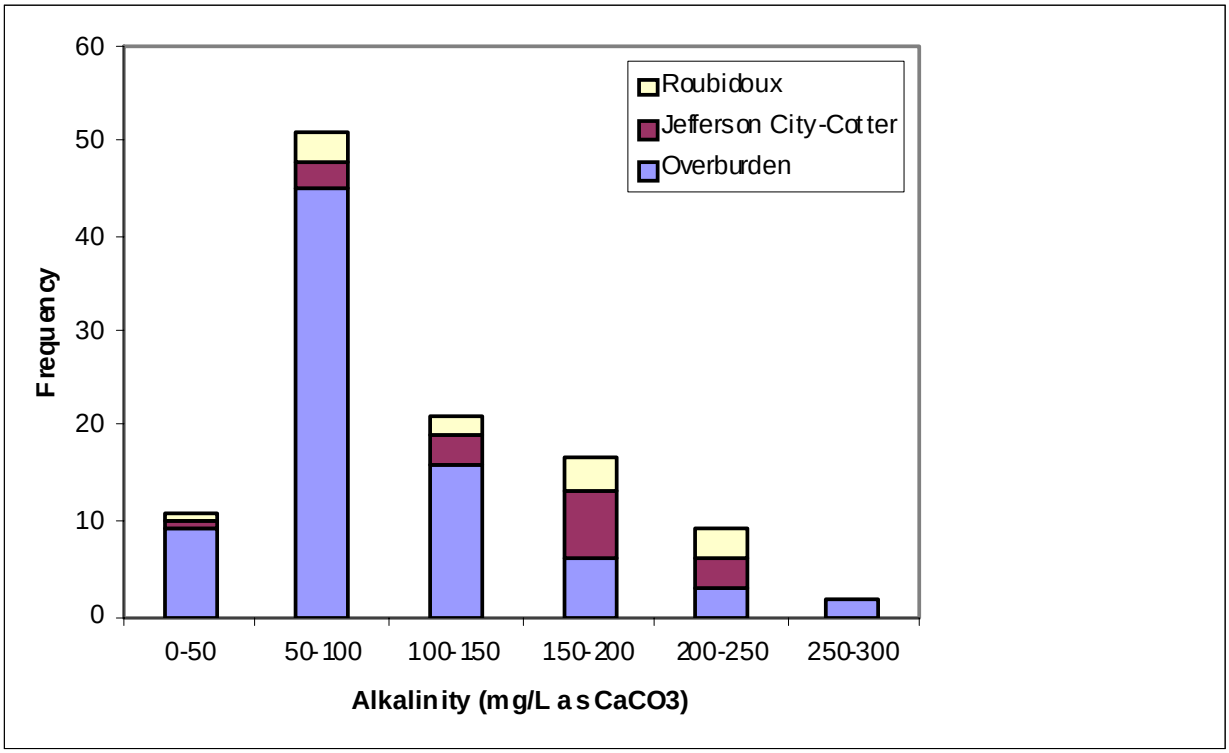


**Fig. 4.7. Histogram of groundwater alkalinity.**

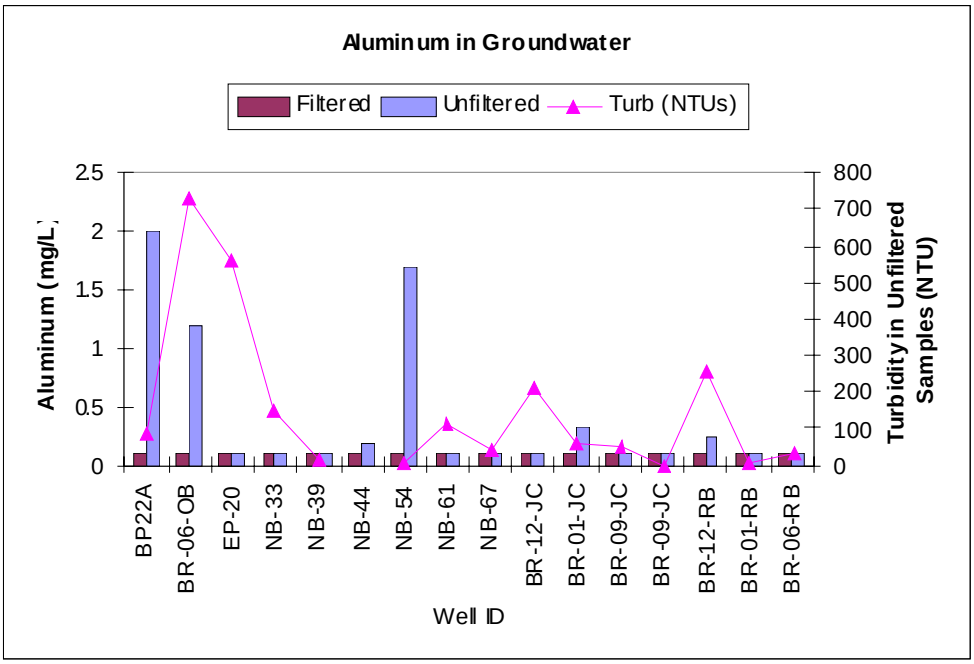


**Fig. 4.8a. Comparison of aluminum concentrations in filtered and unfiltered groundwater samples.**

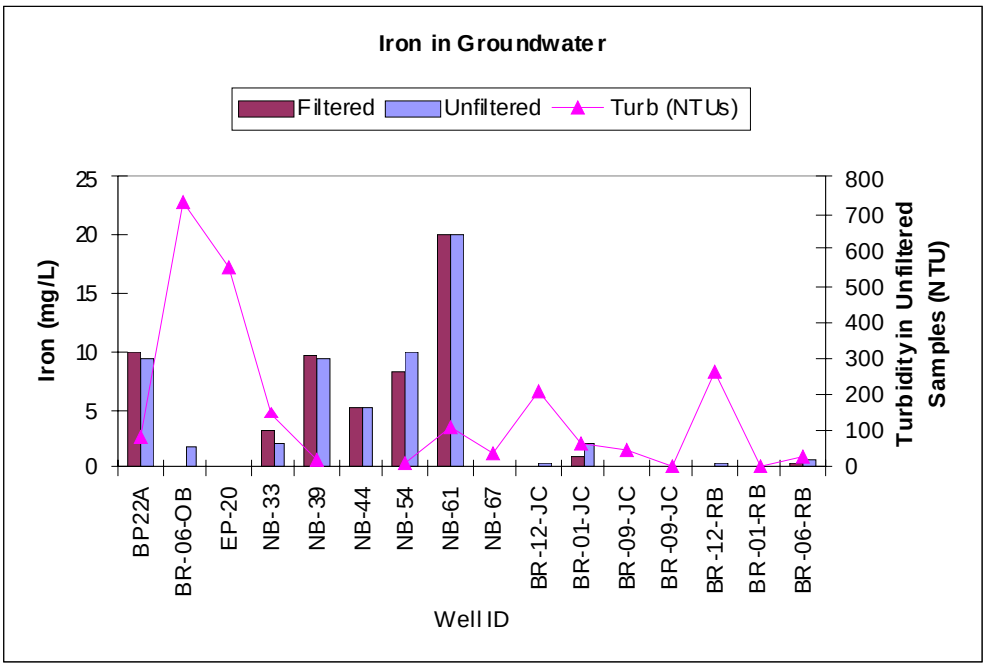


**Fig. 4.8b. Comparison of iron concentrations in filtered and unfiltered groundwater samples.**

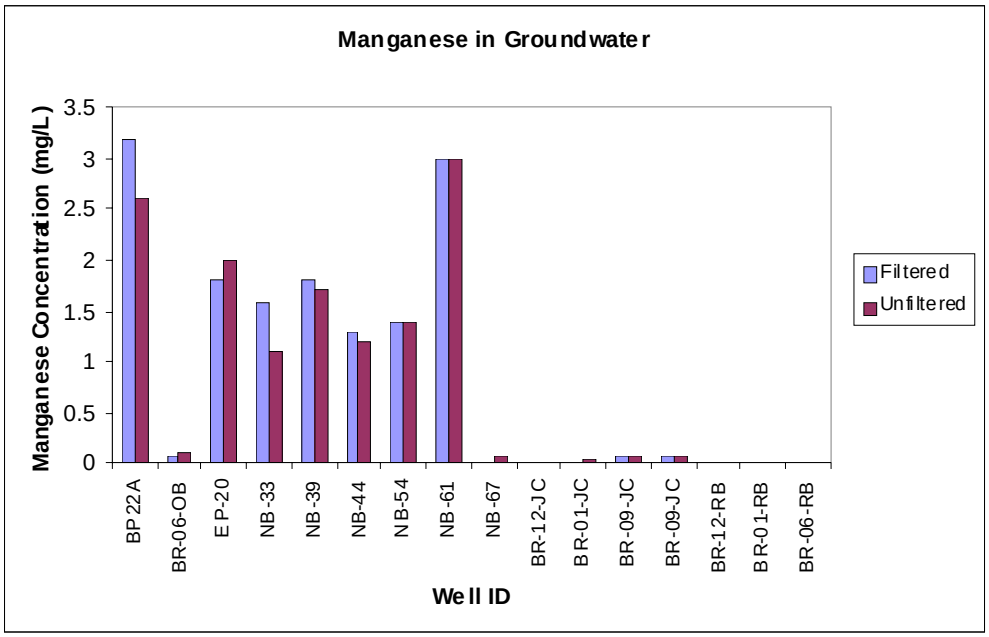


**Fig. 4.8c. Comparison of manganese concentrations in filtered and unfiltered groundwater samples.**

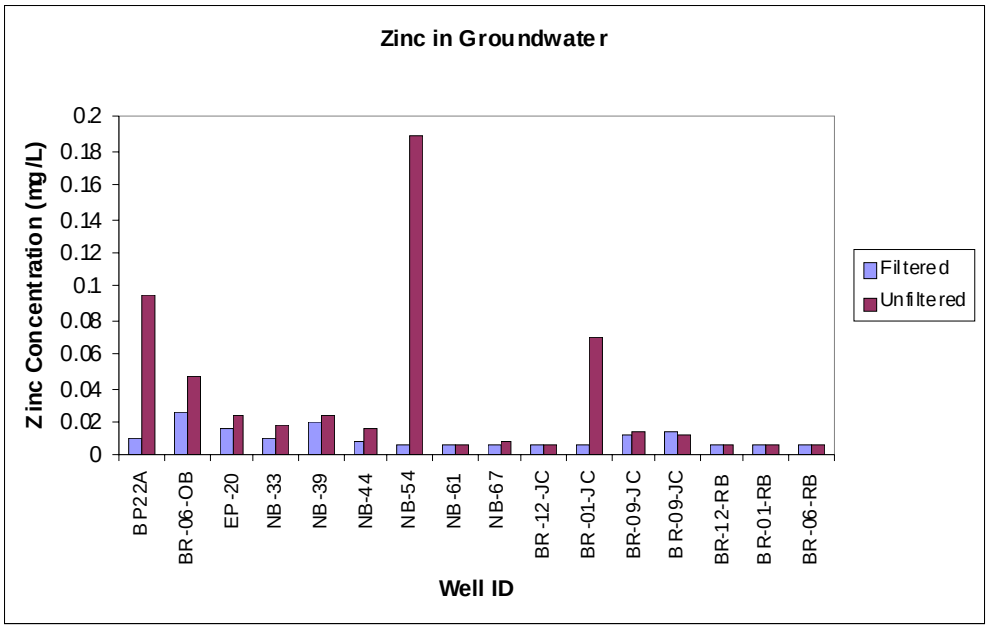


**Fig. 4.8d. Comparison of zinc concentrations in filtered and unfiltered groundwater samples.**

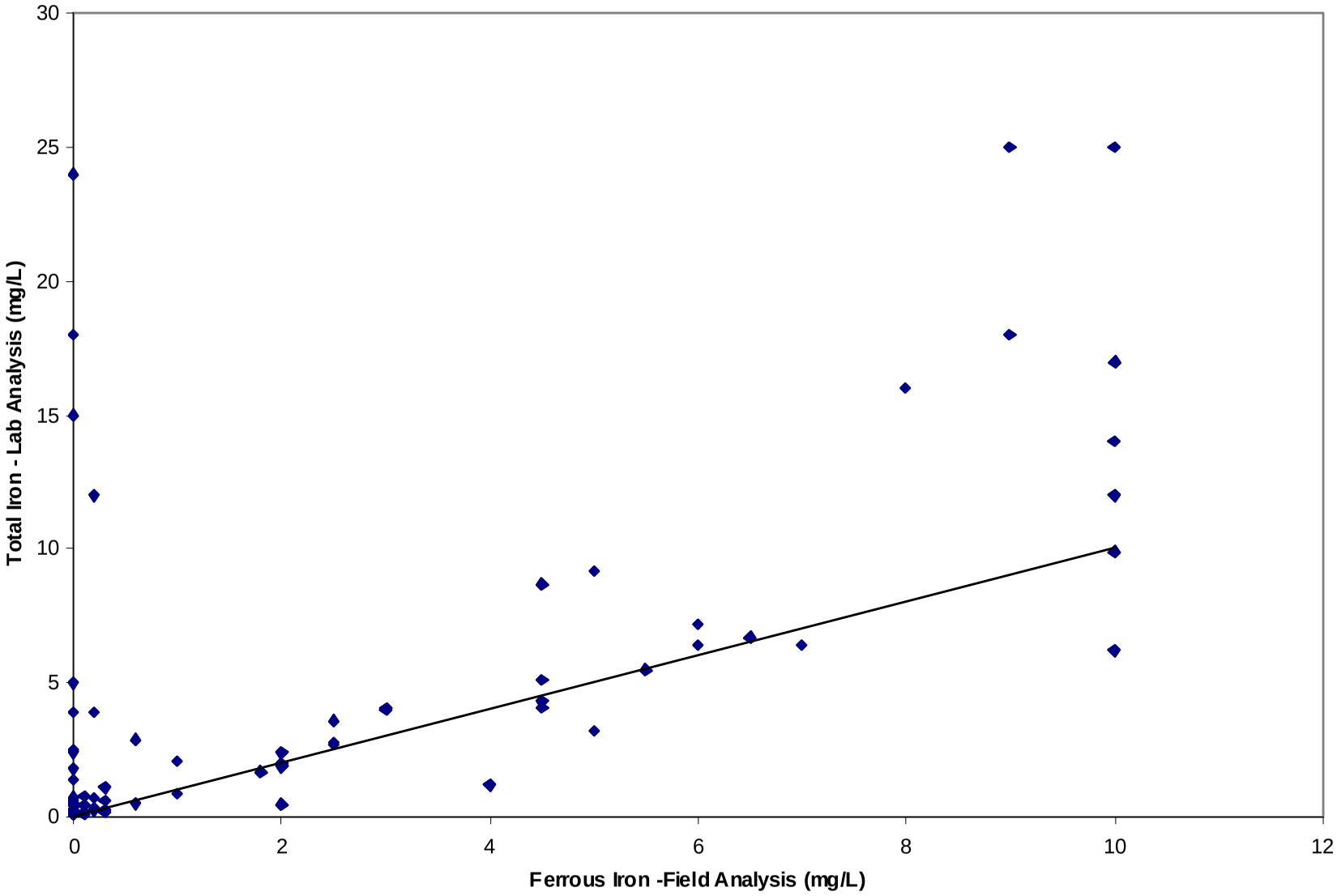


**Fig. 4.8e. Comparison of total iron and ferrous iron concentrations in unfiltered groundwater samples. (Total and ferrous iron concentrations were measured in the laboratory and field, respectively.)**

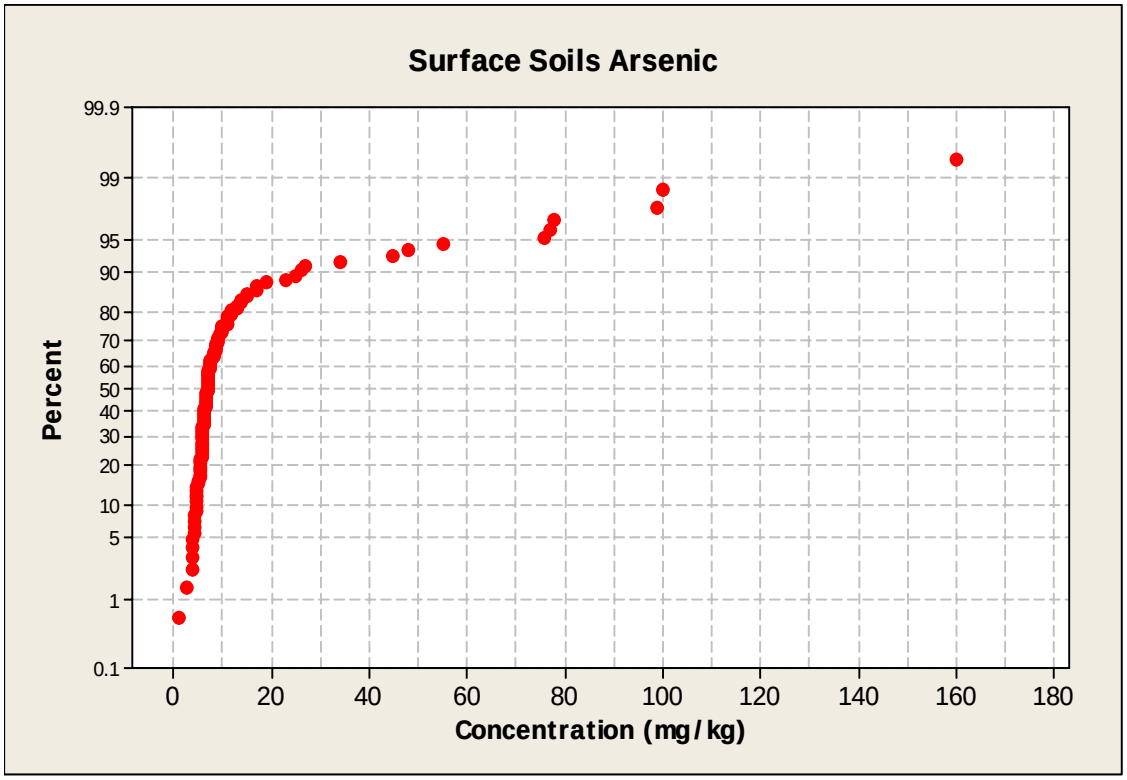


**Fig. 4.9. Cumulative frequency plot for arsenic in surface soils.**

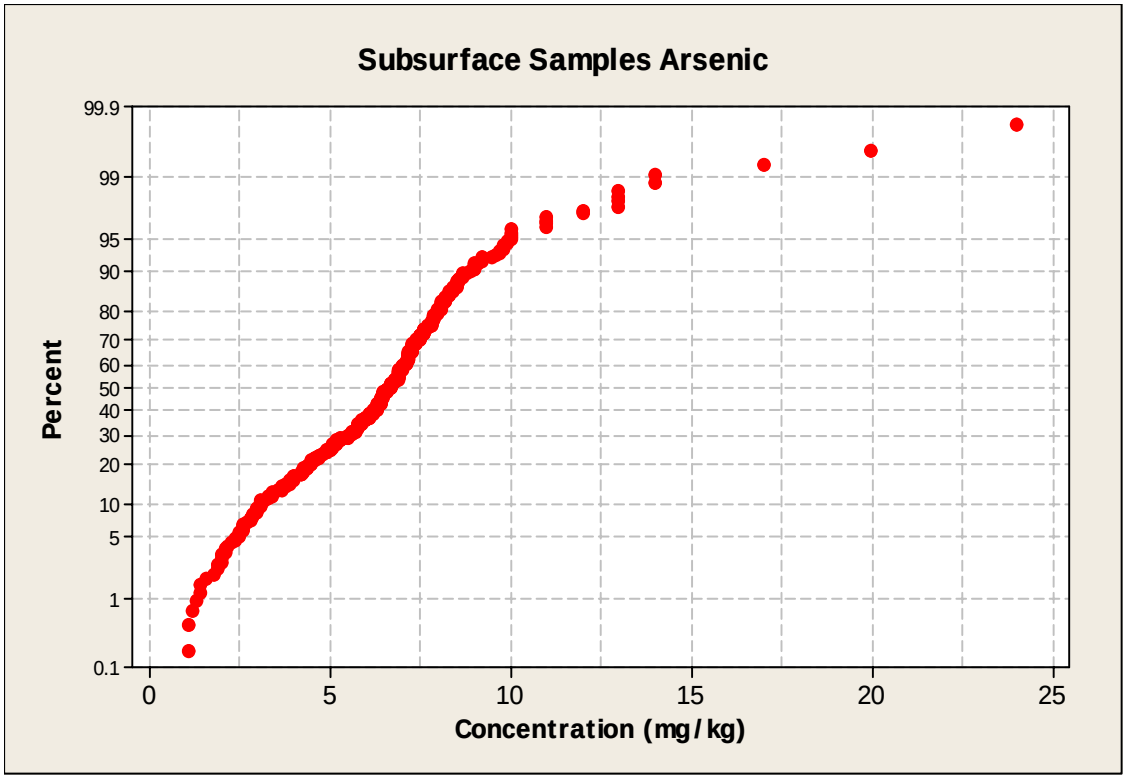


**Fig. 4.10. Cumulative frequency plot for arsenic in subsurface soils.**

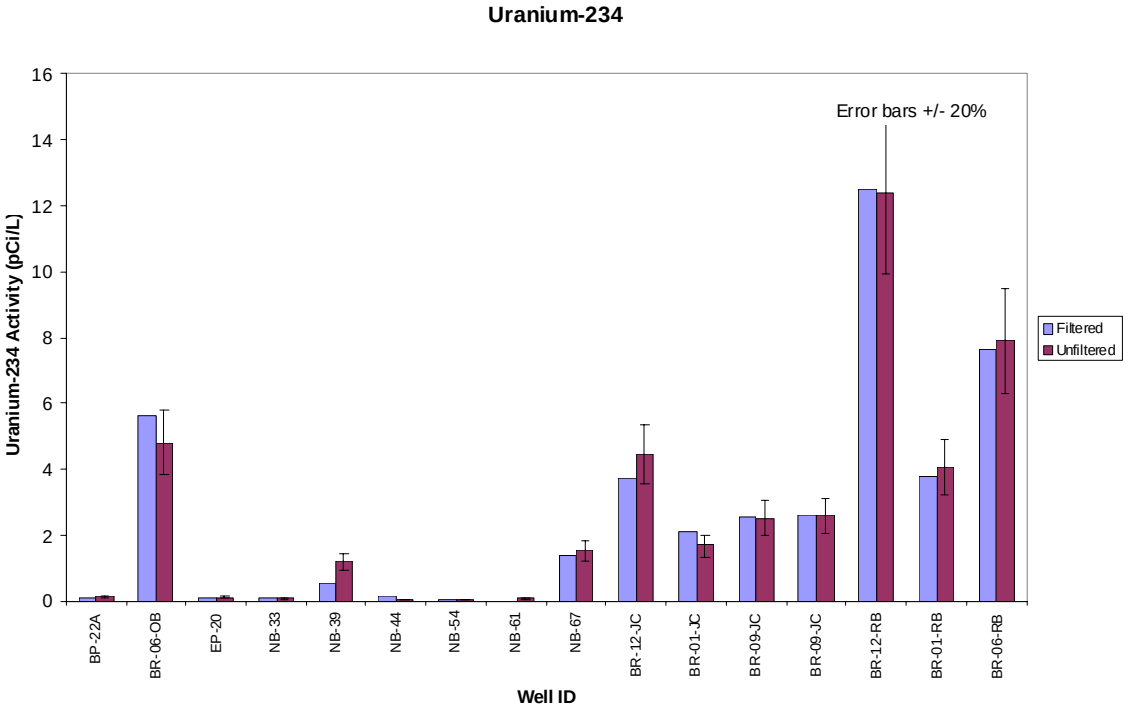


**Fig. 4.13. Comparison between $^{234}$U activities in filtered (<0.45 mm) and unfiltered groundwater samples. (Error bars correspond to estimated average measurement error reported with analytical results.)**

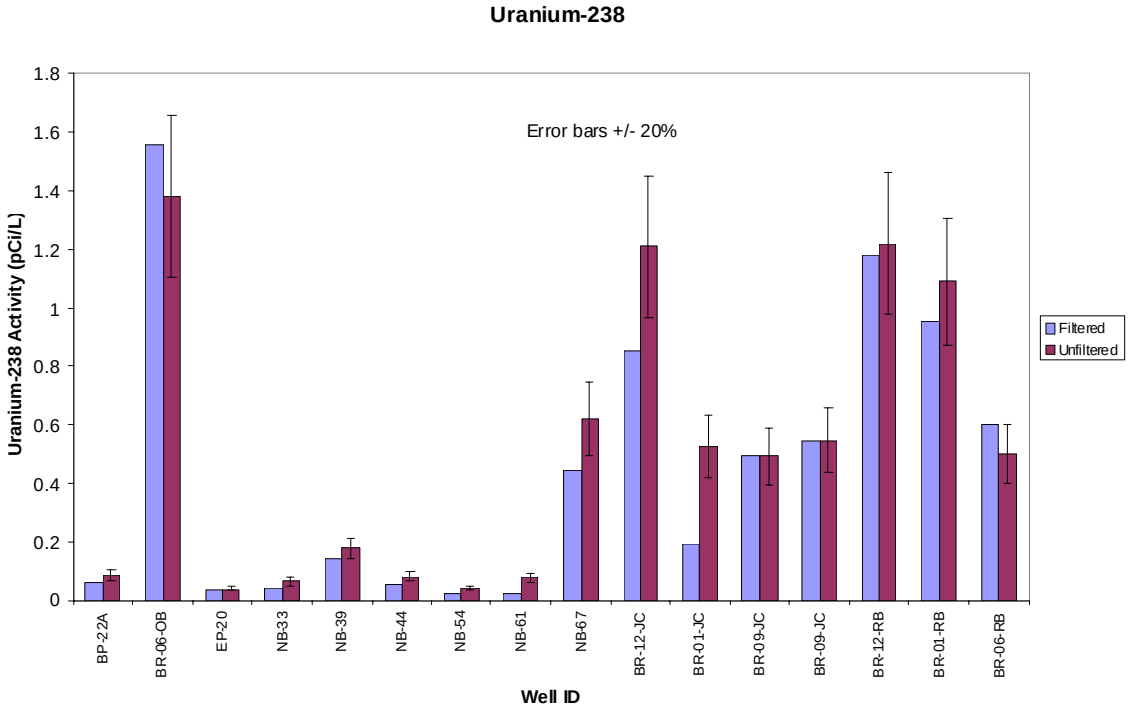


**Fig. 4.14. Comparison between $^{238}$U activities in filtered (<0.45 mm) and unfiltered groundwater samples. (Error bars correspond to estimated average measurement error reported with analytical results.)**

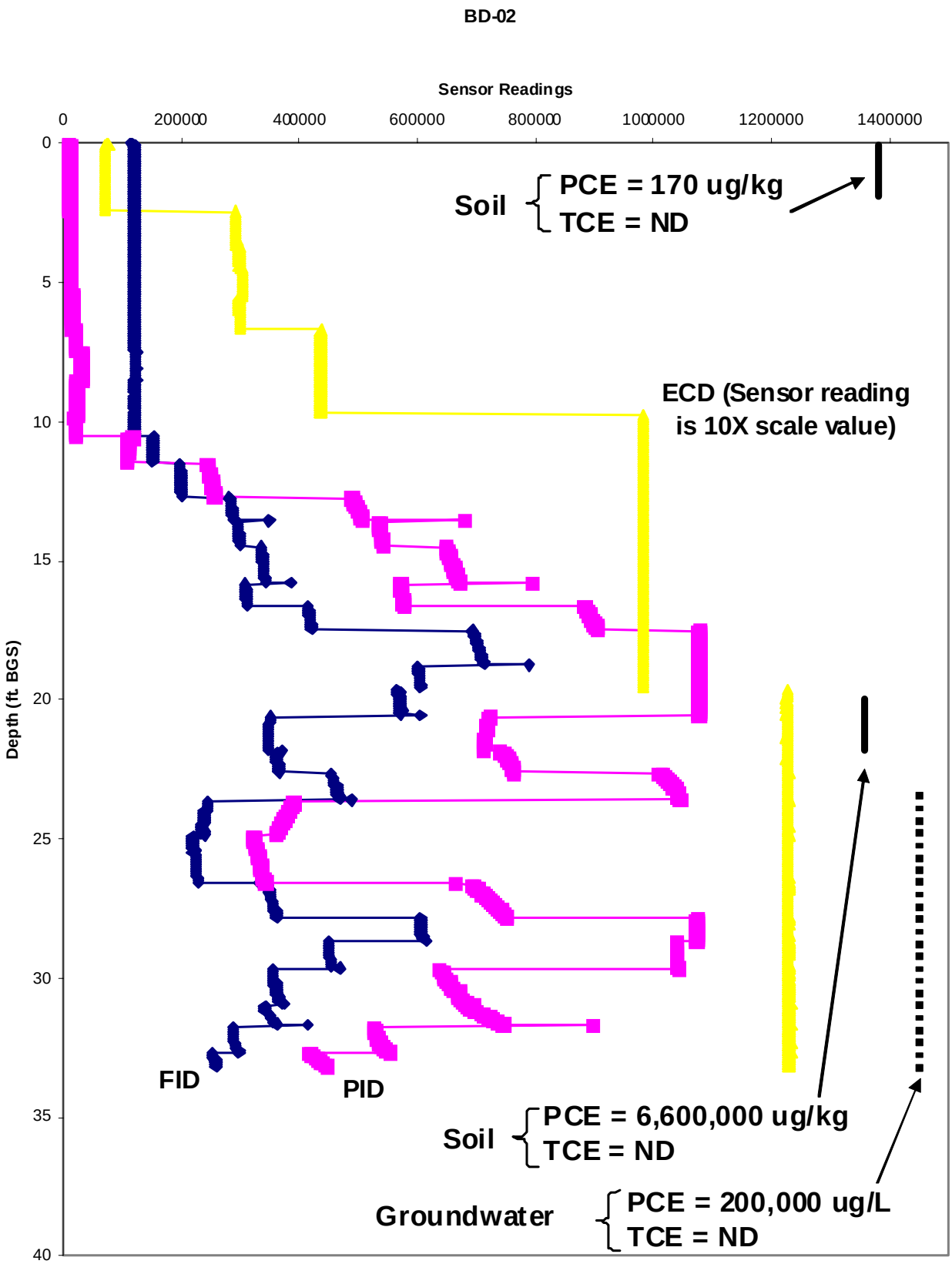


**Fig. 4.22. MIP detector response at BD-02.**

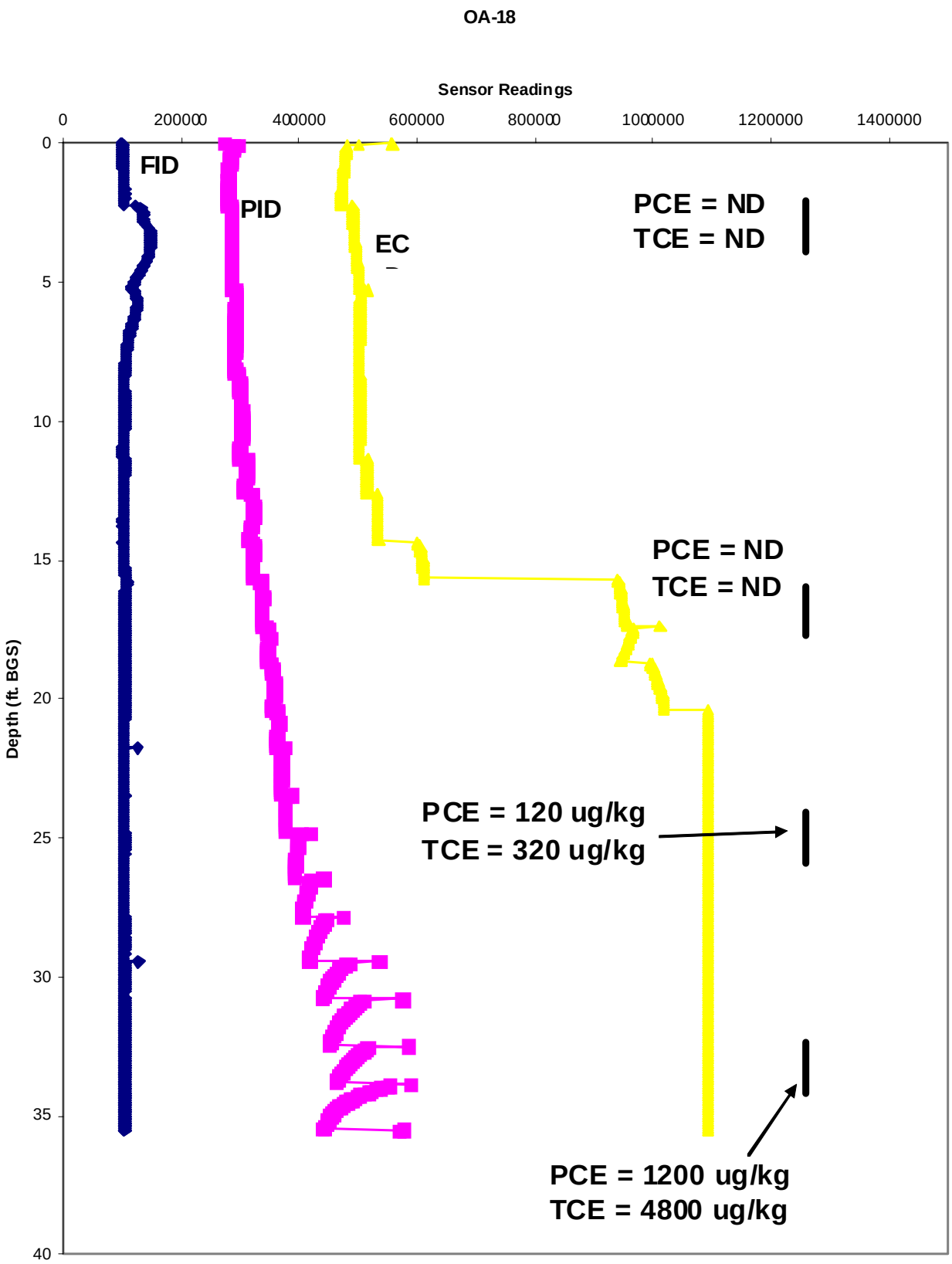


**Fig. 4.23. MIP detector response at OA-18.**

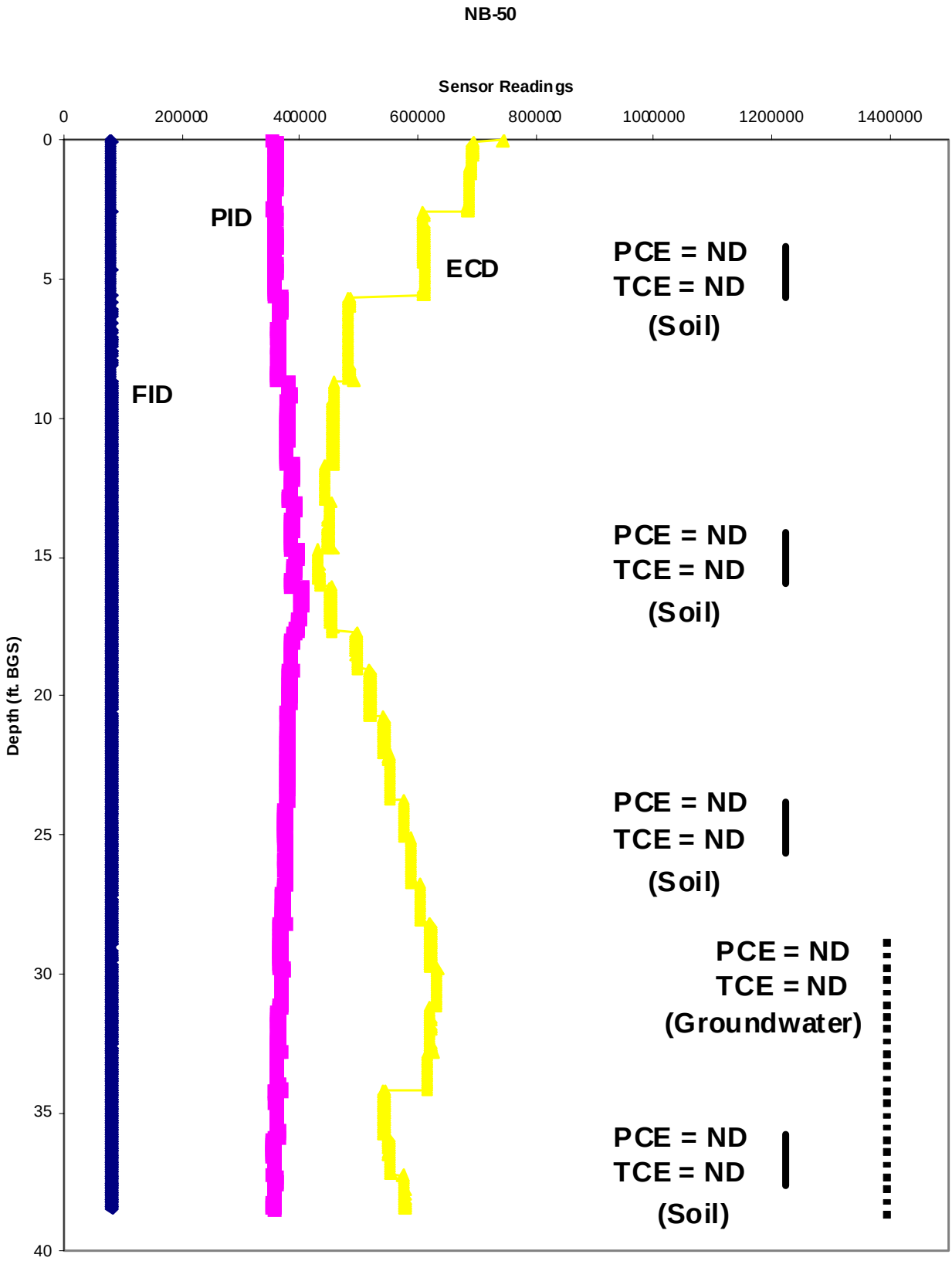


**Fig. 4.24. MIP detector response at NB-50.**

# CHAPTER 4 TABLES

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**Table 4.1. Arsenic concentrations in groundwater samples (All other results less than the reporting limit of 0.01 mg/L; refer to Fig. 2.6a and b for well locations.)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| BD-02 | 0.019 | Deep overburden | Buildings. |
| BD-06 | 0.026 | Deep overburden | Buildings. |
| BD-08 | 0.019 | Deep overburden | Buildings. |
| BD-13 | 0.01 | Deep overburden | Buildings. |
| NB-80 | 0.021 | Deep overburden | East of the Burial Pits. |
| NB-83 | 0.016 | Deep overburden | Between the Hematite Facility and Joachim Creek, towards the east. |
| WS-23 | 0.13 | Deep overburden | Northeast corner of the Hematite Facility, near the Burial Pits. |
| WS-25 | 0.061 | Deep overburden | Northern end of the Burial Pits, towards Northeast Site Creek. |
| WS-29 | 0.013 | Deep overburden | Southern end of the Burial Pits, towards Northeast Site Creek. |
| BR-08-JC | 0.015 | Jefferson City-Cotter | Between WEC and Joachim Creek, towards the east. |
| PZ-03 | 0.014 | Jefferson City-Cotter | Between buildings and Deul's Mountain. |
| PZ-04 | 0.023 | Jefferson City-Cotter | Northeast corner of the Hematite Facility, near the Burial Pits. |
| BR-01-RB | 0.062 | Roubidoux | East of Site Pond. |

**Table 4.2. Chromium concentrations in groundwater samples (All other concentrations were less than the reporting limit of 0.004 mg/L; refer to Fig. 2.6a and b for well locations.)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| WS-16 | 0.0061 | Shallow overburden | Southern end of the Burial Pits. |
| BD-02 | 0.021 | Deep overburden | Buildings. |
| BD-13 | 0.021 | Deep overburden | Buildings. |
| LF-08 | 0.025 | Deep overburden | Former leach field. |
| OB-02 | 0.0059 | Deep overburden | Between the Hematite Facility and Joachim Creek, towards the east. |
| WS-23 | 0.037 | Deep overburden | Northeast corner of the Hematite Facility, near the Burial Pits. |
| WS-25 | 0.013 | Deep overburden | Northern end of the Burial Pits. |
| WS-32 | 0.0069 | Deep overburden | Between Deul's Mountain and the southeast fence line. |

**Table 4.3. Copper concentrations in groundwater samples (All other samples less than the reporting limit of 0.01 mg/L; refer to Fig. 2.6a and b for well locations.)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| WS-15 | 0.028 | Shallow overburden | Burial Pits. |
| BD-02 | 0.039 | Deep overburden | Buildings. |
| BD-03 | 0.029 | Deep overburden | Buildings. |
| BD-13 | 0.019 | Deep overburden | Buildings. |
| SW-07 | 0.02 | Deep overburden | Site Pond. |
| WS-23 | 0.033 | Deep overburden | Northeast corner of the Hematite Facility, near the Burial Pits. |

**Table 4.4. Iron concentrations in groundwater samples (All other samples less than 1 mg/L; refer to Fig. 2.6a and b for well locations.)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| WS-15 | 2.4 | Shallow overburden | Burial Pits. |
| WS-32 | 18 | Deep overburden | Between Deul's Mountain/Fence Line. |
| NB-50 | 2.8 | Deep overburden | Between the Hematite Facility and Highway P. |
| NB-36 | 12 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-38 | 8.7 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-44 (duplicate) | 5.1 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-44 | 5.2 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-72 | 24 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-81 | 34 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-83 | 6.4 | Deep overburden | Between the Hematite Facility and Joachim Creek, towards East. |
| BD-02 | 38 | Deep overburden | Buildings. |
| BD-03 | 15 | Deep overburden | Buildings. |
| BD-04 | 2.9 | Deep overburden | Buildings. |
| BD-05 | 2.5 | Deep overburden | Buildings. |
| BD-06 | 4.1 | Deep overburden | Buildings. |
| BD-13 | 17 | Deep overburden | Buildings. |
| BD-14 | 29 | Deep overburden | Buildings. |
| BD-16 | 1.9 | Deep overburden | Buildings. |
| NB-54 (duplicate) | 8.3 | Deep overburden | Buildings, Parking Lot. |
| NB-54 | 9.9 | Deep overburden | Buildings, Parking Lot. |
| NB-56 | 4 | Deep overburden | Buildings, Parking Lot. |
| NB-57A | 3.2 | Deep overburden | Buildings, Parking Lot. |
| BP-17 | 7.4 | Deep overburden | Burial Pits. |
| BP-22A | 9.4 | Deep overburden | Burial Pits. |
| BP-22A (duplicate) | 10 | Deep overburden | Burial Pits. |
| BP-22B | 1.1 | Deep overburden | Burial Pits. |
| NB-61 | 20 | Deep overburden | Burial Pits. |
| NB-61 (duplicate) | 20 | Deep overburden | Burial Pits. |
| NB-79 | 9.4 | Deep overburden | Burial Pits. |
| NB-80 | 7.2 | Deep overburden | Burial Pits. |
| WS-25 | 25 | Deep overburden | Burial Pits. |
| WS-29 | 18 | Deep overburden | Burial Pits. |
| CB-02 | 16 | Deep overburden | Cistern Burn Pit. |
| DM-02 | 1.7 | Deep overburden | Deul's Mountain. |
| OB-02 | 3.9 | Deep overburden | East of the Hematite Site, near Joachim Creek. |
| NB-46 | 5.5 | Deep overburden | East-northeast of the Hematite Facility, past Northeast Site Creek. |
| NB-71 | 6.7 | Deep overburden | East-northeast of the Hematite Facility, past Northeast Site Creek. |
| NB-74 | 28 | Deep overburden | Evaporation Ponds. |
| LF-08 | 12 | Deep overburden | Former Leach Field. |
| LF-09 | 1.1 | Deep overburden | Former Leach Field. |
| LF-09 (duplicate) | 1.2 | Deep overburden | Former Leach Field. |
| BR-03-OB | 1.4 | Deep overburden | Near Joachim Creek. |

**Table 4.4. Iron concentrations in groundwater samples (All other samples less than 1 mg/L; refer to Fig. 2.6a and b for well locations.) (continued)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| BR-06-OB | 1.8 | Deep overburden | Near Joachim Creek. |
| BR-10-OB | 2.4 | Deep overburden | Near Joachim Creek. |
| NB-66 | 5 | Deep overburden | Near Joachim Creek. |
| WS-23 | 25 | Deep overburden | Northeast corner of the Hematite Facility, near the Burial Pits. |
| SW-07 | 6.2 | Deep overburden | Site Pond. |
| NB-32 | 3.6 | Deep overburden | Southeast of the Hematite Facility Fence Line, towards Joachim Creek. |
| NB-33 | 2 | Deep overburden | Southeast of the Hematite Facility Fence Line, towards Joachim Creek. |
| NB-33 (duplicate) | 3.2 | Deep overburden | Southeast of the Hematite Facility Fence Line, towards Joachim Creek. |
| NB-35 | 17 | Deep overburden | Southeast of the Hematite Facility Fence Line, towards Joachim Creek. |
| NB-39 | 9.2 | Deep overburden | Southeast of the Hematite Facility Fence Line, towards Joachim Creek. |
| NB-39 (duplicate) | 9.6 | Deep overburden | Southeast of the Hematite Facility Fence Line, towards Joachim Creek. |
| NB-84 | 6.4 | Deep overburden | Southeast of the Hematite Facility Fence Line, towards Joachim Creek. |
| PL-04 | 21 | Deep overburden | Southeast of the Hematite Facility Fence Line, towards Joachim Creek. |
| WS-08 | 2.4 | Deep overburden | Southeast of the Hematite Facility Fence Line, towards Joachim Creek. |
| NB-85 | 4.3 | Deep overburden | Southwest of the Hematite Facility, towards Site Creek. |
| NB-86 | 2.7 | Deep overburden | Southwest of the Hematite Facility, towards Site Creek. |
| WS-34 | 14 | Deep overburden | Southwest of the Hematite Facility, towards Site Creek. |
| PZ-03 | 16 | Jefferson City | Between buildings and Deul's Mountain. |
| BR-08-JC | 4.1 | Jefferson City | Between the Hematite Facility and Joachim Creek. |
| BR-01-JC | 2.1 | Jefferson City | East of Site Pond. |
| PZ-04 | 3.9 | Jefferson City | Northeast corner of the Hematite Facility, near Burial Pits. |
| BR-02-JC | 1.7 | Jefferson City | West of the Hematite Site. |

**Table 4.5. Lead concentrations in groundwater samples (All other samples less than reporting limit of 0.003 mg/L; refer to Fig. 2.6a and b for well locations.)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| WS-14 | 0.0037 | Shallow overburden | Burial Pits. |
| NB-50 | 0.0033 | Deep overburden | Between the Hematite Facility and Highway P. |
| BD-02 | 0.0430 | Deep overburden | Buildings. |
| BD-03 | 0.0340 | Deep overburden | Buildings. |
| BD-06 | 0.0033 | Deep overburden | Buildings. |
| BD-13 | 0.0340 | Deep overburden | Buildings. |
| NB-54 | 0.0170 | Deep overburden | Buildings, Parking Lot. |
| BP-22A | 0.0043 | Deep overburden | Burial Pits. |
| WS-25 | 0.0310 | Deep overburden | Burial Pits. |
| WS-32 | 0.0075 | Deep overburden | Deul's Mountain. |
| OB-02 | 0.0057 | Deep overburden | East of the Hematite Site, near Joachim Creek. |
| LF-08 | 0.0200 | Deep overburden | Former Leach Field. |
| NB-66 | 0.0082 | Deep overburden | Near Joachim Creek. |
| WS-23 | 0.0590 | Deep overburden | Northeast corner of the Hematite Facility, near Burial Pits. |
| SW-07 | 0.0058 | Deep overburden | Site Pond. |
| WS-08 | 0.0075 | Deep overburden | Southeast of the Hematite Facility Fence Line, towards Joachim Creek. |
| NB-85 | 0.0045 | Deep overburden | Southwest of the Hematite Facility, towards Site Creek. |
| BR-10-JC | 0.0032 | Jefferson City | Near Joachim Creek. |

**Table 4.6. Nickel concentrations in groundwater samples (All other samples less than 0.05 mg/L; refer to Fig. 2.6a and b for well locations.)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| BD-02 | 0.080 | Deep Overburden | Buildings. |
| BD-05 | 0.097 | Deep Overburden | Buildings. |
| BD-08 | 0.150 | Deep Overburden | Buildings. |
| NB-72 | 0.062 | Deep Overburden | Between the Hematite Facility and Joachim Creek. |
| PZ-03 | 0.067 | Jefferson City-Cotter | Between buildings and Deul's Mountain. |

**Table 4.7. Nitrate (as-N) concentrations in groundwater (All other samples less than 1 mg/L; refer to Fig. 2.6a and b for well locations.)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| WS-07 | 2.2 | Shallow overburden | Pipeline, southeast of the Hematite Facility. |
| WS-17B | 3.3 | Shallow overburden | Deul's Mountain. |
| WS-14 | 1.8 | Shallow overburden | Burial Pits. |
| WS-26 | 3.1 | Shallow overburden | Burial Pits. |
| WS-28 | 1.3 | Shallow overburden | Burial Pits. |
| BD-01 | 67 | Deep overburden | Buildings. |
| BD-02 | 290 | Deep overburden | Buildings. |
| BD-03 | 3.8 | Deep overburden | Buildings. |
| BD-04 | 37 | Deep overburden | Buildings. |
| BD-05 | 2.6 | Deep overburden | Buildings. |
| BR-08-OB | 1.7 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| EP-20 | 90 | Deep overburden | Evaporation Ponds. |
| LF-08 | 1.6 | Deep overburden | Former Leach Fields. |
| NB-34 | 17 | Deep overburden | Southeast of the Hematite Facility towards Joachim Creek. |
| NB-34 (duplicate) | 17 | Deep overburden | Southeast of the Hematite Facility towards Joachim Creek. |
| NB-63 | 4.5 | Deep overburden | Near Joachim Creek. |
| NB-64 | 1.7 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-65 | 2.9 | Deep overburden | Near Joachim Creek. |
| NB-66 | 2.4 | Deep overburden | Near Joachim Creek. |
| NB-67 | 2.2 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-73 | 1.2 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-77 | 2.2 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-78 | 2.6 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-82 | 1.8 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| PL-06 | 4.8 | Deep overburden | Pipeline, southwest of the Hematite Facility. |
| BR-08-JC | 1.4 | Jefferson City-Cotter | Between the Hematite Facility and Joachim Creek. |
| BR-09-JC | 1.1 | Jefferson City-Cotter | Between the Hematite Facility and Joachim Creek. |
| BR-12-RB | 1.6 | Roubidoux | North-northwest of the Hematite Facility across Highway P. |

**Table 4.8. Selenium concentrations in groundwater (All other samples below reporting limit of 0.005 mg/L; refer to Fig. 2.6a and b for well locations.)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| NB-64 | 0.0062 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-78 | 0.0095 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-54 | 0.0057 | Deep overburden | Buildings/Parking Lot. |
| OB-01 | 0.0077 | Deep overburden | East of Site Pond. |
| LF-09 | 0.0065 | Deep overburden | Former Leach Field. |
| NB-65 | 0.0051 | Deep overburden | Near Joachim Creek. |
| WS-14 | 0.0073 | Shallow overburden | Burial Pits. |
| WS-26 | 0.0091 | Shallow overburden | Burial Pits. |

**Table 4.9. Thallium concentrations in groundwater samples (All other samples below reporting limit of 0.01 mg/L; refer to Fig. 2.6a and b for well locations.)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| BD-01 | 0.011 | Deep overburden | Buildings. |
| BD-02 | 0.026 | Deep overburden | Buildings. |
| BP-17 | 0.013 | Deep overburden | Burial Pits. |

**Table 4.10. Vanadium concentrations in groundwater (All other samples below reporting limit of 0.01 mg/L; refer to Fig. 2.6a and b for well locations.)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| BD-02 | 0.037 | Deep overburden | Buildings. |
| BD-03 | 0.034 | Deep overburden | Buildings. |
| BD-13 | 0.034 | Deep overburden | Buildings. |
| LF-08 | 0.018 | Deep overburden | Former Leach Field. |
| WS-23 | 0.044 | Deep overburden | Near Burial Pits. |
| WS-25 | 0.035 | Deep overburden | Burial Pits. |

**Table 4.11. Zinc concentrations in groundwater (All other samples less than 0.05 mg/L; refer to Fig. 2.6a and b for well locations.)**

| Well ID | Result (mg/L) | Formation | Area of concern or general location |
|---|---|---|---|
| NB-83 | 0.050 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-85 | 0.053 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| NB-86 | 0.130 | Deep overburden | Between the Hematite Facility and Joachim Creek. |
| BD-02 | 0.180 | Deep overburden | Buildings. |
| BD-03 | 0.170 | Deep overburden | Buildings. |
| BD-13 | 0.650 | Deep overburden | Buildings. |
| NB-54 | 0.190 | Deep overburden | Buildings/Parking Lot. |
| BP-22A | 0.095 | Deep overburden | Burial Pits. |
| WS-25 | 0.540 | Deep overburden | Burial Pits. |
| WS-32 | 0.075 | Deep overburden | Deul's Mountain. |
| WS-23 | 0.310 | Deep overburden | Near Burial Pits. |
| NB-66 | 0.054 | Deep overburden | Near Joachim Creek. |
| NB-77 | 0.085 | Deep overburden | Near Joachim Creek. |
| SW-07 | 0.210 | Deep overburden | Site Pond. |
| NB-32 | 0.240 | Deep overburden | Southeast of the Hematite Facility. |
| BR-01-JC | 0.069 | Jefferson City-Cotter | East of Site Pond. |
| BR-03-RB | 0.150 | Roubidoux | Roubidoux. |

**Table 4.12 Inorganics in Site Sediment (refer to Fig. 2.3 for sample locations)**

| Sample ID | Aluminum | | Arsenic | | Barium | | Beryllium | | Cadmium | | Chromium | | Cobalt | | Copper | | Fluoride | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Result | Q | Result | Q | Result | Q | Result | Q | Result | Q | Result | Q | Result | Q | Result | Q | Result | Q |
| **Site Pond** | | | | | | | | | | | | | | | | | | |
| SW-01-SS | 9200 | | 4.6 | | 120 | | 0.81 | | 0.76 | | 23 | | 7.7 | | 46 | | 25 | |
| SW-05-SS | 5400 | J | 5.8 | = | 180 | J | 0.61 | U | 0.6 | = | 10 | = | 7.7 | = | 37 | = | 10 | U |
| SW-06-SS | 13000 | J | 9.1 | = | 180 | J | 1.3 | = | 3.2 | = | 48 | = | 14 | = | 110 | = | 28 | = |
| SW-07-SS | 10000 | | 4.5 | | 150 | | 0.57 | U | 1.5 | | 31 | | 7.9 | | 66 | | 17 | |
| **Site Creek** | | | | | | | | | | | | | | | | | | |
| SW-02-SS | 4100 | J | 4.9 | = | 250 | J | 0.38 | U | 0.37 | = | 8.6 | = | 6.2 | = | 9.9 | = | 6.3 | U |
| SW-03-SS | 5300 | J | 4.9 | = | 200 | J | 0.59 | U | 0.44 | = | 11 | = | 8.1 | = | 13 | = | 9.9 | U |
| SW-04-SS | 6500 | J | 11 | = | 940 | J | 0.86 | = | 0.64 | = | 13 | = | 25 | = | 38 | = | 6.7 | U |
| **Northeast Site Creek** | | | | | | | | | | | | | | | | | | |
| SW-11-SS | 7100 | | 6.5 | | 85 | | 0.57 | | 0.28 | U | 13 | | 8 | | 9.5 | | 7.1 | U |
| SW-12-SS | 6100 | | 3.5 | | 47 | | 0.4 | U | 0.27 | U | 10 | | 3.8 | | 6.8 | | 8.6 | |
| SW-13-SS | 5300 | | 8.9 | | 83 | | 0.51 | | 0.3 | U | 12 | | 10 | | 7.4 | | 9.8 | |
| SW-10-SS | 6300 | | 6 | | 140 | | 0.58 | | 0.31 | U | 14 | | 8.8 | | 11 | | 10 | |
| **Joachim Creek** | | | | | | | | | | | | | | | | | | |
| SW-14-SS | 660 | | 3 | | 35 | | 0.37 | U | 0.25 | U | 8.7 | | 2.3 | | 1 | U | 6.2 | U |
| SW-15-SS | 2200 | | 7.4 | | 110 | | 0.35 | | 0.23 | U | 24 | | 8 | | 6.5 | | 5.9 | U |
| SW-16-SS | 1900 | | 3.2 | | 67 | | 0.37 | U | 0.25 | U | 11 | | 3.4 | | 3.4 | | 6.2 | U |
| SW-08-SS | 820 | | 3.5 | | 38 | | 0.36 | U | 0.24 | U | 8.9 | | 2.1 | | 1.7 | | 6.1 | U |
| SW-08-SS-FD | 780 | | 2.2 | | 33 | | 0.35 | U | 0.24 | U | 11 | | 2.3 | | 1.4 | | 5.9 | U |
| **Upstream Sediment** | | | | | | | | | | | | | | | | | | |
| US-04-SS | 3000 | | 5.8 | | 58 | | 0.39 | U | 0.26 | U | 7.6 | | 5.6 | | 4.3 | | 6.5 | UN |
| US-05-SS | 2500 | | 3.5 | | 130 | | 0.37 | U | 0.25 | U | 7.2 | | 4.1 | | 4.3 | | 6.2 | U |
| **Site-Specific Background in Subsurface Soil** | | | | | | | | | | | | | | | | | | |
| Appendix J | 17000 | | 9.8 | | 320 | | 0.92 | | 0.72 | | 24 | | 14 | | 13 | | N.C. | |

*Q = data qualifier; J = estimated (below RL but above MDL); U: below MDL; "=": data point was validated

**Table 4.12 Inorganics in Site Sediment (refer to Fig. 2.3 for sample locations) (continued)**

| Sample ID | Iron | | Lead | | Manganese | | Mercury | | Nickel | | Selenium | | Vanadium | | Zinc | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Result | Q | Result | Q | Result | Q | Result | Q | Result | Q | Result | Q | Result | Q | Result | Q |
| **Site Pond** | | | | | | | | | | | | | | | | |
| SW-01-SS | 15000 | | 27 | | 400 | | 0.12 | | 29 | | 0.96 | U | 25 | | 140 | |
| SW-05-SS | 14000 | J | 130 | = | 890 | J | 0.074 | | 12 | = | 1.1 | = | 20 | = | 87 | = |
| SW-06-SS | 19000 | J | 71 | = | 900 | J | 1.1 | | 48 | = | 1.8 | U | 29 | = | 410 | = |
| SW-07-SS | 11000 | | 58 | | 330 | | 0.27 | | 28 | | 0.95 | U | 29 | | 270 | |
| **Site Creek** | | | | | | | | | | | | | | | | |
| SW-02-SS | 9500 | J | 58 | = | 640 | J | 0.03 | | 8.6 | = | 0.85 | = | 15 | = | 210 | = |
| SW-03-SS | 11000 | J | 53 | = | 830 | J | 0.082 | | 12 | = | 0.99 | U | 18 | = | 150 | = |
| SW-04-SS | 23000 | J | 110 | = | 5600 | J | 0.03 | | 27 | = | 2.6 | = | 33 | = | 130 | = |
| **Northeast Site Creek** | | | | | | | | | | | | | | | | |
| SW-11-SS | 14000 | | 31 | | 600 | | 0.028 | U | 13 | | 0.71 | U | 25 | | 44 | |
| SW-12-SS | 8200 | | 18 | | 170 | | 0.027 | U | 7.7 | | 0.96 | | 16 | | 36 | |
| SW-13-SS | 16000 | | 26 | | 670 | | 0.03 | U | 11 | | 1.7 | | 24 | | 66 | |
| SW-10-SS | 14000 | | 41 | | 850 | | 0.031 | U | 13 | | 0.96 | | 24 | | 59 | |
| **Joachim Creek** | | | | | | | | | | | | | | | | |
| SW-14-SS | 5600 | | 9.8 | | 99 | | 0.025 | U | 2.9 | | 0.62 | U | 13 | | 53 | |
| SW-15-SS | 17000 | | 41 | | 500 | | 0.026 | | 11 | | 0.77 | | 29 | | 160 | |
| SW-16-SS | 5900 | | 29 | | 240 | | 0.025 | U | 4.4 | | 0.73 | | 11 | | 93 | |
| SW-08-SS | 5000 | | 12 | | 77 | | 0.024 | U | 3.1 | | 0.61 | U | 9.6 | | 55 | |
| SW-08-SS-FD | 4400 | | 30 | | 130 | | 0.024 | U | 3.3 | | 0.59 | U | 9.5 | | 61 | |
| **Upstream Sediment** | | | | | | | | | | | | | | | | |
| US-04-SS | 10000 | | 15 | | 550 | * | 0.026 | U | 8.6 | | 0.73 | | 16 | | 23 | E |
| US-05-SS | 6200 | | 35 | | 340 | | 0.025 | U | 4.8 | | 0.62 | U | 11 | | 140 | |
| **Site-Specific Background in Subsurface Soil** | | | | | | | | | | | | | | | | |
| Appendix J | 24000 | | 90 | | 960 | | 0.05 | | 17 | | 0.85 | | 40 | | 370 | |

*Q = data qualifier; J = estimated (below RL but above MDL); U: below MDL; "=": data point was validated

**Table 4.13. Ten highest inorganic concentrations (mg/kg) in surface soils**

| Element | Station ID | Concen-tration (mg/kg) | Element | Station ID | Concen-tration (mg/kg) | Element | Station ID | Concen-tration (mg/kg) | Element | Station ID | Concen-tration (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Antimony | **Site Bkg** | **N.C.** | Arsenic | **Site Bkg** | **9.6** | Beryllium | **Site Bkg** | **0.77** | Cadmium | **Site Bkg** | **0.6** |
| | EP-11 | 1.9 | | EP-02 | 27 | | OA-07 | 1.0 | | BD-12 | 1.5 |
| | EP-06 | 2.2 | | EP-10 | 34 | | EP-03 | 1.1 | | OA-01 | 1.6 |
| | BD-12 | 2.3 | | EP-08 | 45 | | NB-11 | 1.1 | | NB-11 | 2.2 |
| | DM-02 | 2.6 | | BD-11 | 48 | | EP-06 | 1.1 | | EP-06 | 2.2 |
| | EP-01 | 3.2 | | EP-11 | 55 | | SW-01 | 1.2 | | EP-04 | 2.9 |
| | OA-08 | 3.7N | | BD-12 | 76 | | BP-07 | 1.5 | | EP-03 | 3.3 |
| | EP-04 | 5.2 | | EP-12 | 77 | | SW-02 | 2.6 | | SW-02 | 3.5 |
| | EP-02 | 8.4 | | EP-04 | 99 | | EP-01 | 3.4 | | BD-10 | 4.5 |
| | OA-26 | 16 | | EP-09 | 100 | | EP-02 | 4.4 | | EP-01 | 4.7 |
| | BD-10 | 21 | | EP-06 | 160 | | EP-04 | 5.8 | | EP-02 | 11 |
| **Element** | **Station ID** | **Concen-tration (mg/kg)** | **Element** | **Station ID** | **Concen-tration (mg/kg)** | **Element** | **Station ID** | **Concen-tration (mg/kg)** | **Element** | **Station ID** | **Concen-tration (mg/kg)** |
| Chromium | **Site Bkg** | **17** | Cobalt | **Site Bkg** | **17** | Copper | **Site Bkg** | **13** | Lead | **Site Bkg** | **81** |
| | OA-26 | 35 | | OA-28 | 16 | | EP-11 | 39 | | EP-02 | 230 |
| | LF-01 | 35 | | NB-04 | 16 | | SW-02 | 39 | | NB-05 | 230 |
| | BD-12 | 35 | | SW-02 | 16 | | OA-26 | 43 | | BD-10 | 230 |
| | EP-06 | 37 | | BD-10 | 18 | | EP-01 | 50 | | OA-08 | 270 |
| | BP-07 | 52 | | BP-05 | 21 | | NB-04 | 55 | | OA-01 | 370 |
| | EP-02 | 53 | | EP-06 | 33 | | DM-02 | 60 | | NB-22 | 370 |
| | DM-02 | 55 | | OA-23 | 300 | | OA-08 | 150 | | BD-12 | 430 |
| | EP-04 | 76 | | OA-01 | 13 | | EP-04 | 160 | | NB-04 | 490 |
| | OA-08 | 90 | | BP-01 | 13 | | BD-10 | 180 | | OA-04 | 560 |
| | BD-10 | 280 | | NB-05 | 12 | | EP-02 | 1800 | | OA-13 | 1400 |

*Site Bkg: Site-specific background concentration for surface soil, as calculated in Appendix J. N.C.: Not calculated, refer to Appendix J.

**Table 4.13. Ten highest inorganic concentrations (mg/kg) in surface soils (continued)**

| Element | Sample ID | Concen-tration (mg/kg) | Element | Sample ID | Concen-tration (mg/kg) | Element | Sample ID | Concen-tration (mg/kg) | Element | Sample ID | Concen-tration (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Mercury | **Site Bkg** | **0.04** | Nickel | **Site Bkg** | **14** | Selenium | **Site Bkg** | **0.97** | Silver | **Site Bkg** | **N.C.** |
| | OA-23 | 0.58 | | OA-26 | 36 | | SW-04 | 1.5 | | NB-22 | 0.7 |
| | OA-08 | 0.62 | | BD-12 | 39 | | GS-04 | 1.7 | | SW-02 | 0.78 |
| | SW-02 | 0.68 | | EP-03 | 39 | | NB-14 | 1.7 | | NB-14 | 0.82 |
| | EP-03 | 0.82 | | EP-06 | 51 | | EP-06 | 1.8 | | OA-04 | 1.1 |
| | OA-11 | 0.84 | | OA-08 | 61 | | BP-05 | 1.8 | | DM-02 | 1.1 |
| | BD-11 | 0.92 | | EP-01 | 90 | | NB-11 | 1.8 | | BD-10 | 1.1 |
| | OA-13 | 1.1 | | BD-11 | 110 | | SW-02 | 2.6 | | EP-04 | 1.6 |
| | EP-02 | 2.6 | | EP-02 | 150 | | EP-08 | 2.9 | | EP-02 | 2 |
| | EP-04 | 2.8 | | EP-04 | 240 | | BD-10 | 2.9 | | EP-11 | 0.69 |
| | EP-01 | 3.4 | | BD-10 | 300 | | EP-10 | 4.1 | | OA-35 | 0.69 |

| Element | Sample ID | Concen-tration (mg/kg) | Element | Sample ID | Concen-tration (mg/kg) |
|---|---|---|---|---|---|
| Thallium | **Site Bkg** | **Not detected** | Zinc | **Site Bkg** | **310** |
| | SW-01 | 2.1 | | NB-11 | 380 |
| | OA-08 | 2.1 | | NB-10 | 400 |
| | SW-04 | 2.1 | | EP-09 | 500 |
| | OA-03 | 2.2 | | EP-02 | 520 |
| | EP-02 | 2.2 | | BD-10 | 520 |
| | NB-14 | 2.6 | | NB-23 | 540 |
| | EP-06 | 2.9 | | OA-01 | 610 |
| | OA-12 | 3.1 | | EP-06 | 660 |
| | BD-10 | 4.7 | | EP-12 | 900 |
| | SW-02 | 5.4 | | EP-04 | 1300 |

*Site Bkg: Site-specific background concentration for surface soil, as calculated in Appendix J. N.C.: Not calculated, refer to Appendix J.

**Table 4.14. Comparison of Hematite Site surface soil results with local, regional, and international compilations (mg/kg)**

| | Aluminum | Antimony | Arsenic | Barium | Beryllium | Cadmium |
|---|---|---|---|---|---|---|
| **Hematite Site samples** | | | | | | |
| Max | 24,000 | 21 | 160 | 1,500 | 5.8 | 11 |
| Min | 2,000 | 0.87 | 1.1 | 24 | 0.33 | 0.22 |
| **Off-Site samples** | | | | | | |
| Mean | 10,444 | Not detected | 7 | 192 | 0.64 | 0.36 |
| Range | (4,500 to 17,000) | (<~1.2) | (5.1 to 9.6) | (80 to 340) | (<0.36 to 0.92) | (<0.24 to 0.72) |
| Site Background[a] | 17,000. | N.C. | 9.6 | 330. | 0.77 | 0.6 |
| **Tidball (1984)** | | | | | | |
| Geometric mean | 41,000 | | 8.7 | 580 | 0.8 | <1 |
| Range | (11,000 to 79,000) | - | (2.5 to 72) | (100 to 1,500) | (<1 to 2) | (<1 to 11) |
| **IEPA 1994** | | | | | | |
| Mean | | | 6.7 | | | 0.97 |
| Range | | | (0.35 to 24) | | | (ND to 8.2) |
| **Connor and Shacklette (1975), Missouri Region geometric mean or range of means (maximum background value)** | | | | | | |
| Shale/Clay[b] | | | 6.4 to 9 (27) | | 1.1 to 1.7 (3) | <1 (5) |
| Sandstone/Sand[b] | | | 1.1 to 4.3 (25) | | 0.8 (1.5) | ---- |
| Carbonates[b] | | | 0.7 to 2.5 (39) | | <1 (1) | <1 (12) |
| Soil[b] | | | 5.5 to 13 (170) | | 0.8 to 1.3 (2) | <1 (11) |
| Loess[b] | | | 8.3 (13) | | 0.95 (1.5) | ---- |
| **Lindsay (1973), soil** | | | | | | |
| Mean | 71,000 | ---- | 5 | 430 | 6 | 0.06 |
| Range | 10,000-300,000 | | 1 to 50 | 100 to 3,000 | 0.1 to 40 | 0.01 to .7 |
| **Fergusson and Kim (1991)** | | | | | | |
| Urban street dust (range) | 15,000-60,000 | 2 to 10 | 4 to 15 | 310 | ---- | 0.5 to 4 |
| House dust (mean or range) | 25,000 | 10 | 16 | ---- | ---- | 5 to 10 |

[a]Site Background = see Appendix J;

[b]Geometric mean or range of means and maximum background value, Missouri region (Connor and Shacklette 1975).

*Dreher, G.B., and L.R. Follmer 2004. Mercury content of Illinois soils. Water, Air, and Soil Pollution. 156:299-315. This study provides a more recent value from 101 cores, 6 samples per core yielding a mean core content of 33 +/- 20 µg/kg with a background average of 20 +/- 9 µg/kg. The higher value was presumed biased by dry deposition from power plants or waste incinerators.

ND = not detected.

N.C. = Not calculated, refer to Appendix J for discussion of how elements were selected for Site background calculation.

**Table 4.14. Comparison of Hematite Site surface soil results with local, regional, and international compilations (mg/kg) (continued)**

| Element | Calcium | Chromium | Cobalt | Copper | Fluoride | Iron |
|---|---|---|---|---|---|---|
| | | | **Hematite Site samples** | | | |
| Max | 250,000 | 280 | 300 | 1,800 | 170 | 61,000 |
| Min | 860 | 4.9 | 0.86 | 5.6 | 5.7 | 1,600 |
| | | | **Off-Site samples** | | | |
| Mean | 4,192 | 13 | 9 | 11 | --- | 17,365 |
| Range | (830 to 14,000) | (8 to 24) | (4.8 to 14) | (7.6 to 13) | --- | (9,700 to 26,000) |
| Site Background[a] | N.C. | 17 | 17 | 13 | --- | 26000 |
| | | | **Tidball (1984)** | | | |
| Geometric mean | 3,300 | 54 | 10 | 13 | 270 | 21,000 |
| Range | (>700 to 56,000) | (10 to 150) | (<3 to 30) | (5 to 150) | (10 to 6,400) | (4,900 to 54,000) |
| | | | **IEPA 1994** | | | |
| Mean | | 17.3 | | 19.7 | | |
| Range | | (<2 to 151) | | (1 to 156) | | |
| | | | **Connor and Shacklette 1975, Missouri Region** | | | |
| | | | **geometric mean or range of means (maximum background value)** | | | |
| Shale/Clay | | 95 to 130 (700) | | 13 (100) | | |
| Sandstone/Sand | | 2 to 7.4 (100) | | 1.2 to 8.4 (30) | | |
| Carbonates | | 2.7 to 16 (70) | | 0.8 to 5.3 (20) | | |
| Soil | | 30 to 70 (150) | | 11 to 23 (150) | | |
| Loess | | 70 (100) | | 18 (30) | | |
| | | | **Lindsay 1973, soil** | | | |
| Mean | 13,700 | 100 | 8 | 30 | | 38,000 |
| Range | 7,000 to 500,000 | 1 to 1000 | 1-40 | 2 to 100 | | 7,000 to 555,000 |
| | | | **Fergusson and Kim 1991** | | | |
| Urban street dust (range) | 4000 to 120,000 | 20 to 200 | 6-9 | 100 to 300 | ---- | 10,000 to 60,000 |
| House dust (mean or range) | 15,000 | 30 to 100 | 9 | 200 to 300 | ---- | 10,000 |

[a]Site Background: see Appendix J;

[b]Geometric mean or range of means and maximum background value, Missouri region (Connor and Shacklette 1975).

*Dreher, G.B., and L.R. Follmer 2004. Mercury content of Illinois soils. Water, Air, and Soil Pollution. 156:299-315. This study provides a more recent value from 101 cores, 6 samples per core yielding a mean core content of 33 +/- 20 µg/kg with a background average of 20 +/- 9 µg/kg. The higher value was presumed biased by dry deposition from power plants or waste incinerators.

ND = not detected.

N.C. = Not calculated, refer to Appendix J for discussion of how elements were selected for Site background calculation.

**Table 4.14. Comparison of Hematite Site surface soil results with local, regional, and international compilations (mg/kg) (continued)**

| Element | Lead | Magnesium | Manganese | Mercury | Nickel | Potassium |
|---|---|---|---|---|---|---|
| **Hematite Site samples** | | | | | | |
| Max | 1,400 | 53,000 | 4,400 | 3.4 | 300 | 8,000 |
| Min | 3.7 | 790 | 41 | 0.022 | 5.3 | 380 |
| **Off-Site samples** | | | | | | |
| Mean | 41 | 2,528 | 655 | 0.03 | 13 | 740 |
| Range | (12 to 90) | (1,600 to 5,600) | (240 to 1,100) | (<0.23 to 0.053) | (7.4 to 17) | (460 to 1,100) |
| Site Background[a] | 81 | N.C. | 1100 | .0.04 | 14 | N.C. |
| **Tidball (1984)** | | | | | | |
| Geometric mean range | 20 | 2,600 | 740 | 0.039 | 14 | 4,000 |
| | (10 to 7,000) | (500 to 28,000) | (15 to 3,000) | (<0.1 to 0.8) | (<5 to 70) | (3,300 to 37,000) |
| **IEPA 1995** | | | | | | |
| Mean | 49.2 | | | 0.11 | 16.8 | 1,363 |
| Range | (4.7 to 647) | | | (ND to 1.67)* | (<3 to 135) | 270 to 5,820 |
| **Connor and Shacklette 1975, Missouri Region geometric mean or range of means (maximum background value)** | | | | | | |
| Shale/Clay[b] | 11 to 17 (100) | | 140 to 170 (500) | 0.045 (0.19) | 21 to 38 (100) | |
| Sandstone/Sand[b] | 17 (150) | | 29 to 300 (3,000) | 0.008 to 0.016 (0.15) | <5 to 18 (150) | |
| Carbonates[b] | <10 to 4 (7,000) | | 83 to 830 (7,000) | 0.022 to 0.03 (0.17) | <5 to 4.3 (15) | |
| Soil[b] | 18 to 31 (200) | | 350 to 1,100 (>20,000) | 0.03 to 0.16 (1.5) | 8.4 to 23 (300) | |
| Loess[b] | 15 (20) | | 510 (1,000) | 0.035 (0.08) | 22 (30) | |
| **Lindsay (1973), soil** | | | | | | |
| Mean | 10 | 5,000 | 600 | 0.03 | 40 | 8,300 (400- |
| Range | 2 to -100 | 600 to 6,000 | 20 to 3,000 | 0.01 to 0.3 | (5-500) | 30,000) |
| **Fergusson and Kim (1991)** | | | | | | |
| Urban street dust (range) | 500 to 4,000 | 5,000 to 10,000 | 300 to 800 | 0.09 | 50 to 100 | 5,000 to 20,000 |
| House dust (mean or range) | 300 to 1,000 | 6,500 | 200 | ---- | 40 | 13,000 |

[a]Site Background: see Appendix J;

[b]Geometric mean or range of means and maximum background value, Missouri region (Connor and Shacklette 1975).

*Dreher, G.B., and L.R. Follmer 2004. Mercury content of Illinois soils. Water, Air, and Soil Pollution. 156:299-315. This study provides a more recent value from 101 cores, 6 samples per core yielding a mean core content of 33 +/- 20 µg/kg with a background average of 20 +/- 9 µg/kg. The higher value was presumed biased by dry deposition from power plants or waste incinerators.

ND = not detected.

N.C. = Not calculated, refer to Appendix J for discussion of how elements were selected for Site background calculation.

**Table 4.14. Comparison of Hematite Site surface soil results with local, regional, and international compilations (mg/kg) (continued)**

| Element | Selenium | Silver | Sodium | Thallium | Vanadium | Zinc |
|---|---|---|---|---|---|---|
| **Hematite Site samples** | | | | | | |
| Max | 4.1 | 1.1 | 3,300 | 2.2 | 45 | 1,300 |
| Min | 0.54 | 4.54 | 120 | 0.87 | 5.4 | 19 |
| **Off-Site samples** | | | | | | |
| Mean | 0.75 | ND | 141 | ND | 28 | 127 |
| Range | (<0.6 to <1.2) | | (<120 to 210) | | (16 to 36) | (33 to 370) |
| Site Background[a] | 0.97. | | N.C. | | 39 | 310 |
| **Tidball (1984)** | | | | | | |
| Mean Range | 0.28 | <0.7 | 5,300 | - | 69 | 49 |
| | (<0 to 1-2.7) | (<0.7 to 3) | (700 to 12,000) | | (15 to 150) | (18 to 640) |
| **IEPA 1994** | | | | | | |
| Mean Range | 0.5 | 0.84 | 216 | 0.57 | 25 | 102.9 |
| | (<.1 to 2.6) | (<0.06 to 5.9) | (14.1 to 7,600) | (0.02 to 2.8) | (<2.5 to 80) | (<5.5 to 798) |
| **Connor and Shacklette (1975), Missouri Region geometric mean or range of means (maximum background value)** | | | | | | |
| Shale/Clay[b] | | | | | | 55 to 82 (250) |
| Sandstone/Sand[b] | | | | | | 5 to 31 (280) |
| Carbonates[b] | | | | | | 6 to 24 (140) |
| Soil[b] | | | | | | 30 to 68 (640) |
| Loess[b] | | | | | | 61 (90) |
| **Lindsay 1973, soil** | | | | | | |
| Mean (range) | 0.3 | 0.05 | 6,300 | | 100 | 50 |
| | (0.1 to 2) | (0.1 to 5) | (750 to 7,500) | | (20 to 500) | (10 to 300) |
| **Fergusson and Kim 1991** | | | | | | |
| Urban street dust (range) | 1 to 8 | 0.2 to 1.2 | 5,000 to 20,000 | ---- | 40 to 200 | 300 to 900 |
| House dust (mean or range) | ----- | ---- | 12,000 | ---- | 30 | 800 to 1,600 |

[a]Site Background: see Appendix J;

[b]Geometric mean or range of means and maximum background value, Missouri region (Connor and Shacklette 1975).

*Dreher, G.B., and L.R. Follmer 2004. Mercury content of Illinois soils. Water, Air, and Soil Pollution. 156:299-315. This study provides a more recent value from 101 cores, 6 samples per core yielding a mean core content of 33 +/- 20 µg/kg with a background average of 20 +/- 9 µg/kg. The higher value was presumed biased by dry deposition from power plants or waste incinerators.

ND = not detected.

N.C. = Not calculated, refer to Appendix J for discussion of how elements were selected for Site background calculation.

**Table 4.15. Ten highest inorganic concentrations (mg/kg) in subsurface soils (Last two digits of Station ID-Depth refers to sample depth in ft.)**

| | Station ID-depth | Conc. (mg/kg) | | Station ID-depth | Conc. (mg/kg) | | Station ID-depth | Conc. (mg/kg) | | Station ID-depth | Conc. (mg/kg) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Site Bkg** | **9.8** | | **Site Bkg** | **N.C.** | | **Site Bkg** | **0.92** | | **Site Bkg** | **0.72** |
| Arsenic | NB-47-15 | 12 | Antimony | BD-15-17 | 1.2 | Beryllium | SW-07-23 | 1.1 | Cadmium | NB-86-19 | 0.93 |
| | BD-16-19 | 13 | | DM-03-25 | 1.2 | | SW-08-15 | 1.1 | | NB-78-18 | 0.99 |
| | BP-20-27 | 13 | | EP-20-25 | 1.2 | | CB-02-05 | 1.1 | | SW-02-09 | 1 |
| | EP-13-30 | 13 | | NB-38-15 | 1.2 | | BP-13-25 | 1.1 | | PL-06-29 | 1.1 |
| | NB-72-19 | 13 | | NB-53-13 | 1.2 | | SW-02-09 | 1.1 | | NB-36-15 | 1.1 |
| | EP-14-05 | 14 | | NB-55-25 | 1.2 | | NB-47-15 | 1.1 | | NB-51-25 | 1.2 |
| | OA-18-25 | 14 | | NB-65-13 | 1.2 | | BD-14-25 | 1.2 | | SW-02-15 | 1.3 |
| | EP-18-09 | 17 | | NB-69-22 | 1.2 | | SW-02-15 | 1.2 | | BD-05-23 | 1.5 |
| | DM-03-34 | 20 | | NB-50-25 | 1.5 | | BD-15-17 | 1.8 | | NB-32-27 | 3.7 |
| | BP-18-25 | 24 | | NB-39-15 | 1.8 | | SW-02-01 | 2.8 | | SW-02-01 | 4.7 |
| | **Station ID-depth** | **Conc. (mg/kg)** | | **Station ID-depth** | **Conc. (mg/kg)** | | **Station ID-depth** | **Conc. (mg/kg)** | | **Station ID-depth** | **Conc. (mg/kg)** |
| Chromium | **Site Bkg** | **24** | Cobalt | **Site Bkg** | **14** | Copper | **Site Bkg** | **13** | Lead | **Site Bkg** | **90** |
| | BP-20-03 | 26 | | NB-31-05 | 17 | | NB-68-25 | 29 | | RR-04-05 | 51 |
| | NB-29-22 | 26 | | GS-07-05 | 17 | | SW-08-15 | 30 | | NB-42-13 | 53 |
| | NB-83-23 | 27 | | LF-07-15 | 18 | | NB-49-25 | 30 | | NB-41-05 | 68 |
| | BD-02-21 | 28 | | BD-04-02 | 19 | | DM-02-25 | 30 | | NB-29-05 | 86 |
| | NB-82-05 | 28 | | NB-46-25 | 20 | | OA-19-25 | 31 | | BD-13-09 | 95 |
| | NB-84-33 | 28 | | BD-06-01 | 31 | | NB-51-25 | 31 | | NB-42-05 | 98 |
| | EP-18-09 | 29 | | BD-07-02 | 32 | | BP-18-15 | 31 | | NB-67-05 | 110 |
| | NB-83-11 | 35 | | BD-08-01 | 39 | | NB-47-15 | 32 | | NB-82-05 | 110 |
| | NB-76-24 | 41 | | BD-01-01 | 50 | | NB-50-25 | 32 | | NB-63-05 | 120 |
| | BD-05-01 | 49 | | NB-36-15 | 54 | | BD-05-23 | 38 | | NB-75-19 | 680 |

Site Bkg: Site background, see Appendix J.

N.C. = Not calculated; refer to Appendix J, Background Calculation, regarding selection of elements for background calculations.

**Table 4.15. Ten highest inorganic concentrations (mg/kg) in subsurface soils (Last two digits of Station ID-Depth refers to sample depth in ft.) (continued)**

| | Station ID-depth | Concentration (mg/kg) | | Station ID-depth | Concentration (mg/kg) | | Station ID-depth | Concentration (mg/kg) |
|---|---|---|---|---|---|---|---|---|
| Mercury | **Site Bkg** | **0.05** | Nickel | **Site Bkg** | **17** | Selenium | **Site Bkg** | **0.85** |
| | OA-18-33 | 0.055 | | BP-18-15 | 37 | | NB-69-05 | 2 |
| | BD-05-23 | 0.056 | | NB-58-29 | 38 | | BD-05-23 | 2.2 |
| | NB-32-27 | 0.057 | | NB-49-25 | 39 | | NB-49-25 | 2.2 |
| | BD-16-25 | 0.06 | | SW-08-15 | 39 | | NB-50-25 | 2.2 |
| | NB-47-15 | 0.061 | | NB-50-25 | 40 | | NB-51-37 | 2.2 |
| | BD-16-34 | 0.068 | | EP-18-09 | 42 | | SW-08-25 | 2.3 |
| | SW-08-15 | 0.073 | | NB-47-15 | 44 | | NB-37-15 | 2.4 |
| | EP-18-09 | 0.19 | | NB-36-15 | 60 | | NB-47-15 | 2.6 |
| | SW-02-09 | 0.25 | | BD-05-23 | 71 | | NB-50-15 | 2.6 |
| | SW-02-01 | 0.54 | | NB-85-25 | 97 | | NB-47-31 | 2.9 |

| | Station ID-depth | Concentration (mg/kg) | | Station ID-depth | Concentration (mg/kg) |
|---|---|---|---|---|---|
| Thallium | **Site Bkg** | **Not detected** | Zinc | **Site Bkg** | **370** |
| | BD-16-25 | 2.3 | | NB-67-05 | 220 |
| | NB-50-25 | 2.3 | | NB-82-05 | 230 |
| | NB-48-15 | 2.4 | | BP-18-31 | 230 |
| | BD-16-19 | 2.6 | | NB-29-05 | 240 |
| | OA-18-03 | 2.9 | | NB-77-24 | 240 |
| | OA-19-05 | 3 | | BD-13-30 | 240 |
| | BP-18-15 | 3.2 | | NB-82-20 | 300 |
| | NB-36-15 | 5 | | NB-42-05 | 380 |
| | NB-37-15 | 5.1 | | NB-76-24 | 520 |
| | BD-05-23 | 5.4 | | NB-63-05 | 850 |

Site Bkg: Site background, see Appendix J. N.C. = Not calculated; refer to Appendix J, Background Calculation, regarding selection of elements for background calculations.

**Table 4.16. Comparison of Hematite Site subsurface soil results with local, regional, and international compilations (mg/kg)**

| Element | Aluminum | Antimony | Arsenic | Barium | Beryllium | Cadmium |
|---|---|---|---|---|---|---|
| | | | **Hematite Site samples** | | | |
| Max | 27,000 | 1.8 | 24 | 790 | 2.8 | 4.7 |
| Min | 680 | 0.85 | 1.1 | 9.6 | 0.32 | 0.21 |
| | | | **Off–Site samples** | | | |
| Mean | 10,444 | Not detected | 7 | 192 | 0.64 | 0.36 |
| Range | (4,500 to 17,000) | (<~1.2) | (5.1 to 9.6) | (80 to 340) | (<0.36 to 0.92) | (<0.24 to 0.72) |
| Site Background[a] | 17,000 | N.C. | 9.8 | 320 | 0.92 | 0.72 |
| | | | **Tidball (1984)** | | | |
| Geometric mean | 41,000 | - | 8.7 | 580 | 0.8 | <1 |
| Range | (11,000 to -79,000) | | (2.5 to 72) | (100 to 1,500) | (<1 to 2) | (<1 to 11) |
| | | | **IEPA 1994** | | | |
| Mean | | | 6.7 | | | 0.97 |
| Range | | | (0.35 to 24) | | | (ND to 8.2) |
| | | | **Connor and Shacklette 1975, Missouri Region** | | | |
| | | | **geometric mean or range of means (maximum background value)** | | | |
| Shale/Clay | | | 6.4 to 9 (27) | | 1.1-1.7 (3) | <1 (5) |
| Sandstone/Sand | | | 1.1 to 4.3 (25) | | 0.8 (1.5) | ---- |
| Carbonates | | | 0.7 to 2.5 (39) | | <1 (1) | <1 (12) |
| Soil | | | 5.5 to 13 (170) | | 0.8-1.3 (2) | <1 (11) |
| Loess | | | 8.3 (13) | | 0.95 (1.5) | ----- |
| | | | **Lindsay 1973, soil** | | | |
| Mean | 71,000 | ---- | 5 | 430 | 6 | 0.06 |
| Range | (10,000 to 300,000) | | (1 to 50) | (100 to 3,000) | (0.1 to 40) | (0.01 to .7) |

[a]Site Background: see Appendix J;

[b]Dreher, G.B., and L.R. Follmer. 2004. Mercury content of Illinois soils. Water, Air, and Soil Pollution. 156:299-315. This study provides a more recent value from 101 cores, 6 samples per core yielding a mean core content of 33 +/- 20 μg/kg with a background average of 20 +/- 9 μg/kg. The higher value was presumed biased by dry deposition from power plants or waste incinerators.

ND = Not detected.

N.C. = Not calculated, refer to Appendix J for discussion of how elements were selected for Site background calculation.

**Table 4.16. Comparison of Hematite Site subsurface soil results with local, regional, and international compilations (mg/kg) (Continued)**

| Element | Calcium | Chromium | Cobalt | Copper | Fluoride | Iron |
|---|---|---|---|---|---|---|
| | | | **Hematite Site samples** | | | |
| Max | 190,000 | 49 | 54 | 38 | 190 | 35,000 |
| Min | 300 | 5.8 | 1.7 | 1.5 | 5.4U | 2,100 |
| | | | **Off-Site samples** | | | |
| Mean | 4,192 | 13 | 9 | 11 | --- | 17,365 |
| Range | (830 to 14,000) | (8 to 24) | (4.8 to 14) | (7.6 to 13) | --- | (9,700 to 26,000) |
| Site Background[a] | N.C. | 24. | 14. | 13. | --- | 24,000. |
| | | | **Tidball (1984)** | | | |
| Geometric mean | 3,300 | 54 | 10 | 13 | 270 | 21,000 |
| Range | (<700 to 56,000) | (10 to 150) | (<3 to 30) | (5 to 150) | (10 to 6400) | (4,900 to 54,000) |
| | | | **IEPA, 1994** | | | |
| Mean | | 17.3 | | 19.7 | | |
| Range | | (<2-151) | | (1-156) | | |
| | | | **Connor and Shacklette 1975, Missouri Region** | | | |
| | | | **geometric mean or range of means (maximum background value)** | | | |
| Shale/Clay | | 95 to 130 (700) | | 13 (100) | | |
| Sandstone/Sand | | 2 to 7.4 (100) | | 1.2 to 8.4 (30) | | |
| Carbonates | | 2.7 to 16 (70) | | 0.8 to 5.3 (20) | | |
| Soil | | 30 to 70 (150) | | 11 to 23 (150) | | |
| Loess | | 70 (100) | | 18 (30) | | |
| | | | **Lindsay 1973, soil** | | | |
| Mean | 13,700 | 100 | 8 | 30 | | 38,000 |
| Range | 7,000 to 500,000 | 1 to 1,000 | 1 to 40 | 2 to 100 | | 7,000 to 555,000 |

[a]Site Background: see Appendix J

.[b]Dreher, G.B., and L.R. Follmer. 2004. Mercury content of Illinois soils. Water, Air, and Soil Pollution. 156:299-315. This study provides a more recent value from 101 cores, 6 samples per core yielding a mean core content of 33 +/- 20 µg/kg with a background average of 20 +/- 9 µg/kg. The higher value was presumed biased by dry deposition from power plants or waste incinerators.

ND = Not detected.

N.C. = Not calculated, refer to Appendix J for discussion of how elements were selected for Site background calculation

**Table 4.16. Comparison of Hematite Site subsurface soil results with local, regional, and international compilations (mg/kg) (Continued)**

| | Lead | Magnesium | Manganese | Mercury | Nickel | Potassium |
|---|---|---|---|---|---|---|
| | | | **Hematite Site samples** | | | |
| Max | 680 | 77,000 | 5,700 | 0.54 | 97 | 4,400 |
| Min | 3.8 | 160 | 20 | 0.013 | 2.7 | 110 |
| | | | **Off-Site samples** | | | |
| Mean | 41 | 2528 | 655 | 0.03 | 13 | 740 |
| Range | (12 to 90) | (1,600 to 5,600) | (240 to 1,100) | (<0.23 to 0.053) | (7.4 to 17) | (460 to 1,100) |
| Site Background[a] | 90 | N.C. | 960 | 0.05 | 17. | N.C. |
| | | | **Tidball (1984)** | | | |
| Mean | 20 | 2600 | 740 | 0.039 | 14 | 14,000 |
| Range | (10 to 7,000) | (500 to 28,000) | (15 to 3,000) | (<0.01 to 0.8) | (<5 to 70) | (3,300 to 37,000) |
| | | | **IEPA 1994** | | | |
| Mean | 49.2 | | | 0.11 | 16.8 | |
| Range | (4.7 to 647) | | | (ND to 1.67)[b] | (ND to 135) | |
| | | | **Connor and Shacklette 1975, Missouri Region geometric mean or range of means (maximum background value)** | | | |
| Shale/Clay | 11 to 17 (100) | | 140 to 170 (500) | | 21 to 38 (100) | |
| Sandstone/Sand | 17 (150) | | 29 to 300 (3,000) | | <5 to 18 (150) | |
| Carbonates | <10 to 4 (7,000) | | 83 to 830 (7,000) | | <5 to 4.3 (15) | |
| Soil | 18 to 31 (200) | | 350 to 1,100 (>20,000) | | 8.4 to 23 (300) | |
| Loess | 15 (20) | | 510 (1,000) | | 22 (30) | |
| | | | **Lindsay 1973, soil** | | | |
| Mean | 10 | 5,000 | 600 | 0.03 | 40 | 8,300 |
| Range | 2 to 100 | 600 to 6,000 | 20 to 3,000 | 0.01 to 0.3 | 5 to 500 | 400 to 30,000 |

[a]Site Background: see Appendix J;

[b]Dreher, G.B., and L.R. Follmer. 2004. Mercury content of Illinois soils. Water, Air, and Soil Pollution. 156:299-315. This study provides a more recent value from 101 cores, 6 samples per core yielding a mean core content of 33 +/- 20 µg/kg with a background average of 20 +/- 9 µg/kg. The higher value was presumed biased by dry deposition from power plants or waste incinerators.

ND = Not detected.

N.C. = Not calculated; refer to Appendix J, Background Calculation, regarding selection of elements for UTL calculations.

**Table 4.16. Comparison of Hematite Site subsurface soil results with local, regional, and international compilations (mg/kg) (Continued)**

| | Selenium | Silver | Sodium | Thallium | Vanadium | Zinc |
|---|---|---|---|---|---|---|
| | | | **Hematite Site samples** | | | |
| Max | 2.9 | 0.85 | 1,600 | 2.6 | 56 | 850 |
| Min | 0.53 | 0.53 | 110 | 0.85 | 8 | 18 |
| | | | **Off-Site samples** | | | |
| Mean | 0.75 | ND | 141 | ND | 28 | 127 |
| Range | (<0.6 to <1.2) | | (<120 to 210) | | (16 to 36) | (33 to 370) |
| Site Background[a] | 0.85. | | N.C. | | 40. | 370 |
| | | | **Tidball (1984)** | | | |
| Mean | 0.28 | <0.7 | 5,300 | - | 69 | 49 |
| Range | (<0.1 to 2.7) | (<0.7 to 3) | (700 to 12,000) | | (15 to 150) | (70 to 700) |
| | | | **IEPA 1994** | | | |
| Mean | | | | | | 102.9 |
| Range | | | | | | (ND-798) |
| | | | **Connor and Shacklette 1975, Missouri Region geometric mean or range of means (maximum background value)** | | | |
| Shale/Clay | | | | | | 55 to 82 (250) |
| Sandstone/Sand | | | | | | 5 to 31 (280) |
| Carbonates | | | | | | 6 to 24 (140) |
| Soil | | | | | | 30 to 68 (640) |
| Loess | | | | | | 61 (90) |
| | | | **Lindsay 1973, Soil** | | | |
| Mean | 0.3 | 0.05 | 6,300 | - | 100 | 50 |
| Range | 1 to 2 | 0.01 to 5 | 750 to 7,500 | | 20 to 500 | 10 to 300 |

[a]Site Background: see Appendix J

[b]Dreher, G.B., and L.R. Follmer. 2004. Mercury content of Illinois soils. Water, Air, and Soil Pollution. 156:299-315. This study provides a more recent value from 101 cores, 6 samples per core yielding a mean core content of 33 +/- 20 µg/kg with a background average of 20 +/- 9 µg/kg. The higher value was presumed biased by dry deposition from power plants or waste incinerators.

ND = Not detected.

N.C. = Not calculated; refer to Appendix J, Background Calculation, regarding selection of elements for UTL calculations.

**Table 4.17. Uranium activities in Hematite Site surface water samples (pCi/L) (Refer to Fig. 2.2 for sampling locations.)**

| Sample ID | $^{234}U$ | $^{235}U$ | $^{238}U$ | Surface water body sampled |
|---|---|---|---|---|
| SW-01-SW | 29.6 | 1.24 | 4.77 | Site Pond, near dam. |
| SW-02-SW | 1.49 | 0.14J | 0.418 | Lake Virginia Tributary/Site Creek combined stream. |
| SW-08-SW | 0.839 | 0.0804LT | 0.363 | Northeast Site Creek/East Lake Tributary combined stream. |
| SW-09-SW | 1.78 | 0.106LT | 0.818 | Northeast Site Creek, downstream of Burial Pits |
| SW-14-SW | 0.549 | 0.0545LT | 0.276 | Joachim Creek. |
| SW-15-SW | 0.594 | 0.0641LT | 0.321 | Joachim Creek. |
| SW-16-SW | 0.483 | U | 0.152LT | Joachim Creek. |
| US-01-SW | 0.492 | 0.0306LT | 0.281 | Northeast Site Creek, upstream of Burial Pits. |
| US-02-SW | 0.678 | U | 0.74 | Lake Virginia Tributary, upstream of Site Creek confluence point. |
| US-03-SW | 0.538 | U | 0.215 | Site Pond, near Site Spring. |
| US-04-SW | 0.516 | U | 0.329 | East Lake Tributary. |
| US-05-SW | 0.439 | U | 0.221 | Joachim Creek. |

LT = result is less than requested minimum detectable activity (MDA) but greater than sample MDA.
J = estimated value.
U = below MDA, ~0.05 pCi/L.

**Table 4.18. Uranium activity in groundwater by alpha spectrometry (Samples with $^{234}U$ activity > 2 pCi/L; refer to Figs. 2.6a and 2.6b for well locations.)**

| Sampling station/ well ID | Formation | Area of concern or general location | $^{234}U$ (pCi/L) | $^{235}U$ (pCi/L) | $^{238}U$ (pCi/L) |
|---|---|---|---|---|---|
| BD-01 | Deep overburden | Buildings. | 8.91 | 0.383 | 1.58 |
| BD-02 | Deep overburden | Buildings. | 8 | 0.427 | 1.61 |
| BD-03 | Deep overburden | Buildings. | 13.8 | 0.451 | 2.03 |
| BD-05 | Deep overburden | Buildings. | 8.8 | 0.355 | 1.58 |
| BD-06 | Deep overburden | Buildings. | 2.33 | 0.131 J | - |
| BD-08 | Deep overburden | Buildings. | 6.17 | 0.179 LT | - |
| BD-16 | Deep overburden | Buildings. | 11.1 | 0.526 | 7.84 |
| DM-02 | Deep overburden | Deul's Mountain. | 315 | 16.5 | 56.3 |
| OA-19 | Deep overburden | Buildings, Deul's Mountain. | 3.04 | - | - |
| WS-07 | Shallow overburden | Evaporation Ponds. | 12.6 | 0.532 | 1.95 |
| WS-15 | Shallow overburden | Burial Pits. | - | 0.107 LT | - |
| WS-24 | Shallow overburden | Burial Pits. | 172 | 7.57 | 26.6 |
| WS-26 | Shallow overburden | Burial Pits. | 19 | 0.675 | 10.9 |
| NB-67 | Deep overburden | South of Facility, towards Joachim Creek. | - | 0.114 LT | 0 |
| WS-30 | Jefferson City-Cotter | Burial Pits. | 6.03 | 0.161 LT | 1.72 |
| BR-01-JC | Jefferson City-Cotter | West of the Hematite Facility. | 2.13 | - | - |
| BR-01-RB | Roubidoux | West of the Hematite Facility. | 4.08 | - | 1.09 |
| BR-02-RB | Roubidoux | Southeast of the Hematite Facility. | 3.62 | - | - |
| BR-03-JC | Jefferson City-Cotter | South-southeast of the Hematite Facility near Joachim Creek. | 3.42 | - | - |
| BR-03-RB | Roubidoux | South-southeast of the Hematite Facility near Joachim Creek. | 2.07 | - | - |
| BR-04-JC | Jefferson City-Cotter | East-northeast of the Hematite Site. | 3.78 | - | - |
| BR-04-RB | Roubidoux | East-northeast of the Hematite Site. | 3.28 | - | - |
| BR-05-RB | Roubidoux | East-northeast of the Hematite Facility. | 5.82 | - | - |
| BR-06-OB | Overburden | South of the Hematite Facility near Joachim Creek. | 5.65 | 0.251 LT | 1.56 |
| BR-06-RB | Roubidoux | South of the Hematite Facility near Joachim Creek. | 7.91 | - | - |
| BR-07-JC | Jefferson City-Cotter | South-southeast of the Hematite Facility, across Joachim Creek. | 4.72 | - | 1.43 |
| BR-07-RB | Roubidoux | South-southeast of the Hematite Facility, across Joachim Creek. | 5.22 | - | - |
| BR-08-RB | Roubidoux | South-southeast of the Hematite Facility, towards Joachim Creek. | 5.78 | - | - |
| BR-09-JC | Jefferson City-Cotter | East of the Hematite Facility. | 2.57 | - | - |
| BR-10-JC | Jefferson City-Cotter | South-southeast of the Hematite Facility, near Joachim Creek. | 2.05 | - | - |
| BR-10-RB | Roubidoux | South-southeast of the Hematite Facility, near Joachim Creek. | 4.5 | - | - |
| BR-11-JC | Jefferson City-Cotter | East of the Hematite Facility near Joachim Creek. | 2.16 | - | - |
| BR-12-JC | Jefferson City-Cotter | North-northwest of the Hematite Facility, across Highway P. | 4.45 | - | 1.21 |
| BR-12-RB* | Roubidoux | North-northwest of the Hematite Facility, across Highway P. | 12.5 (5.73) | - | 1.22 (0.69) |

LT = below the required minimum detectable concentration (MDC) but higher than the sample-specific MDC.
J = estimated value.
"-" = below the sample-specific MDC.
*Numbers in parentheses are activities measured in a groundwater sample collected in June 2005.

**Table 4.19. Isotopic thorium in unfiltered groundwater samples (pCi/L)**

| Sample Station/ Well ID | Formation | Area of concern or general location | $^{228}Th^{a}$ | $^{230}Th^{a}$ | $^{232}Th^{a,b}$ |
|---|---|---|---|---|---|
| BD-02 | Deep overburden | Buildings. | 0.644 | 0.907 | 0.586 |
| BD-03 | Deep overburden | Buildings. | 0.288 | 0.405 | 0.265 |
| BD-05 | Deep overburden | Buildings. | - | 0.25 | 0.244 |
| BD-06 | Deep overburden | Buildings. | 0.167 J | - | - |
| BD-16 | Deep overburden | Buildings. | 1.1 | 1 | 0.834 |
| BR-01-JC[c] | Jefferson City-Cotter | West of the Hematite Facility. | 0.997 | 0.694 | 0.736 |
| BR-07-RB | Jefferson City-Cotter | South-southeast of the Hematite Facility across creek. | 0.141 J | - | - |
| EP-15 | Deep overburden | Evaporation Ponds. | - | - | 0.00709 |
| EP-20 | Deep overburden | Evaporation Ponds. | - | 0.225M3 | - |
| NB-35 | Deep overburden | South of the Hematite Facility. | 0.228 | 0.354 | 0.222 |
| NB-73 | Deep overburden | South of the Hematite Facility, towards Joachim Creek. | 0.25 | 0.219 | - |
| OB-2 | Deep overburden | East of the Hematite Facility, near Joachim Creek. | 0.259 | 0.306 | 0.241 |
| WS-14 | Shallow overburden | Burial Pits. | - | 0.207 | - |
| WS-23 | Deep overburden | Near Burial Pits. | - | 0.383 | 0.233 |
| WS-25 | Deep overburden | Burial Pits. | - | 0.206 | - |

[a]"-" = not detected; J = estimated; M3 = requested minimum detectable concentration (MDC) not met, activity is greater than the reported MDC.

[b]There are other "detects" for $^{232}Th$ but all are qualified LT (below the required MDC but above the sample-specific MDC).

[c]Thorium isotopes not detected in filtered BR-01-JC samples; detection limits of 0.132, 0.149, and 0.018 pCi/L for $^{228}Th$, $^{230}Th$, and $^{232}Th$, respectively.

**Table 4.20. $^{99}$Tc activities in groundwater (pCi/L)**

| Sample ID | Formation | Area of concern or general location | $^{99}$Tc |
|---|---|---|---|
| BD-01 | Deep overburden | Buildings. | 191 |
| BD-02 | Deep overburden | Buildings. | 5100 |
| BD-04 | Deep overburden | Buildings. | 298 |
| BD-05 | Deep overburden | Buildings. | 117 |
| BD-08 | Deep overburden | Buildings. | 20.5 |
| BP-22B | Shallow overburden | Burial Pits. | 70.3 |
| DM-02 | Deep overburden | Deul's Mountain. | 44.1 |
| EP-15 | Deep overburden | Evaporation Ponds. | 362 |
| EP-16 | Deep overburden | Evaporation Ponds. | 675 |
| EP-16 (duplicate) | Deep overburden | Evaporation Ponds. | 712 |
| EP-20 | Deep overburden | Evaporation Ponds. | 2080 |
| LF-08 | Deep overburden | Former Leach Fields. | 246 |
| NB-31 | Deep overburden | South-southeast of the Hematite Facility. | 30.6 |
| PL-06 | Deep overburden | Pipeline, South of the Hematite Facility. | 92.3 |
| WS-14 | Shallow overburden | Burial Pits. | 138 |
| WS-15 | Shallow overburden | Burial Pits. | 20.9 |
| WS-16 | Shallow overburden | Burial Pits. | 24 |
| WS-17B | Shallow overburden | Deul's Mountain. | 3610 |
| WS-24 | Shallow overburden | Burial Pits. | 23.8 |
| WS-28 | Shallow overburden | Burial Pits. | 20.9 |
| WS-07 | Shallow overburden | Evaporation Ponds. | 476 |

**Table 4.21. Isotopic uranium activity in sediments (pCi/g) (Refer to Fig. 2.3 for sample locations.)**

| | Alpha spectroscopy | | | Gamma spectroscopy |
|---|---|---|---|---|
| **Sample ID** | **$^{234}U$ (pCi/g)** | **$^{235}U$ (pCi/g)** | **$^{238}U$ (pCi/g)** | **$^{235}U$ (pCi/g)** |
| SW-01-SS | 236 M3 | 10.6 | 29.5 M3 | 12.2 G |
| SW-02-SS | 3.99 | 0.175 | 1.03 | - |
| SW-03-SS | 7.92 | 0.402 | 1.39 | - |
| SW-04-SS | 2.8 | 0.093 J | 0.952 | - |
| SW-05-SS | 19.1 | 0.78 | 3.33 | - |
| SW-06-SS | 937 | 41.7 | 84.6 | 37.3 |
| SW-07-SS | 291 | 14.1 | 41.4 | 14.8 G |
| SW-08-SS | 0.331 | - | 0.299 | - |
| SW-08-SS-FD | 0.32 | - | 0.283 | - |
| SW-10-SS | 0.468 | - | 0.517 | - |
| SW-11-SS | 1.12 | | 0.599 | - |
| SW-12-SS | 1.47 | 0.076 LT | 0.566 | - |
| SW-13-SS | 0.989 | 0.0488 LT | 0.593 | - |
| SW-14-SS | 0.25 | 0.024 LT | 0.244 | - |
| SW-15-SS | 0.548 | 0.0272 LT | 0.619 | - |
| SW-16-SS | 0.28 | - | 0.262 | - |
| US-04-SS | 0.265 | 0.0265 LT | 0.322 | - |
| US-05-SS | 0.229 | - | 0.262 | - |

G = sample density differs by more than 15% of LCS density.
J = estimated result.
LT = result is < than the requested minimum detectable concentration (MDC), but > than the sample-specific MDC.
M3 = requested MDC was not met, but the result exceeded the sample-specific MDC.
"-" = below the detection limit.

**Table 4.22. $^{99}$Tc activity in sediments (pCi/g) (Refer to Fig. 2.3 for sample locations.)**

| Sample ID | $^{99}$Tc |
|---|---|
| SW-01-SS | 255 |
| SW-02-SS | 1.36 LT |
| SW-03-SS | 2.8 LT |
| SW-04-SS | 1.91 LT |
| SW-05-SS | 16.8 |
| SW-06-SS | 284 |
| SW-07-SS | 36.3 |
| SW-08-SS | - |
| SW-10-SS | - |
| SW-11-SS | - |
| SW-12-SS | 4.36 |
| SW-13-SS | 1.54 LT |
| SW-14-SS | - |
| SW-15-SS | - |
| SW-16-SS | - |
| US-04-SS | - |
| US-05-SS | - |

LT = result is < than the requested minimum detectable concentration (MDC), but > than the sample-specific MDC.
"-" $^{99}$Tc was not detected; detection limit of 2 pCi/L.

**Table 4.23. Isotopic uranium in surface soils (pCi/g) (Samples analyzed using alpha spectroscopy and samples with detectable $^{235}U$ activities from gamma spectroscopy analysis are shown in the table; shaded sample results are potentially contaminated using $^{235}U$ = 0.14 pCi/g as a reference value to distinguish contaminated from uncontaminated soils. Refer to text for discussion of reference value.)**

| Sample ID | Alpha spectroscopy | | | Gamma spectroscopy |
|---|---|---|---|---|
| | $^{234}U$ | $^{235}U$ | $^{238}U$ | $^{235}U$ |
| BP-12-00-SL | 2.35 | 0.138 | 1 | 0.32 U,G |
| EP-11-00-SL | 103 | 4.26 | 11.2 | 2.43 U,G |
| NB-02-00-SL | 0.759 | 0.026 LT | 0.373 | 0.334 U,G |
| NB-06-00-SL | 0.888 | 0.0565 LT | 0.851 | 0.3 U,G |
| NB-12-00-SL | 1.45 | 0.08 LT | 0.903 | 0.155 U,G |
| NB-14-00-SL | 52.3 | 1.98 | 3.53 | 0.606 U,G |
| NB-17-00-SL | 1.09 | 0.0328 LT | 0.801 | 0.106 U,G |
| NB-23-00-SL | 1.12 | 0.0843 LT | 0.913 | 0.0327 U,G |
| OA-08-00-SL | 472 M3 | 19.5 M3 | 74.3 M3 | 23.2 U,G |
| OA-37-00-SL | 1.93 | 0.127 | 1.08 | 0.154 U,G |
| BD-09-00-SL | NA | NA | NA | 3.63 G |
| BD-10-00-SL | NA. | NA | NA | 104 G |
| BD-11-00-SL | NA. | NA | NA | 102 G |
| BD-12-00-SL | NA | NA | NA | 20.2 G |
| BP-03-00-SL | NA | NA | NA | 35.3 G |
| BP-04-00-SL | NA | NA | NA | 1.2 G,TI |
| BP-07-00-SL | NA | NA | NA | 53.5 G |
| CB-01-00-SL | NA | NA | NA | 2.87 |
| DM-01-00-SL | NA | NA | NA | 308 G |
| DM-02-00-SL | NA | NA | NA | 237 G |
| EP-01-00-SL | NA | NA | NA | 31.2 G |
| EP-02-00-SL | NA | NA | NA | 30.3 G |
| EP-03-00-SL | NA | NA | NA | 6.97 G |
| EP-04-00-SL | NA | NA | NA | 184 G |
| EP-05-00-SL | NA | NA | NA | 18.5 G |
| EP-06-00-SL | NA | NA | NA | 96.5 G |
| EP-08-00-SL | NA | NA | NA | 8.87 G |
| EP-09-00-SL | NA | NA | NA | 4.95 G |
| EP-10-00-SL | NA | NA | NA | 51.4 G |
| EP-12-00-SL | NA | NA | NA | 4.81 G |
| NB-03-00-SL | NA | NA | NA | 0.682 G,TI |
| NB-11-00-SL | NA | NA | NA | 3 G |
| OA-01-00-SL | NA | NA | NA | 4.57 |
| OA-02-00-SL | NA | NA | NA | 3.61 |
| OA-04-00-SL | NA | NA | NA | 12.2 G |
| OA-07-00-SL | NA | NA | NA | 1.51 G |
| OA-11-00-SL | NA | NA | NA | 2.71 G |
| OA-13-00-SL | NA | NA | NA | 3.6 G |
| OA-14-00-SL | NA | NA | NA | 1.14 G |
| OA-16-00-SL | NA | NA | NA | 1.03 G,TI |
| OA-21-00-SL | NA | NA | NA | 2.88 G |
| OA-22-00-SL | NA | NA | NA | 1.86 |
| OA-23-00-SL | NA | NA | NA | 120 |
| OA-26-00-SL | NA | NA | NA | 39 |
| PL-01-00-SL | NA | NA | NA | 2.43 G |
| PL-03-00-SL | NA | NA | NA | 0.0394 |
| LS-03-00-SL | NA | NA | NA | 1.67 G |

continued next page

**Table 4.23 (continued). Isotopic uranium in surface soils (pCi/g) (Samples analyzed using alpha spectroscopy and samples with detectable $^{235}U$ activities from gamma spectroscopy analysis are shown in the table; shaded sample results are potentially contaminated using $^{235}U$ = 0.14 pCi/g as a reference value to distinguish contaminated from uncontaminated soils. Refer to text for discussion of reference value.) (continued)**

| Sample ID | Alpha spectroscopy | | | Gamma spectroscopy |
|---|---|---|---|---|
| | $^{234}U$ | $^{235}U$ | $^{238}U$ | $^{235}U$ |
| RR-01-00-SL | NA | NA | NA | 57.9 |
| SW-01-00-SL | NA | NA | NA | 2.86 |
| SW-02-00-SL | NA | NA | NA | 11.8 |

G = sample density differed by more than 15% from the LCS density.

LT= result is < than the requested minimum detectable concentration (MDC), but > than the sample-specific MDC.

NA = not analyzed.

TI = radionuclide identification was tentative.

**Table 4.24. $^{99}$Tc in surface soil (pCi/g) (Refer to Fig. 4.17 for anomalous sample locations and Figs. 2.4a and 2.4b for locations of all samples analyzed for $^{99}$Tc; samples with activities above the MDC (1 pCi/g) are shown below.)**

| Sample ID | $^{99}$Tc | Sample ID | $^{99}$Tc |
|---|---|---|---|
| BD-09-00-SL | 86.9 | BD-10-00-SL | 176 M3 |
| BD-12-00-SL | 574 | BD-11-00-SL | 19 M3 |
| BP-03-00-SL | 8.83 | BP-02-00-SL | 1.13 LT |
| BP-04-00-SL | 68.3 | BP-05-00-SL | 2.81 LT |
| BP-06-00-SL | 6.36 | DM-01-00-SL | 35.8 M3 |
| BP-07-00-SL | 26.3 | DM-02-00-SL | 154 M3 |
| CB-01-00-SL | 5.15 | EP-02-00-SL | 219 M3 |
| EP-01-00-SL | 183 | EP-04-00-SL | 189 M3 |
| EP-03-00-SL | 17.2 | EP-10-00-SL | 17100 M3 |
| EP-05-00-SL | 5.24 | EP-11-00-SL | 112 M3 |
| EP-06-00-SL | 51 | LF-02-00-SL | 0.902 LT |
| EP-07-00-SL | 23.5 | LF-03-00-SL | 1.56 LT |
| EP-08-00-SL | 3420 | LF-04-00-SL | 2.38 LT |
| EP-09-00-SL | 111 | NB-13-00-SL | 1.2 LT |
| EP-12-00-SL | 59.9 | NB-14-00-SL | 7.43 M3 |
| LF-01-00-SL | 5.49 | NB-15-00-SL | 1.81 LT |
| LF-05-00-SL | 12.3 | OA-07-00-SL | 1.59 LT |
| NB-11-00-SL | 12.7 | OA-12-00-SL | 1.64 LT |
| OA-01-00-SL | 10.3 | OA-26-00-SL | 109 M3 |
| OA-02-00-SL | 7.39 | OA-28-00-SL | 0.928 LT |
| OA-08-00-SL | 58.1 | OA-29-00-SL | 0.907 LT |
| OA-10-00-SL | 20.8 | OA-35-00-SL | 1.57 LT |
| OA-11-00-SL | 53 | OA-36-00-SL | 1.39 LT |
| OA-13-00-SL | 5.85 | OA-39-00-SL | 1.45 LT |
| OA-14-00-SL | 12.4 | PL-02-00-SL | 1.58 LT |
| OA-15-00-SL | 8.22 | PL-03-00-SL | 2.96 LT |
| OA-16-00-SL | 21.3 | LS-01-00-SL | 94.1 |
| OA-20-00-SL | 52.6 | LS-02-00-SL | 93.6 |
| OA-21-00-SL | 640 | LS-03-00-SL | 22.7 |
| OA-22-00-SL | 691 | | |
| OA-23-00-SL | 189 | | |
| OA-24-00-SL | 13.1 | | |
| OA-25-00-SL | 87.6 | | |
| PL-01-00-SL | 37.9 | | |
| RR-01-00-SL | 14.9 | | |
| RR-02-00-SL | 1.76 | | |
| SW-01-00-SL | 22.3 | | |
| SW-02-00-SL | 18.4 | | |

LT = result is < than the requested minimum detectable concentration (MDC), but > than sample-specific MDC.

M3 = requested MDC was not met, but the sample result exceeds the requested MDC.

**Table 4.25. Isotopic thorium activities in surface soils (pCi/g) [Refer to Figs. 2.4a and 2.4b for sample locations; thorium activities were not detected (MDC of 0.1 pCi/g) in the rest of the samples.]**

| Sample ID | $^{228}$Th | $^{230}$Th | $^{232}$Th |
|---|---|---|---|
| EP-11-00-SL | 0.9 | 1.07 | 0.939 |
| NB-02-00-SL | 0.316 | 0.415 | 0.281 |
| NB-06-00-SL | 1.06 | 1.09 | 0.84 |
| NB-14-00-SL | 1.02 | 1.05 | 0.774 |
| OA-37-00-SL | 1.21 | 1.2 | 1.1 |

**Table 4.26. $^{241}$Am activity reported in surface soil (pCi/g) [Refer to Figs. 2.4a and 2.4b for sample locations; $^{241}$Am not detected in other samples, with a MDC that ranged from 0.3 to 4 pCi/g.]**

| Sample ID | $^{241}$Am |
|---|---|
| DM-01-00-SL | 2.3 G,TI |
| DM-02-00-SL | 2.94 G,TI |
| EP-04-00-SL | 3.12 G,TI |
| EP-06-00-SL | 1.04 G,TI |

G = sample density differed by more than 15% from the LCS density.

TI indicates the radionuclide identification was tentative.

**Table 4.27. $^{239}$Pu /$^{240}$Pu activity in surface soils (pCi/g) [Refer to Figs. 2.4a and b for sample locations; $^{239}$Pu/$^{240}$Pu activities not detected on other samples (MDC ~0.02 pCi/g).]**

| Sample Location | $^{239}$Pu/$^{240}$Pu |
|---|---|
| BD-12-00-SL | 0.00794 LT |
| EP-02-00-SL | 0.0297 LT |
| NB-03-00-SL | 0.0334 LT |
| NB-06-00-SL | 0.0155 LT |
| BP-03-00-SL | 0.00706 LT |
| OA-37-00-SL | 0.00872 LT |
| OA-01-00-SL | 0.0144 LT |

LT indicates result is < than the requested minimum detectable concentration (MDC), but > than sample-specific MDC.

**Table 4.28. Isotopic uranium in subsurface soils (pCi/g) [Refer to Fig. 4.18 for sampling locations and Figs. 2.5a and 2.5b for all sampling locations; table includes all samples that were analyzed by alpha spectrometry, and samples with gamma activities that were above the detection limit (0.5 to 2 pCi/g).]**

| | Alpha spectrometry | | | Gamma spectrometry |
|---|---|---|---|---|
| Sample ID[a] | $^{234}U$ | $^{235}U$ | $^{238}U$ | $^{235}U$ |
| BD-13-09-SL | 1.08 | 0.0884 LT | 0.892 | -0.115 U,G |
| BD-14-05-SL | 1.24 | 0.081 LT | 0.924 | 0.472 U,G |
| BD-16-05-SL | 1.73 | 0.0741 LT | 0.867 | 0.309 U,G |
| BLD253-02-04 | 172 J | 7.74 J | 11.1 J | 5.9 |
| BLD255-08-01 | 604 J | 23.1 J | 13.8 J | 13.4 |
| BLD260-06-01 | 17.8 | 0.79 | 5.04 | 0.87 TI |
| BP-13-05-SL | 0.943 | 0.0476 LT | 0.853 | 0.319 U,G |
| CB-02-05-SL | 2.48 | 0.14 | 1.14 | 0.0896 U,G |
| DM-02-05-SL | | | | 9.24 |
| DM-02-22-SL | 157 | 6.38 | 27.2 | 8.18 |
| DM-02-33-SL | | | | 2.91 |
| DM-03-05-SL | 0.712 | 0.0574 LT | 0.856 | 0.0728 U,G |
| EP-13-03-SL | | | | 1.34 J |
| EP-16-05-SL | 2.42 | 0.154 | 1.13 | -0.153 U,G |
| EP-17-05-SL | 2.67 | 0.148 | 1.15 | 0.442 U,G |
| EP-18-09-SL | | | | 1.61 J |
| EP-19-05-SL | | | | 1.49 J |
| EP-19-13-SL | | | | 1.54 J |
| LF-06-05-SL | 5.62 | 0.24 | 1.42 | 0.356 U,G |
| NB-30-05-SL | 0.917 | 0.0363 LT | 0.884 | 0.123 U,G |
| NB-31-15-SL | 0.923 | 0.0356 LT | 0.847 | 0.237 U,G |
| NB-36-05-SL | 0.753 | 0.0518 LT | 0.83 | -0.175 U,G |
| NB-36-15-SL | 0.976 | 0.0268 LT | 0.794 | 0.202 U,G |
| NB-44-05-SL | 0.494 | 0.0344 LT | 0.474 | 0.0978 U |
| NB-51-05-SL | 0.83 | 0.0458 LT | 0.813 | 0.189 U,G |
| NB-55-05-SL | 0.836 | 0.059 LT | 0.9 | 0.119 U,G |
| NB-63-05-SL | 0.738 | 0.035 LT | 0.736 | 0.162 U,G |
| NB-71-01-SL | 1.7 | 0.058 LT | 0.838 | 0.184 U,G |
| NB-78-07-SL | 0.736 | 0.0446 LT | 0.689 | 0.234 U,G |
| NB-81-09-SL | 0.713 | 0.0228 LT | 0.771 | 0.148 U,G |
| OA-18-03-SL | 0.747 | 0.0233 LT | 0.787 | 0.0943 U |
| PL-04-05-SL | 4.44 | 0.25 | 1.21 | 0.29 U,G |
| PL-05-05-SL | 1.08 | 0.111 | 0.899 | -0.179 U,G |
| RR-04-07-SL | 0.751 | 0.0561 LT | 0.76 | -0.0326 U,G |
| RR-05-05-SL | 2.8 | 0.157 | 1.28 | 0.571 U,G |
| SW-02-01-SL | 240 | 12.8 | 20.1 | 8.64 G |
| SW-07-05-SL | 0.87 | 0.0414 LT | 0.829 | -0.165 U,G |

[a] Sample ID, AA-AA-DD-SL, consists of the sampling station AA-AA and sample depth DD in feet. For samples collected from under the buildings, sample ID consists of BLDXXX-AA-DD where XXX is the building number where borehole is located, AA is boring number, sample depth is DD in feet.

G = sample density differed by more than 15% from the LCS density.

J = estimated value.

LT= result is < than the requested minimum detectable concentration (MDC), but > than the sample-specific MDC.

TI = radionuclide identification was tentative.

U = analyte was not detected; note that gamma spectroscopy is not as sensitive as alpha spectroscopy.

**Table 4.29. $^{99}$Tc in subsurface soils (pCi/g) (Refer to Figs. 2.5a and 2.5b for sample locations.)**

| Sample ID[a] | $^{99}$Tc | Sample ID | $^{99}$Tc |
|---|---|---|---|
| BD-16-05-SL | 1.61 LT | EP-17-15-SL | 3.74 |
| BLD253-02-04 | 7.5 | EP-17-25-SL | 5.21 |
| BLD255-08-01 | 30.2 | EP-18-09-SL | 11.7 |
| BP-17-05-SL | 4.26 | EP-18-29-SL | 0.952 UJ |
| BP-17-15-SL | 2.46 LT | EP-19-05-SL | 11.4 |
| BP-17-23-SL | 1.66 LT | EP-19-13-SL | 10.4 |
| CB-02-05-SL | 0.785 LT | EP-19-25-SL | 4.77 |
| DM-02-05-SL | 13.9 | EP-19-31-SL | 0.708 UJ |
| DM-02-22-SL | 10.9 | EP-20-05-SL | 3.04 |
| DM-03-05-SL | 2.54 LT | EP-20-15-SL | 2.74 LT |
| DM-03-13-SL | 5.84 | EP-20-25-SL | 3.93 |
| DM-03-25-SL | 7.04 | LF-06-05-SL | 4.26 |
| EP-13-03-SL | 13.9 | LF-08-05-SL | 4.37 |
| EP-13-13-SL | 8.58 | LF-08-37-SL | 4.21 |
| EP-13-25-SL | 6.39 | LF-09-03-SL | 1.6 LT |
| EP-13-30-SL | 131 | NB-32-27-SL | 1.68 LT |
| EP-14-05-SL | 12.8 | NB-39-05-SL | 2.11 LT |
| EP-14-13-SL | 1.53 J | NB-39-15-SL | 2.43 LT |
| EP-14-25-SL | 2.06 J | NB-40-25-SL | 0.83 LT |
| EP-14-31-SL | 0.538 UJ | NB-74-05-SL | 7.49 |
| EP-15-05-SL | 3.42 | NB-74-17-SL | 2.81 LT |
| EP-15-13-SL | 4.31 | NB-74-25-SL | 2.45 LT |
| EP-15-25-SL | 11 | OA-19-05-SL | 1.67 LT |
| EP-16-05-SL | 2.62 LT | PL-04-05-SL | 4.54 |
| EP-16-15-SL | 17.1 | PL-06-33-SL | 1.18 LT |
| EP-16-27-SL | 5.24 | SW-02-01-SL | 2.97 LT |
| EP-17-05-SL | 1.17 LT | SW-02-09-SL | 0.907 LT |

[a] Sample ID, AA-AA-DD-SL, consists of the sampling station AA-AA and sample depth DD in feet. For samples collected from under the buildings, sample ID consists of BLDXXX-AA-DD where XXX is the building number where borehole is located, AA is boring number, sample depth is DD in feet.

LT = result is < than the requested minimum detectable concentration (MDC), but > than sample-specific MDC.

J = Indicates that the radionuclide was positively identified and the numerical value is approximate.

UJ = Indicates that the analyte was not detected above the sample quantitation limit but the quantitation limit is approximate.

**Table 4.30. Isotopic thorium in subsurface soils (pCi/g) (Refer to Figs. 2.5a and 2.5b for sampling locations.)**

| Sample ID[a] | $^{228}$Th | $^{230}$Th | $^{232}$Th |
|---|---|---|---|
| BD-14-05-SL | 1.02 | 1.13 | 1.13 |
| BLD240-01-01 | 1.14 M3 | 1.06 M3 | 0.987 |
| BLD240-01-31 | 0.66 M3 | 0.792 M3 | 0.517 |
| BLD240-03-04 | 1.32 M3 | 1.22 M3 | 1.13 |
| BLD240-03-14 | 1.24 M3 | 1.14 M3 | 1.07 M3 |
| BLD240-04-02 | 1.3 M3 | 1.01 M3 | 1.07 |
| BLD240-04-33 | 0.542 M3 | 0.756 M3 | 0.418 |
| BLD253-02-04 | 1.3 M3 | 1.3 M3 | 1.1 J |
| BLD253-02-21 | 1.06 M3 | 1.13 M3 | 0.876 |
| BLD255-05-01 | 1.2 3 M3 | 1.04 M3 | 1.1 |
| BLD255-05-23 | 1.55 M3 | 1.42 M3 | 1.18 M3 |
| BLD255-07-02 | 1.29 M3 | 1.08 M3 | 1.12 |
| BLD255-07-33 | 1.33 M3 | 1.1 M3 | 1.06 |
| BLD255-08-01 | 0.988 M3 | 0.918 M3 | 0.807 |
| BLD255-08-08 | 1.25 M3 | 1.25 M3 | 1.21 |
| BLD260-06-01 | 1.11 M3 | 1.08 M3 | 1.08 |
| BLD260-06-31 | 0.685 M3 | 0.675 M3 | 0.656 |
| BP-17-05-SL | 1.07 | 1.14 | 1.16 |
| CB-02-05-SL | 0.971 | 1.01 | 1.07 |
| DM-02-22-SL | 1.54 M3 | 1.74 M3 | 1.59 |
| DM-03-05-SL | 1.23 | 1.14 | 1.15 |
| EP-17-05-SL | 1.2 | 1.2 | 1.13 |
| NB-30-05-SL | 1.15 | 1.26 | 1.2 |
| NB-36-05-SL | 0.843 | 0.992 | 0.804 |
| NB-55-05-SL | 1.15 | 1.14 | 1.08 |
| NB-71-01-SL | 1.23 | 1.16 | 1.12 |
| NB-78-07-SL | 0.92 | 0.897 | 0.854 |
| PL-04-05-SL | 1.15 | 1.15 | 1.09 |
| PL-05-05-SL | 1.28 | 1.2 | 0.934 |
| RR-04-07-SL | 1.34 | 1.13 | 1.29 |
| RR-05-05-SL | 1.17 | 1.24 | 1.07 |
| SW-02-01-SL | 2.39 M3 | 1.71 M3 | 2.5 |

[a] Sample ID, AA-AA-DD-SL, consists of the sampling station AA-AA and sample depth DD in feet. For samples collected from under the buildings, sample ID consists of BLDXXX-AA-DD where XXX is the building number where borehole is located, AA is boring number, sample depth is DD in feet.

M3 = requested minimum detectable concentration (MDC) was not met, but the sample result exceeds the requested MDC.

**Table 4.31. $^{239}$Pu /$^{240}$Pu in subsurface soils (pCi/g)**

| Location[a] | $^{239}$Pu or $^{240}$Pu |
|---|---|
| BLD255-05-01 | 0.00556LT |
| BLD260-06-01 | 0.00277LT |
| EP-17-05-SL | 0.00479LT |
| BLD255-08-08 | 0.00783LT |
| EP-18-09-SL | 0.00715LT |
| BLD240-03-14 | 0.00266LT |
| BLD240-01-31 | 0.00524LT |
| BLD255-07-33 | 0.00402LT |

[a] Sample ID, AA-AA-DD-SL, consists of the sampling station AA-AA and sample depth DD in feet. For samples collected from under the buildings, sample ID consists of BLDXXX-AA-DD where XXX is the building number where borehole is located, AA is boring number, sample depth is DD in feet.

LT = result is < than the requested minimum detectable concentration (MDC), but > than the sample-specific MDC.

**Table 4.32. Number of sediment and soil samples with organic analyte concentrations above detection limits. Note that sample counts include samples with concentrations below the reporting limit. Maximum concentrations are given in parentheses. Sample results with associated contaminated laboratory blanks were not included in the sample counts. Green shaded cells indicate that none of the samples exceeded detection limits. Grey shaded cells indicate that analytes were not measured.**

| | Sediment (mg/kg) | | Surface Soil (mg/kg) | | Subsurface | CALM | PRG |
|---|---|---|---|---|---|---|---|
| | Upstream | On-site | Background | On-site[a] | Soil (mg/kg) | (mg/kg) | (mg/kg) |
| **BNAs** | | | | | | | |
| **Total Number of Samples** | **2** | **16** | **0** | **124** | **393** | | |
| Bis(2-Ethylhexyl) phthalate | | 3 (3.6) | | 23 (4.7) | 28 (2.4) | 410 | 35 |
| Butyl benzyl phthalate | | | | 10 (0.22) | 3 (1.5) | 930 | 12,000 |
| Di-n-butyl phthalate | | 1 (2.1) | | 20 (4.3) | 1 (0.28) | 2,300 | 6,100 |
| Di-n-octyl phthalate | | | | 2 (.35)[a] | 1 (0.093) | 0.3 | 2,400 |
| Carbazole | | 3 (3.5) | | 22 (0.91) | 5 (0.25) | 82 | 24 |
| Hexachlorobenzene | | | | 1 (.04) | | 0.9 | 0.3 |
| Hexachloroethane | | | | | 5 (0.43) | 70 | 35 |
| Isophorone | | | | 1 (0.2) | | 1,700 | 510 |
| 2-Methylphenol | | | | | 1 (0.034) | 3,500 | 3,100 |
| Phenol | | | | | | 5,200 | 18,000 |
| **Dioxins** | | | | | | | |
| **Total number of samples** | **0** | **0** | **0** | **2** | **4** | | |
| 2,3,7,8-TCDD[b] | | | | 2 (16.7E-06)[a] | 3 (0.3E-06)[a] | | 3.90E-06 |
| **PAHs** | | | | | | | |
| **Total Number of Samples** | **2** | **16** | **0** | **124** | **393** | | |
| Acenaphthene | | 2 (0.58) | | 19 (.38) | 8 (.74) | 1,700 | 3,700 |
| Anthracene | | 2 (2.4) | | 21 (1.1) | 7 (.42) | 8,500 | 22,000 |
| Benzo(*a*)anthracene | 1 (0.041) | 9 (21) | | 85 (6.4) | 19 (.63) | 1 | 0.62 |
| Benzo(*a*)pyrene | 1 (0.029) | 9 (29) | | 83 (6.6) | 15 (.78) | 0.2 | 0.062 |
| Benzo(*b*)fluoranthene | 1 (0.039) | 9 (57) | | 90 (7.8) | 20 (1.8) | 0.9 | 0.62 |
| Benzo(*k*)fluoranthene | | 9 (20) | | 54 (3.2) | 11 (.62) | 8 | 6.2 |
| Chrysene | 1 (0.033) | 9 (29) | | 83 (8.1) | 17 (1.0) | 36 | 62 |
| Dibenzo(*a*,*h*)anthracene | | 1 (4.7) | | 3 (.44) | | 0.2 | 0.062 |
| Fluoranthene | 1 (0.086) | 10 (58) | | 97 (14) | 25 (3.5) | 1,600 | 2,300 |
| Fluorene | | 2 (0.97) | | 17 (0.53) | 5 (0.5) | 1,100 | 2,700 |
| Indeno(1,2,3-*cd*)pyrene | | 9 (11) | | 49 (5) | 5 (0.36) | 3 | 0.62 |
| Naphthalene | | 1 (0.25) | | 12 (0.1) | 1 (0.019) | 120 | 56 |
| Pyrene | 1 (0.066) | 9 (68) | | 72 (18) | | 2,100 | 2300 |

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**Table 4.32. (continued) Number of sediment and soil samples with organic analyte concentrations above detection limits. Note that sample counts include samples with concentrations below the reporting limit. Maximum concentrations are (mg/kg) given in parentheses. Samples with associated contaminated laboratory blanks were not included in the sample counts. Green shaded cells indicate that none of the samples exceeded detection limits. Grey shaded cells indicate that analytes were not measured.**

| | Sediment (mg/kg) | | Surface Soils (mg/kg) | | Subsurface | CALM | PRG |
|---|---|---|---|---|---|---|---|
| | Upstream | On-site | Background | On-site[a] | Soil (mg/kg) | (mg/kg) | (mg/kg) |
| **Pesticides** | | | | | | | |
| **Total Number of Samples** | **2** | **16** | **0** | **124** | **393** | | |
| DDD | | | | 2 (0.002) | | 12 | 2.4 |
| DDE | | | | 5 (0.005) | 1 | 8 | 1.7 |
| DDT | | | | 13 (0.025) | 2 | 8 | 1.7 |
| Dieldrin | | | | 3 (0.007) | | 0.1 | 0.03 |
| Endosulfan I | | | | 2 (0.001) | | 420 | 370 |
| Endosulfan II | | | | 7 (0.004) | 1 (0.0008) | | |
| Endrin | | 9 (0.003) | | 11 (.021) | 1 (0.0007) | 21 | 18 |
| Heptachlor | | | | 2 (.013) | | 0.3 | 0.11 |
| Alpha BHC (HCH) | | | | 2 (.046) | 5 (0.001) | 0.3 | 0.09 |
| Gamma BHC (HCH, Lindane) | | | | | 2 (0.0002) | 1 | 0.44 |
| **PCBs** | | | | | | | |
| **Total Number of Samples** | **2** | **16** | **32** | **124[a]** | **393** | | |
| PCB-1254 | | | | 15 (0.54) | 2 (.067) | 0.6 | 0.22 |
| PCB-1260 | | 2 (0.059) | | 27 (0.56) | 3 (0.006) | 0.6 | 0.22 |
| **Petroleum Hydrocarbons** | | | | | | | |
| **Total Number of Samples** | **0** | **0** | **0** | **6** | **9** | | |
| Diesel | | | | 3 (0.035) | | NA | NA |
| Gasoline | | | | 1 (0.0003) | | NA | NA |

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**Table 4.32 (continued). Number of sediment and soil samples with organic analyte concentrations above detection limits. Note that sample counts include samples with concentrations below the reporting limit. Maximum concentrations (mg/kg) are given in parentheses. Green shaded cells indicate that none of the samples exceeded detection limits. Grey shaded cells indicate that analytes were not measured. (continued)**

| Analyte | Sediment (mg/kg) | | Surface Soil (mg/kg) | | Subsurface | CALM | PRG |
|---|---|---|---|---|---|---|---|
| | Upstream | On-site | Background | On-site | Soil (mg/kg) | (mg/kg) | (mg/kg) |
| **VOCs** | | | | | | | |
| **Total Number of Samples** | **2** | **16** | **32** | **124[a]** | **393** | | |
| Acetone | 1 (0.018) | 10 (0.053) | | 4 (0.0085) | 79 (.22) | 2,700 | 14,000 |
| Benzene | | | | | | 6 | 0.64 |
| Bromodichloromethane | | | | | | 11 | 0.82 |
| Carbon disulfide | | | | | 7 (.24) | 630 | 360 |
| Carbon tetrachloride | | | | | 1 (.045) | 2 | 0.25 |
| Chloroethane | | | | | 2 (0.029) | | 3 |
| Chloroform | | | | | 2 (.012) | 0.8 | 0.22 |
| Chloromethane | | | | | | | 47 |
| 1,1-Dichloroethane | | | | | 46 (.62) | | 510 |
| 1,2-Dichloroethane | | | | | 4 (.0097) | 2 | 0.28 |
| 1,1-Dichloroethene | | | | | 46 (3.6) | 0.4 | 120 |
| *cis*-1,2-Dichloroethene | | 3 (0.028) | | | 70 (.39) | 1,200 | 43 |
| *trans*-1,2-Dichloroethene | | 1 (0.0072) | | | 6 (.022) | 2,900 | 69 |
| Methylene Chloride | | | 12 (0.025) | 1 (.0039) | 81 (.019) | 51 | 9.1 |
| MEK (2-Butanone) | | 1 (0.014) | | | 15 (.046) | 7,400 | 22,000 |
| Tetrachloroethene (PCE) | | 2 (0.0073) | | 10 (.034) | 127 (6600) | 40 | 0.48 |
| Toluene | 1 (0.009) | 3 (0.02) | 7 (0.0057) | 3 (.0093) | 17 (.015) | 650 | 520 |
| 1,1,1-Trichloroethane | | | | | 24 (.34) | 1,200 | 1,200 |
| 1,2,4-Trichlorobenezene | | | | | 1 (.0025) | 270 | 62 |
| 1,1,2-Trichloroethane | | | | | | 5 | 0.73 |
| Trichloroethene (TCE) | | 3 (0.011) | | 1 (.0013) | 97 (4.8) | 40 | 0.053 |
| Vinyl chloride (VC) | | 1 (0.022) | | | 12 (.015) | 0.3 | 0.079 |
| Xylenes (o, m, p) | | | | | | 418 | 270 |

[a]Includes composite samples from limestone storage/fill areas.
[b]Concentration reported as "Total Equivalent Concentration" of 2,3,7,8-TCDD using Toxicity Equivalence Factors from EPA (1989).
BNA = base-neutral-acid extractable organic.
NA = not available.
PAH = polycyclic aromatic hydrocarbon.
PCB = polychlorinated biphenyl.
PRG = preliminary remediation goal.
VOC = volatile organic compound.

**Table 4.33. Number of surface water and groundwater samples with organic analyte concentrations above detection limits. Note that sample counts include samples with concentrations below the reporting limit. Maximum concentrations (µg/L) are given in parentheses. Sample results with associated contaminated laboratory blanks were not included in the sample counts. Green shaded cells indicate that none of the samples exceeded detection limits. Grey shaded cells indicate that analytes were not measured.**

| Analyte | Surface Water (µg/L) Upstream | Surface Water (µg/L) On-site | Groundwater (µg/L) | CALM (µg/L) | PRG (µg/L) |
|---|---|---|---|---|---|
| **BNAs** | | | | | |
| **Total number of samples** | **5** | **8** | **42** | | |
| Bis(2-Ethylhexyl) phthalate | | | 8 (26) | 6 | 4.8 |
| Butyl benzyl phthalate | | | | 3,000 | 7,300 |
| Di-n-butyl phthalate | | | | 2,700 | 3,600 |
| Di-n-octyl phthalate | | | | | 1,500 |
| Carbazole | | | | | 3.4 |
| Hexachlorobenzene | | | | 1 | 0.042 |
| Hexachloroethane | | | 1 (6.5) | 1 | 4.8 |
| Isophorone | | | | 100 | 71 |
| 2-Methylphenol | | | | | 1,800 |
| Phenol | | | 2 (9.8) | 4,000 | 11,000 |
| **Dioxins** | | | | | |
| **Total number of samples** | **0** | **0** | **1** | | |
| 2,3,7,8-TCDD | | | 1 (0.37E-07)[a] | | 4.50E-07 |
| **PAHs** | | | | | |
| **Total number of Samples** | **5** | **8** | **42** | | |
| Acenaphthene | | | | 1,200 | 370 |
| Anthracene | | | | 9,600 | 1,800 |
| Benzo(*a*)anthracene | | | | 0.0044 | 0.092 |
| Benzo(*a*)pyrene | | | | 0.2 | 0.0092 |
| Benzo(*b*)fluoranthene | | | | 0.0044 | 0.092 |
| Benzo(*k*)fluoranthene | | | | 0.0044 | 0.92 |
| Chrysene | | | | 0.0044 | 9.2 |
| Dibenzo(*a,h*)anthracene | | | | 0.0044 | 0.0092 |
| Fluoranthene | | 1 (0.97) | | 300 | 1,500 |
| Fluorene | | | | 1,300 | 240 |
| Indeno(1,2,3-*cd*)pyrene | | | | 0.0044 | 0.092 |
| Naphthalene | | | | 100 | 6.2 |
| Pyrene | | | | 960 | 180 |

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**Table 4.33. (continued) Number of surface water and groundwater samples with organic analyte concentrations above detection limits. Note that sample counts include samples with concentrations below the reporting limit. Maximum concentrations (µg/L) are given in parentheses. Sample results with associated contaminated laboratory blanks were not included in the sample counts. Green shaded cells indicate that none of the samples exceeded detection limits. Grey shaded cells indicate that analytes were not measured.**

| Analyte | Surface Water (µg/L) Upstream | Surface Water (µg/L) On-site | Groundwater (µg/L) | CALM (µg/L) | PRG (µg/L) |
|---|---|---|---|---|---|
| **Pesticides** | | | | | |
| **Total number of samples** | **5** | **8** | **17** | | |
| DDD | | | | 2 | 0.28 |
| DDE | | | | 2 | 0.2 |
| DDT | | | | 2 | 0.2 |
| Dieldrin | | | | 0.002 | 0.0042 |
| Endosulfan | | | | | 220 |
| Endrin | | | | 2 | 11 |
| Heptachlor | | | | 0.4 | 0.015 |
| Alpha BHC (HCH) | | | | 0.0022 | 0.011 |
| Gamma BHC (HCH, Lindane) | | | | 0.2 | 0.052 |
| **PCBs** | | | | | |
| **Total number of samples** | **5** | **8** | **17** | | |
| Arochlor 1254 | | | | 0.5 | 0.034 |
| Arochlor 1260 | | | | 0.5 | 0.034 |
| **Petroleum** | | | | | |
| **Total number of samples** | **0** | **0** | **0** | | |
| Diesel | | | | | |
| Gasoline | | | | | |
| **VOCs** | | | | | |
| **Total number of samples** | **5** | **8** | **95** | | |
| Acetone | | | 5 (76) | | 5,500 |
| Benzene | | | 2 (4.8) | 5 | 0.35 |
| Bromodichloromethane | | | | 80 | 0.18 |
| Carbon Disulfide | | | 4 (8) | | 1,000 |
| Carbon Tetrachloride | | | | 5 | 0.17 |
| Chloroethane | | | 4 (52) | | 4.6 |
| Chloroform | | | 5 (6.8) | 80 | 0.17 |
| Chloromethane | | | 1 (1.3) | | 160 |
| 1,1-Dichloroethane | | | 59 (610) | | 810 |
| 1,2-Dichloroethane | | | 8 (8.7) | 5 | 0.12 |
| 1,1-Dichloroethene | | | 56 (5100) | 7 | 340 |

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**Table 4.33. (continued) Number of surface water and groundwater samples with organic analyte concentrations above detection limits. Note that sample counts include samples with concentrations below the reporting limit. Maximum concentrations (µg/L) are given in parentheses. Sample results with associated contaminated laboratory blanks were not included in the sample counts. Green shaded cells indicate that none of the samples exceeded detection limits. Grey shaded cells indicate that analytes were not measured.**

| Analyte | Surface Water (µg/L) Upstream | Surface Water (µg/L) On-site | Groundwater (µg/L) | CALM (µg/L) | PRG (µg/L) |
|---|---|---|---|---|---|
| **VOCs (continued)** | | | | | |
| **Total number of samples** | **5** | **8** | **95** | | |
| *cis*-1,2-Dichloroethene | | 2 (4.4) | 70 (19000) | 70 | 61 |
| *trans*-1,2-Dichloroethene | | | 22 (630) | 100 | 120 |
| Methylene Chloride | | | 20 (1600) | 5 | 4.3 |
| MEK (2-Butanone) | | | 2 (150) | | 7,000 |
| Tetrachloroethene (PCE) | | 3 (2.1) | 75 (200000) | 5 | 0.1 |
| Toluene | 1 (0.85) | | 6 (3.7) | 150 | 720 |
| 1,1,1-Trichloroethane | | | 11 (85) | 200 | 3,200 |
| 1,2,4-Trichlorobenezene | | | | 70 | 7.2 |
| 1,1,2-Trichloroethane | | | 5 (8.4) | 5 | 0.2 |
| Trichloroethene (TCE) | | 2 (0.84) | 77 (18000) | 5 | 0.028 |
| Vinyl Chloride (VC) | | | 25 (1000) | 2 | 0.02 |
| Xylenes (O, M, P) | | | 1 (3.7) | 320 | 210 |

[a]Concentration reported as "Total Equivalent Concentration" of 2,3,7,8-TCDD using Toxicity Equivalence Factors from EPA (1989).
BNA = base-neutral-acid extractable organic.
GTARC = Groundwater target concentrations.
PAH = polycyclic aromatic hydrocarbon.
PCB = polychlorinated biphenyl.
PRG = preliminary remediation goal.
VOC = volatile organic compound.

**Table 4.34. VOC concentrations in surface water (μg/L) (Refer to Fig. 2.2 for sample locations; only VOCs detected above the reference levels are shown.)**

| Sample ID | Tetrachloroethylene | Trichloroethene |
|---|---|---|
| SW-01-SW | 2.1 J | - |
| SW-02-SW | 0.73 J | - |
| SW-09-SW | 0.87 J | 0.84 J |
| SW-16-SW | - | 0.64 J |

VOC = volatile organic compound.

**Table 4.35. PAHs in sediment samples (μg/kg) (Refer to Fig. 2.3 for sampling locations; only PAHs detected above the reference levels are shown.)**

| Sample ID | Benzo(*a*) anthracene | Benzo(*a*) pyrene | Benzo(*b*) fluoranthene | Benzo(*k*) fluoranthene | Dibenz(*a,h*) anthracene | Indeno(1,2,3-*cd*) pyrene |
|---|---|---|---|---|---|---|
| SW-01-SS | - | 260 J | - | - | - | - |
| SW-02-SS | - | 82 J | - | - | - | - |
| SW-03-SS | - | 190 J | - | - | - | - |
| SW-04-SS | - | 71 J | - | - | - | - |
| SW-05-SS | - | 420 J | 730 | - | - | - |
| SW-06-SS | - | 890 J | 1,800 | - | - | 800 J |
| SW-07-SS | 21,000 | 29,000 | 57,000 | 20,000 | 4,700 | 11,000 J |
| SW-10-SS | - | 100 J | - | - | - | - |
| SW-12-SS | - | 110 J | - | - | - | - |

*J = estimated, below estimated quantitation limit.
PAH = polycyclic aromatic hydrocarbon.

**Table 4.36. Dioxins in surface soil (pg/g) (Refer to Fig. 2.4b for sample location.)**

| Sample ID | 1,2,3,4,6,7,8-HPCDD | OCDD | OCDF |
|---|---|---|---|
| CB-01-00-SL | 110 J | 5600 J | 12 J |
| CB-01-00-SL-FD | 94 | 4600 | 11 J |

*J = estimated, concentration below quantitation limit.

**Table 4.37. PAHs in surface soils (µg/kg) (Refer to Figs. 2.4a and 2.4b for surface soil sampling locations; only PAHs detected above the MDL are shown.)**

| Sample ID | Benzo(*a*) anthracene | Benzo(*a*) pyrene | Benzo(*b*) fluoranthene | Dibenz(*a,h*) anthracene | Indeno(1,2,3-*cd*) pyrene |
|---|---|---|---|---|---|
| BD-09-00-SL | - | 630 | 870 | - | - |
| BD-10-00-SL | 6400 | 6600 | 7800 | - | 5000 |
| BD-11-00-SL | - | 110 J | - | - | - |
| BD-12-00-SL | - | 400 | - | - | - |
| BP-05-00-SL | - | 76 J | - | - | - |
| CB-01-00-SL | - | 63 J | - | - | - |
| DM-02-00-SL | - | 240 J | - | - | - |
| EP-01-00-SL | 710 | 870 | 1300 | - | - |
| EP-02-00-SL | - | 210 J | 740 | - | - |
| EP-04-00-SL | - | 200 J | - | - | - |
| EP-04-00-SL-FD | - | 160 J | - | - | - |
| EP-06-00-SL | - | 350 J | - | - | - |
| LF-01-00-SL | 640 | 900 | 1100 | | 910 |
| LF-03-00-SL | - | 70 J | - | - | - |
| LF-04-00-SL | - | 99 J | - | - | - |
| NB-04-00-SL | - | 360 J | 770 | - | - |
| NB-05-00-SL | - | 250 J | - | - | - |
| NB-11-00-SL | - | 180 J | - | - | - |
| NB-14-00-SL | 4500 | 3800 | 7000 | - | 2400 |
| NB-15-00-SL | - | 100 J | - | - | - |
| NB-21-00-SL | - | 120 J | - | - | - |
| NB-22-00-SL | - | 460 J | 1100 | - | - |
| NB-24-00-SL | - | 67 J | - | - | - |
| OA-04-00-SL | - | 98 J | - | - | - |
| OA-05-00-SL | - | 270 J | - | - | - |
| OA-07-00-SL | 2500 | 3200 | 3800 | - | 3900 |
| OA-08-00-SL | 1400 J | 1700 | 2800 | - | 1700 |
| OA-09-00-SL | - | 220 J | - | - | - |
| OA-10-00-SL | 730 | 590 | 920 | - | - |
| OA-11-00-SL | 860 | 920 | 1300 | - | - |
| OA-12-00-SL | - | 130 J | - | - | - |
| OA-13-00-SL | - | 300 J | - | - | - |
| OA-15-00-SL | 3700 | 4600 | 7000 | 440 | 2800 J |
| OA-16-00-SL | 4700 | 5300 | 6800 | - | 3200 J |
| OA-23-00-SL | 630 | 610 | 1000 | - | - |
| OA-26-00-SL | - | 590 | 1100 | - | - |
| OA-28-00-SL | - | 76 J | - | - | - |
| OA-31-00-SL | - | 220 J | - | - | - |
| OA-32-00-SL | - | 130 J | - | - | - |
| OA-33-00-SL | - | 160 J | - | - | - |
| RR-03-00-SL | - | 74 J | - | - | - |

**Table 4.38. PCBs in surface soils (μg/kg) (Refer to Fig. 2.4 for sample locations; only samples with PCBs detected above the risk-based screening levels are shown.)**

| Sample ID | PCB-1254 | PCB-1260 |
|---|---|---|
| BP-07-00-SL | – | 230 |
| EP-04-00-SL | – | 300 |
| EP-04-00-SL-FD | – | 320 |
| LF-01-00-SL | – | 560 |
| OA-08-00-SL | – | 400 |
| RR-01-00-SL | 540 J | 310 |

*J = estimated, below quantitation limit.
PCB = polychlorinated biphenyl.

**Table 4.39. Petroleum in surface soils (mg/kg) [Refer to Fig. 2.4a for sample locations; only samples with detectable diesel fuel and gasoline-range organics detected above the detection limit are shown.]**

| Sample ID | Diesel fuel | Gasoline |
|---|---|---|
| GS-03-00-SL | 15 HZ | - |
| GS-04-00-SL | 35 HZ | 0.29 J |
| GS-05-00-SL | 26 ZH | - |

H = the final pattern was in the heavier end of the retention time window for the analyte.
Z = a significant fraction of the reported result did not resemble the patterns of diesel.

**Table 4.40. Dioxins in subsurface soil (pg/g) (Refer to Fig. 2.5b for sample location.)**

| Sample ID | 1,2,3,4,6,7,8-HPCDD | OCDD |
|---|---|---|
| CB-02-05-SL | 61 B | 2200 B |
| CB-02-05-SL-FD | 98 B | 4000 B |
| CB-02-15-SL | 15 B | 710 B |
| CB-02-25-SL | 4.2 QJB | 200 B |

B = detected in the method blank.
J = estimated, below quantitation limit.

**Table 4.41. PAHs in subsurface soil (μg/kg) (Refer to Figs. 2.5a and 2.5b for sample location.)**

| Sample ID | Benzo(*a*) anthracene | Benzo(*a*) pyrene | Benzo(*b*) fluoranthene |
|---|---|---|---|
| LF-08-03-SL | - | 120 J | - |
| LF-08-03-SL-FD | - | 64 J | - |
| LF-09-03-SL | - | 140 J | - |
| NB-53-05-SL | - | 160 J | - |
| NB-53-33-SL | 630 | 780 | 1800 |
| NB-55-13-SL | 630 | 260 J | - |
| NB-56-05-SL | - | 380 J | 770 |
| NB-57-34-SL | - | 200 J | - |
| NB-78-18-SL | - | 300 J | - |
| OA-19-05-SL | - | 220 J | - |

J = estimated, below quantitation limit.
PAH = polycyclic aromatic hydrocarbon.

**Table 4.42. VOCs in subsurface soil samples (μg/kg) (Refer to Fig. 4.21 for sample locations and Figs. 2.5a and 2.5b for all locations samples.)**

| Sample ID[a] | 1,1-Dichloro ethene | Methylene chloride | Tetrachloro ethylene | Trichloro ethene |
|---|---|---|---|---|
| BD-13-09-SL | - | - | 830 | - |
| BD-13-15-SL | - | - | 8,900 | - |
| BD-13-23-SL | - | - | 27,000 | - |
| BD-13-30-SL | - | - | 13,000 | - |
| BD-14-31-SL | - | - | - | 62 |
| BLD240-01-31 | - | - | 4,800 | - |
| BLD240-01-31FD | - | - | 3,600 | - |
| BLD240-05-23 | - | - | - | 470 |
| BLD253-02-21 | 3,600 J | - | 6,600,000 | - |
| BLD253-02-21FD | - | 54,000 J[b] | 800,000 | - |
| BLD255-08-24 | - | - | 1,600 | 1,600 |
| BLD260-06-31 | - | - | - | 350 |
| BP-22-33-SL | - | - | - | 170 |
| EP-15-29-SL | - | - | 4,600 | 110 |
| EP-17-30-SL | - | - | 18,000 | 400 |
| EP-20-25-SL | - | - | 490 | - |
| NB-31-32-SL | - | - | - | 76 |
| NB-40-31-SL | - | - | 4,600 | 410 |
| NB-45-33-SL | - | - | - | 54 |
| NB-64-17-SL | - | - | - | 76 |
| NB-72-19-SL | - | - | - | 280 |
| NB-72-22-SL | - | - | - | 310 |
| NB-78-18-SL | - | - | - | 260 |
| OA-18-25-SL | - | - | - | 320 |
| OA-18-33-SL | - | - | - | 4,800 |
| OA-19-33-SL | - | - | - | 64 |

[a] Sample ID AA-XX-YY-SL, refers to the sampling station (AA-XX) shown on Figs. 2.5a and 2.5b and Fig. 4.21, while YY refers to the sample depth in ft BGS. For samples collected from under the buildings, sample ID consists of BLDXXX-AA-DD where XXX is the building number where borehole is located, AA is boring number, sample depth is DD in feet.

[b] J = estimated, below quantitation limit.

B = detected in method blank.

"-" = not detected below the MDL.

**Table 4.43. BNAs in groundwater (μg/L) (Refer to Figs. 2.6a and 2.6b for well locations; only samples with detectable BNAs are shown.)**

| Well ID | Bis(2-ethylhexyl) phthalate | Hexachloroethane |
|---|---|---|
| BD-02 | - | 6.5 J |
| EP-15 | 20 | - |
| LF-08 | 26 | - |
| RR-05 | 6.3 J | - |
| SW-07 | 9 J | - |

J = estimated; below quantitation limit.

"-" = below detection limit.

**Table 4.44. VOCs in groundwater (μg/L) (Refer to Figs. 2.6a and 2.6b for well locations; only samples with VOCs above reference levels are shown.)**

| Sample ID | 1,1,2-Trichloroethane | 1,1-Dichloroethene | 1,2-Dichloroethane | Benzene | Chloroethane | Chloroform | *cis*-1,2-Dichloroethene | Methylene chloride | Tetrachloro ethylene | *trans*-1,2-Dichloroethene | Trichloro ethene | Vinyl chloride |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW-BD1-121704 | 6.7 | 790 | 5.3 | - | - | 6.1 | - | - | 4,900 | - | 26 | 1.5 J |
| GW-BD13-122804 | - | 290 | - | - | - | - | 520 | - | 900 | 630 | 900 | - |
| GW-BD14-122904 | - | 120 J | - | - | - | - | 250 | - | 2,100 | 100 J | 1,000 | - |
| GW-BD16-122204 | - | 39 | 1.1 J | - | - | - | - | - | 2.9 J | - | 1.2 J | - |
| GW-BD2-121604 | - | 5,100 J | - | - | - | - | - | - | 200,000 | - | - | - |
| GW-BD3-121704 | 1.8 J | 82 | | - | - | 1.5 J | - | - | 3,000 | - | 16 | - |
| GW-BD4-121704 | - | 120 | - | - | - | - | - | - | 1,200 | - | 130 | 1.5 J |
| GW-BD5-121504 | - | 34 | - | - | - | - | 100 | - | 190 | - | 440 | - |
| GW-BD6-121404 | 2.7 J | 560 | 7.7 | 4.8 J | - | 6.8 | 19,000 | - | 2,100 | 170 J | 18,000 | 1,000 |
| GW-BD7-121504 | - | - | - | - | - | - | - | - | 8.7 | - | 5.8 | - |
| GW-BD8-122804 | 1.4 J | - | 8.7 | - | - | 2 J | 7,200 | - | 1,400 J | - | 12,000 | - |
| GW-BP17-122204 | - | 11 J | - | - | - | - | 340 | - | - | - | 15 J | 7.8 J |
| GW-BP22A-122804 | - | - | - | - | 52 J | - | 550 | - | 420 | - | 990 | 41 J |
| GW-BP22B-122804 | - | - | - | - | - | - | - | - | 270 | - | 99 | - |
| GW-BR10JC-121304 | - | 28 | - | - | - | - | 180 | - | 160 | - | 520 | 16 |
| GW-BR10OB-120804 | - | - | - | - | - | - | - | - | 110 | - | 90 | - |
| GW-BR3OB-120804 | - | - | - | - | - | - | - | - | 20 | - | 5.8 | - |
| GW-BR4JC-121404 | - | 26 J | - | - | - | - | - | - | 1,700 | - | 210 | - |
| GW-BR6RB-120704 | - | - | - | - | - | - | - | - | - | - | 1.9 J | - |
| GW-BR7JC-121504 | - | - | - | - | - | - | - | - | 6 | - | 20 | - |
| GW-BR7RB-121404 | - | - | - | - | - | - | - | 7.6 B | - | - | 1.3 J | - |
| GW-BR8JC-120604 | - | 190 J | - | - | - | - | 2,400 | - | 530 | - | 5,800 | 180 J |
| GW-BR8OB-120604 | - | - | - | - | - | - | 220 | - | 40 | - | 190 | - |
| GW-BR9JC-121404 | - | 100 J | - | - | - | - | 1,400 | - | 1,000 | - | 2,800 | 150 J |
| GW-DM02-122204 | | 27 | - | - | - | - | 240 | - | 470 | - | 270 | - |
| GW-EP16-121304 | - | - | - | - | - | - | - | - | 7.6 | - | 1.6 J | - |
| GW-EP20-121504 | | - | - | - | - | - | - | - | 2,400 | - | - | - |
| NB-34 (dup) | - | 180 | - | - | - | | 68 J | 74 J | 2,000 | - | 530 | - |
| ED-16 (dup) | - | - | - | - | - | - | - | - | 6.1 | - | 1.2 J | - |
| BR-09-JC (dup) | - | 85 J | - | - | - | - | 1,400 | - | 1,000 | - | 2,800 | 150 J |
| WS-31 (dup) | - | 62 J | - | - | - | - | 730 | - | 130 | - | 1,800 | - |
| BR-10-JC (dup) | - | 26 | - | - | - | - | 180 | - | 150 | - | 520 | 16 |
| LF-09 (dup) | - | - | - | - | - | - | 280 J | 1,600 | 14,000 | - | 1,900 | - |
| GW-LF08-122104 | - | - | - | - | - | - | - | - | 65 | - | 5.6 | - |
| GW-LF09-122004 | - | - | - | - | - | - | 260 J | 1,200 | 14,000 | - | 1,900 | - |
| GW-NB31-122104 | - | 33 J | - | - | - | - | 280 | - | 88 | - | 830 | 35 J |
| GW-NB32-122004 | - | 22 J | - | - | - | - | 170 | 19 J | 34 | - | 360 | - |
| GW-NB33-122104 | - | - | - | - | - | - | - | - | 23 | - | 2.1 J | - |
| GW-NB34-120704 | - | 210 | - | - | - | - | 72 J | 74 J | 2,600 | - | 620 | - |
| GW-NB35-122104 | - | 89 J | - | - | - | - | 870 | - | 74 J | - | 3,600 | - |
| GW-NB36-122204 | - | 40 J | - | - | - | - | 290 | - | 38 J | - | 810 | - |
| GW-NB39-121504 | - | 39 | - | - | - | - | 190 | - | - | | 510 | 7.5 J |
| GW-NB44-120604 | - | 8.9 J | - | - | - | - | - | - | 680 | - | 410 | - |
| GW-NB54-122004 | - | - | - | - | - | - | - | - | 1,400 | - | 380 | - |

**Table 4.44. VOCs in groundwater (µg/L) (Refer to Figs. 2.6a and 2.6b for well locations; only samples with VOCs above screening levels are shown.) (continued)**

| Sample ID | 1,1,2-Trichloroethane | 1,1-Dichloroethene | 1,2-Dichloroethane | Benzene | Chloroethane | Chloroform | *cis*-1,2-Dichloroethene | Methylene chloride | Tetrachloro ethylene | trans-1,2-Dichloroethene | Trichloro ethene | Vinyl chloride |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| GW-NB56-121604 | - | - | - | - | - | - | - | - | 6.4 | - | - | - |
| GW-NB61-122204 | - | - | - | - | - | - | - | - | 1.4 J | - | - | |
| GW-NB64-122104 | - | 49 | 1.1 J | - | - | - | 830 | - | 230 J | - | 1,600 | 1.9 J |
| GW-NB65-122004 | - | - | - | - | - | - | - | 12 | 60 | - | 15 | - |
| GW-NB67-120704 | - | - | - | - | - | - | - | 4.3 J | - | - | - | - |
| GW-NB72-122104 | - | 380 J | - | - | - | - | 3,700 | - | - | | 15,000 | - |
| GW-NB73-122004 | - | 48 J | - | - | - | - | - | 180 | 1,200 | - | 240 | - |
| GW-NB74-121304 | - | 460 | 3.4 J | 1.3 J | - | - | 260 | - | 4,100 | - | 3,000 | 11 |
| GW-NB77-122004 | - | 8.1 J | - | - | | - | - | - | 260 | - | 60 | - |
| GW-NB78-122104 | - | 28 | - | - | - | - | 870 | - | 15 | - | 880 | 3.9 J |
| GW-NB80-121704 | 8.4 | - | - | - | - | - | - | - | 290 | - | 2,600 | - |
| GW-NB83-120904 | - | - | - | - | - | - | - | 4.5 | - | - | - | - |
| GW-NB84-120804 | - | - | - | - | - | - | 93 | - | 460 | - | 240 | - |
| GW-OA19-122104 | - | 12 J | - | - | - | - | 250 | - | 7.3 J | - | 120 | - |
| GW-OB1-121404 | - | - | - | - | - | - | - | - | 10 | - | - | - |
| GW-OB2-121404 | - | - | - | - | - | - | - | - | 3.7 J | - | - | - |
| GW-PL04-122204 | - | 28 J | - | - | - | - | 340 | - | 230 | - | 1,100 | 22 J |
| GW-PL06-121504 | - | - | - | - | - | - | - | - | 60 | - | 4.9 J | - |
| GW-PW16JC-121604 | - | - | - | - | - | - | - | - | 7.6 | - | 66 | - |
| GW-PW16RB-121604 | - | - | - | - | - | - | - | - | - | - | 15 | - |
| GW-PW19JC-121504 | - | 42 J | - | - | - | - | 460 | - | 87 | | 710 | 44 J |
| GW-PW19RB-121504 | - | 29 | - | - | - | - | 350 | - | 34 | - | 500 | 8.5 J |
| GW-PW6JC-121604 | - | - | - | - | - | - | - | - | 1.5 J | - | 7.6 | - |
| GW-PZ3-121704 | - | 240 J | 3.9 J | - | - | - | 1,900 | - | 1,900 | - | 7,700 | 77 |
| GW-PZ4-121304 | - | 9.1 | - | - | - | - | 170 | - | 21 | - | 250 | 1.9 J |
| GW-WS14-121604 | - | - | - | - | - | - | 800 | - | 1,400 | - | 120 J | - |
| GW-WS16-121604 | - | - | - | - | - | - | - | - | 120 | - | 13 | - |
| GW-WS17B-121704 | - | - | - | - | - | - | - | - | 5 J | - | 42 | - |
| GW-WS24-121504 | - | - | - | - | - | - | - | - | 36 | - | 14 | - |
| GW-WS27-121504 | - | - | - | - | - | - | - | - | 3.5 J | - | 5.6 | - |
| GW-WS28-121604 | - | - | - | - | - | - | - | - | 41 | - | 15 | - |
| GW-WS29-121604 | - | - | - | - | - | - | 1,100 | - | - | - | 550 | 150 J |
| GW-WS30-121604 | - | 52 J | - | - | - | - | 2,100 | - | 2,200 | - | 3,700 | - |
| GW-WS31-121604 | - | 70 J | - | - | - | - | 770 | - | 150 | - | 1,900 | - |
| GW-WS32-121704 | - | - | - | - | - | - | - | - | 21 | - | 69 | - |
| GW-WS34-121404 | - | - | - | - | - | - | - | - | - | - | 18 | - |

VOC = volatile organic compound.

**Table 4.45. Mobile versus analytical laboratory results**

| | TCE | | | PCE | | |
|---|---|---|---|---|---|---|
| | **Analytical** | **Mobile** | **% Diff** | **Analytical** | **Mobile** | **% Diff** |
| BW-BR6-65-80-GW-SS | 5 U | 5 U | --- | 5 U | 5 U | --- |
| BW-BR7-65-75-GW-SS | 5 U | 0.5 U | --- | 5 U | 0.5 U | --- |
| NB-34-22-32-OL-GW-SS | 570 E | 559 | 0.02 | 2500 E | 2399 | 0.04 |
| PW-03-161-181-GW | 25 | 23.6 | 0.04 | 17 | 14.9 | 0.12 |
| PW-03-201-221-GW-SS | 24 | 23.8 | 0.01 | 15 | 13.9 | 0.07 |
| PW-19-207-227-GW-SS | 460 | 212 | 0.54 | 78 | 39 | 0.5 |
| PW-19-207-227-GW-SS | 350 E | 212 | 0.39 | 63 | 39 | 0.38 |
| | **1,1-DCA** | | | **1,1-DCE** | | |
| | **Analytical** | **Mobile** | **% Diff** | **Analytical** | **Mobile** | **% Diff** |
| BW-BR6-65-80-GW-SS | 5 U | 5 U | --- | 10 U | 5 U | --- |
| BW-BR7-65-75-GW-SS | 5 U | 0.5 U | --- | 5 U | 0.5 U | --- |
| NB-34-22-32-OL-GW-SS | 48 | 43 | 0.1 | 190 | 454 | 0.58 |
| PW-03-161-181-GW | 3.8 J | 3.8 | 0 | 5 U | 0.5 U | --- |
| PW-03-201-221-GW-SS | 3.4 J | 3.6 | 0.06 | 0.7 J | 1.2 | 0.42 |
| PW-19-207-227-GW-SS | 46 | 17 | 0.63 | 15 J | 26 | 0.42 |
| PW-19-207-227-GW-SS | 38 | 17 | 0.55 | 12 | 26 | 0.54 |
| | ***cis*-1,2-DCE** | | | ***trans*-1,2-DCE** | | |
| | **Analytical** | **Mobile** | **% Diff** | **Analytical** | **Mobile** | **% Diff** |
| BW-BR6-65-80-GW-SS | 5 U | 5 U | --- | 5 U | 5 U | --- |
| BW-BR7-65-75-GW-SS | 5 U | 0.5 U | --- | 5 U | 0.5 U | --- |
| NB-34-22-32-OL-GW-SS | 71 | 63 | 0.11 | 11 | 13 | 0.15 |
| PW-03-161-181-GW | 14 | 13.6 | 0.03 | 5 U | 0.5 U | --- |
| PW-03-201-221-GW-SS | 12 | 11.8 | 0.02 | 5 U | 0.5 U | --- |
| PW-19-207-227-GW-SS | 210 | 84 | 0.6 | 25 U | 0.5 U | --- |
| PW-19-207-227-GW-SS | 170 E | 84 | 0.5 | 2.2 J | 0.5 U | --- |
| | **Vinyl chloride** | | | | | |
| | **Analytical** | **Mobile** | **% Diff** | | | |
| BW-BR6-65-80-GW-SS | 10 U | 5 U | --- | | | |
| BW-BR7-65-75-GW-SS | 10 U | 0.5 U | --- | | | |
| NB-34-22-32-OL-GW-SS | 1.9 J | 5 U | --- | | | |
| PW-03-161-181-GW | 0.68 J | 0.5 U | --- | | | |
| PW-03-201-221-GW-SS | 0.84 J | 0.5 U | --- | | | |
| PW-19-207-227-GW-SS | 4 J | 0.5 U | --- | | | |
| PW-19-207-227-GW-SS | 3 J | 0.5 U | --- | | | |

DCA = dichloroethane.
DCE = dichloroethylene.
PCE = perchloroethene.
TCE = trichloroethylene.

**Table 4.46. Locations where soil, sediment, surface water, and groundwater samples were obtained and analyzed for VOCs in previous investigations**

| Location | LBG (1999) | LBG (2002) |
|---|---|---|
| **Groundwater** | | |
| Location 1 (near WS-7) | X | |
| WS-7 | X | |
| Location 2 (near WS-17) | X | |
| Location 3 (near WS-14) | X | |
| WS-14 | X | |
| Location 4 (near WS-16) | X | |
| WS-16 | X | |
| Location 5 (near WS 15) | X | |
| WS-15 | X | |
| WS-17B | X | |
| WS-22 | X | |
| WS-23 | X | |
| WS-24 | X | |
| WS-25 | X | |
| WS-27 | X | |
| WS-28 | X | |
| WS-29 | X | |
| WS-30 | X | |
| WS-31 | X | |
| WS-32 | X | |
| WS-33 | X | |
| WS-34 | X | |
| BR-1* | | X |
| BR-2* | | X |
| BR-3* | | X |
| BR-4* | | X |
| OB-1 | | X |
| OB-2 | | X |
| Surface Water | X | |
| SW-1 | X | |
| SW-2 | X | |
| SW-3 | X | |
| SW-4 | X | |
| **Soil** | | |
| WS-23* | X | |
| WS-25* | X | |
| WS--27* | X | |
| WS-29* | X | |
| WS-32* | X | |
| WS-34* | X | |
| BR-1* | | X |
| BR-2* | | X |
| BR-3* | | X |
| BR-4* | | X |
| OB-1* | | X |
| OB-2* | | X |
| **Sediment** | | |
| SS-1 | X | |
| SS-2 | X | |

* Multiple samples were analyzed from different depths.

Locations where at least one VOC was detected (common laboratory contaminants excluded).

VOC = volatile organic compound.