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SITE 21 MANGANESE INVESTIGATION TECHNICAL MEMORANDUM NSWC INDIAN HEAD
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Site 21 (Bronson Road Landfill) Manganese Investigation Technical Memorandum

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1.0 Introduction

This technical memorandum presents the results of field activities completed at Site 21 (Bronson Road Landfill) at the Naval Support Facility, Indian Head (NSF-IH), Indian Head, Maryland. The field activities were performed in accordance with the *Final Site 21 (Bronson Road Landfill) Manganese Investigation Work Plan*, CH2M HILL, July 16, 2008.

The purpose of this technical memorandum is to provide the following information:

- Present the analytical, geochemical, and hydrogeological results and interpretations for the manganese in groundwater investigation activities performed at Site 21 in July/August and November 2008.
- Provide an updated understanding of the groundwater flow conditions at Site 21 based on the new data available from the additional monitoring wells and synoptic water level measurements.
- Perform an assessment as to whether the manganese in groundwater at Site 21 is from a natural source (i.e., not from the Site 21 landfill materials) using geochemical analysis.
- Provide an assessment of the potential human health risk from groundwater based on the current understanding of groundwater conditions and manganese concentrations.
- Provide a remedial action recommendation for groundwater at Site 21.

- Suggest an overall remedial action determination for all media at Site 21.

The remainder of this technical memorandum is organized as follows:

- Section 2 – Investigation Rationale and Abbreviated History for Site 21 Manganese Investigation
- Section 3 – Investigation Activities Completed, Associated Results, and Data Presentation
- Section 4 – Groundwater Conditions
- Section 5 – Geochemical Analysis
- Section 6 – Human Health Risk Assessment for Groundwater
- Section 7 – Summary and Recommendations
- Section 8 – References

2.0 Investigation Rationale and Abbreviated History for Site 21 Manganese Investigation

The Remedial Investigation conducted at Site 21 indicated that up to 22 feet of waste is below the water table (CH2M HILL, 2004). Groundwater samples collected in 2000 and 2002 from monitoring well IS21MW02 (Figure 1), immediately downgradient from the landfill, contained total manganese concentrations of 23,100 and 10,900 micrograms per liter ($\mu\text{g}/\text{L}$). The elevated concentrations of manganese were considered to be the result of groundwater flowing through the waste material. The Feasibility Study for Site 21 considered several alternatives for this site (CH2M HILL, 2006a). One of the alternatives was the installation of a Resource Conservation and Recovery Act of 1976 (RCRA) Subtitle C-equivalent cap (Alternative 3). Another included the installation of a soil cover (Alternative 2). A geochemical assessment and groundwater modeling were conducted to evaluate the potential effects of installing a RCRA Subtitle C-equivalent cap at the site. The results of the geochemical assessment strongly suggested that the presence of manganese in groundwater is attributable to low redox conditions that may be created by the presence of the waste and not direct leaching of manganese from the waste (CH2M HILL, 2006b). The assessment also suggested that installing a RCRA Subtitle C-equivalent cap will further degrade groundwater quality by exacerbating reducing conditions; thereby, mobilizing additional manganese. The groundwater modeling results suggested that a RCRA Subtitle C-equivalent cap will provide minimal hydraulic benefit because the water table would only be lowered by approximately 1.54 feet, which would still result in a significant volume of waste lying below the water table and in contact with the groundwater. The overall conclusion from both studies was that a soil cover would be a more environmentally effective remedy that is equally protective of human health and at a cost at least an order of magnitude less than a RCRA Subtitle C-equivalent cap. Institutional controls and long-term monitoring were components of each alternative identified in the Feasibility Study.

The results of the geochemical assessment were presented to the Maryland Department of the Environment (MDE) on December 20, 2007. Based on the geochemical and hydrologic

results presented, the MDE indicated that they would consider three options for moving forward with the site:

1. Install the RCRA Subtitle C-equivalent cap;
2. Further demonstrate that manganese is from a natural source (i.e., not from landfill materials); or
3. Provide additional data to support the results that installing a RCRA C-equivalent cap would create more of a manganese issue than installing a soil cover.

If option 2 was successful, then there would be no need to address the manganese issue as it is not the result of site-related activities. There still may be the need to place a soil cover over the former landfill, but no additional activities would be needed, such as long-term monitoring. If option 3 was successful, then a soil cover, which allows oxygenated water to infiltrate, would be a viable option that the MDE would be open to consider (i.e., more protective of human health and the environment). Both options 2 and 3 require collection of additional information but could alleviate the costly potential of selecting option 1.

Consequently, a sampling approach for option 2 was presented to the Indian Head Installation Restoration Team (IHIRT) during meetings in February, April, and July 2008. The sampling approach outlined an investigation that would be focused on understanding manganese concentrations in groundwater and associated geochemical conditions in the area of the Site 21 landfill. The resulting work plan titled *Final Site 21 (Bronson Road Landfill) Manganese Investigation Work Plan* (CH2M HILL, 2008) was finalized on July 16, 2008 and identified the following investigation items:

- Groundwater Monitoring Well Installation - Install four new monitoring wells (one upgradient and three downgradient of the landfill) to provide additional groundwater elevation and quality data. The selection of the new groundwater monitoring wells was based on previous groundwater flow information and direct push manganese in groundwater characterization efforts previously completed in 2006 as presented in CH2M HILL (2006c).
- Piezometer Installation - Install a single piezometer within the landfill to provide representative groundwater elevation conditions within landfill; no groundwater samples will be collected from this piezometer.
- Soil/Solids Sampling - Collect soil samples during the installation of the four new monitoring wells plus solids will be collected from the bottom of existing well IS21MW02 to provide a geochemical understanding of manganese in the shallow aquifer parent material to assess potential differences in upgradient and downgradient conditions.
- Groundwater Sampling - Conduct two quarterly rounds of groundwater sampling from eight monitoring wells (four existing and four new) to provide understanding of current, representative manganese concentrations in groundwater and geochemical conditions upgradient and downgradient of landfill.

In addition, the following decision path for remedial action for groundwater at Site 21 was identified at the April 2008 IHIRT meeting:

1. If manganese is naturally-occurring, then no further action for Site 21 groundwater is required.
2. If manganese is not naturally-occurring, but representative human health risk is acceptable, then no further action for Site 21 groundwater is required.
3. If manganese is not naturally-occurring and representative risk is unacceptable, consider further analysis and pursuit of December 20, 2007 Option 3 (Provide additional data to support impact on manganese from a RCRA Subtitle C Cap).

The field activities for the manganese investigation were completed in August and November 2008. The investigation activities and associated results are presented in Section 3 below.

3.0 Investigation Activities Completed, Associated Results, and Data Presentation

3.1 Activities Completed

Four new monitoring wells (IS21MW05 through IS21MW08) and one piezometer (IS21PZ01) were installed in July 2008 in the first-encountered groundwater table as presented in Figure 1. Soil boring logs and well construction diagrams for these five locations are presented in Attachments 1 and 2, respectively. A summary of the well construction information for the newly-installed monitoring wells at Site 21 in addition to the four existing monitoring wells (IS21MW01 through IS21MW04) is presented in Table 1.

Four subsurface soil samples were collected from each of the four monitoring well soil borings from the saturated soil below the water table representing the shallow aquifer as identified in Table 2.¹ Table 2 also presents the analyses performed on the soil samples.

Groundwater samples were collected from the Site 21 monitoring well network consisting of eight monitoring wells during two quarterly events, the first in August 2008 and the second in November 2008. The analyses performed for the two groundwater sampling rounds are presented in Table 3.

3.2 Associated Results

The analytical results for the four soil samples collected from the monitoring well soil borings are presented in Table 4. Geochemical-related analyses and results for the soil samples submitted for Sequential Extraction analysis and X-Ray Diffraction/Electron Microprobe analysis are presented in Attachments 3 and 4.

Table 1 presents the groundwater elevation measurements collected during synoptic gauging events in August and November 2008. Table 5 presents the field parameter results

¹ The Work Plan (CH2M HILL, 2008) also identified the collection of solids at the base of existing monitoring well IS21MW02 for analysis; however, there was not enough sediment within the base of the well to allow for sample collection based on the sample collection effort made on July 25, 2008.

obtained during the second round of groundwater sampling in November 2008 as representative of current geochemical conditions at the site. Table 6 presents the analytical results for the eight groundwater samples collected from the site monitoring wells during the August and November 2008 sampling events.²

3.3 Data Presentation

The focus of the data presentation is on manganese groundwater concentrations based on the rationale presented in Section 2 above. Figure 2 presents the manganese groundwater concentrations (total, filtered at 0.45 micron [μm], and filtered at 0.10 μm) measured in the Site 21 monitoring well network during five sampling events conducted between September 2000 and November 2008. Figure 3 presents the trend graph of total manganese groundwater concentrations over the same eight year period with two comparison criteria: (1) the background concentration of manganese in groundwater of 824 micrograms per liter ($\mu\text{g/L}$) based on the 95 % upper confidence level of the mean (CH2M HILL, 2004); and (2) the Regional Screening Level (RSL) - Tap Water for manganese of 880 $\mu\text{g/L}$.³

Groundwater elevation contours for the synoptic water level measurement events in August and November 2008 are presented in Figures 4 and 5. Figure 6 presents an updated fill thickness map for the landfill at Site 21 based on Figure 7-3 in CH2M HILL (2004). The boring log for the piezometer installed in the former landfill area, designated as IS21PZ01, is included in Attachment 1. Detailed description of the soil samples collected during drilling is provided on the log and indicates that silt and clay represent the majority of the subsurface materials encountered with a minor amount of fill. The fill encountered is composed mainly of glass and wood fragments. Metallic debris was not found during drilling. Based on these descriptions, the material in the former landfill is better characterized as a mixture of silts and clays with glass and wood fragments, and that metal debris, if any, likely represents a minor component of the fill.

Data analysis and interpretation is performed in the following sections specifically Section 4 (Groundwater Conditions), Section 5 (Geochemical Analysis), and Section 6 (Human Health Risk Assessment for Groundwater).

4.0 Groundwater Conditions

4.1 Groundwater Flow Direction

Depth to groundwater in the site monitoring wells and piezometer were measured on August 11, 2008 and November 5, 2008 (Table 1). These measurements were converted to groundwater elevations using the surveyed casing elevations of the wells and piezometer. Groundwater elevations from the August 11, 2008 and November 5, 2008 measurement events were plotted on Figures 4 and 5, respectively, and contoured to generate

² Groundwater samples were also collected for analyses unrelated to the Site 21 Manganese Investigation in August 2008. Specifically, a groundwater sample was collected from new upgradient monitoring well IS21MW05 for facility-wide groundwater explosives analysis. In addition, groundwater samples were also collected for Agent Orange-related analyses as agreed with the IHIRT in July 2008. The results of these analyses unrelated to Site 21 are not discussed further herein and are discussed in separate documentation.

³ As identified at <http://epa-prgs.ornl.gov/chemicals/guide.shtml> (accessed January 16, 2009).

groundwater flow maps. A review of these maps indicates that the groundwater flow at the site is to the southwest under a hydraulic gradient of about 0.022 ft/ft. The flow direction and hydraulic gradient noted in Figures 4 and 5 are similar and indicate that seasonal variation in groundwater elevations at the site is minor.

The groundwater flow conditions noted in August 11, 2008 and November 5, 2008 are similar to those noted in the Remedial Investigation and Feasibility Study reports (CH2M HILL 2004; CH2M HILL, 2006a), and in subsequent supporting documents. The installation of additional measurement points, especially the piezometer IS21PZ01, provide a more detailed understanding of the groundwater flow conditions and are consistent with the groundwater flow conditions used in the groundwater flow model (CH2M HILL, 2006b). Confirmation of the hydraulic gradient input value used in the groundwater model strengthen the validity of the model output, which indicates that placement of a RCRA Subtitle C Cap over the former landfill area would lower the water table about 1.54 ft under the cap area. Results from the Remedial Investigation demonstrated that there is currently up to 22 ft of fill below the water table; thus, lowering the water table by 1.54 ft would not effectively remove the contact between the fill material and the groundwater flowing through the site.

Review of the figures show that monitoring wells IS21MW04 and IS21MW05 are upgradient of the former landfill. Monitoring wells IS21MW02, IS21MW03, IS21MW07, and IS21MW08 are immediately downgradient from a groundwater flow path through the landfill area, whereas monitoring wells IS21MW01 and IS21MW06 area along groundwater flow paths that do not go through the landfill.

As presented in the CH2M HILL (2006b), the fill associated with Site 21 extends below the groundwater table, which is confirmed with the installation of the piezometer in the fill area. The groundwater flow conditions noted on August 11, 2008 and November 5, 2008, including measurements from the piezometer, are consistent with historical data and support the information that a significant portion of fill is below the groundwater table. The updated groundwater elevation information also demonstrates that perched groundwater conditions do not exist at the site.

4.2 Manganese Spatial and Temporal Distribution

Figure 2 presents the total manganese concentrations in groundwater while Figures 4 and 5 present the groundwater flow direction based on August 2008 and November 2008 water level data.

The spatial distribution of manganese in groundwater for November 2008 is similar to previous sampling events. The lowest manganese groundwater concentrations are detected in upgradient monitoring wells IS21MW04 and IS21MW05, and in monitoring well IS21MW01, which is hydraulically downgradient of the site boundary, but cross-gradient from the main filled area as shown in Figures 4 and 5. Total manganese groundwater concentrations in these three monitoring wells are below both the background concentration (824 µg/L) and RSL-Tap Water (880 µg/L) concentration.

Manganese groundwater concentrations in three downgradient monitoring wells (IS21MW03, IS21MW06, and IS21MW08) located on the southern downgradient side of the site were below both the background concentration and RSL-Tap Water criteria, with the

exception of the November 2008 sampling event where the concentration was 1,680 µg/L at well IS21MW03. Well IS21MW08 contained the lowest manganese concentrations within these three wells and is the farthest well from the site. Also, monitoring well IS21MW08 is located downgradient from monitoring well IS21MW02 and the former landfill area.

Manganese groundwater concentrations in two downgradient wells (IS21MW02 and IS21MW07) located on the western downgradient side of the site were above the background and RSL-Tap Water criteria, with a maximum detection from the August and November 2008 sampling event of 6,110 µg/L (well IS21MW07).

Figure 3 presents a trend graph of the total manganese groundwater concentrations for the eight monitoring wells including the average (normal mean) for each of the five sampling events between September 2000 and November 2008. As shown in the figure, the overall trend for total manganese in groundwater is decreasing from the first two events (September 2000 and July 2002) based on results from the individual wells and the average concentration for each event. For example, the highest total manganese concentration detected at Site 21 was 23,100 µg/L in well IS21MW02 in September 2000 whereas recent (August and November 2008) manganese concentrations in IS21MW02 are almost an order of magnitude lower at a concentration of 2,400 µg/L (November 2008). The average total manganese concentration for each sampling event ranging from 655 to 6,119 µg/L has typically been above both the background concentration (824 µg/L) and RSL-Tap Water (880 µg/L) with the exception of June 2006 (655 µg/L).

5.0 Geochemical Analysis

A detailed geochemical analysis was conducted to understand the characteristics of the naturally occurring manganese in the aquifer materials and to assess if the naturally occurring manganese could account for the distribution of the manganese in the aquifer. This analysis also included a comparison of the geochemical conditions from a typical landfill and those noted at the site. Based on these analyses, the manganese concentrations and geochemistry at the site are consistent with natural conditions and are not necessarily related to the presence of the former landfill material.

Source of Manganese

A detailed review of soil descriptions from soil borings advanced in the former landfill indicates that the former landfill material is predominantly soil with minor amounts of wood, glass, brick, and coal fragments. These materials are not preferentially enriched in manganese and are not considered to be a source of the manganese in the groundwater. Representative soil samples of the aquifer material were collected during installation of the upgradient monitoring well (IS21MW05) and downgradient monitoring wells IS21MW06, IS21MW07, and IS21MW08 (Figure 1), and submitted for petrographic analyses, including X-ray diffraction (XRD) and electron microprobe (EM) analysis. The XRD analysis identifies the main crystalline phases present in the samples whereas the EM analysis identifies the manganese-bearing crystalline phases and other potential sources of manganese.

Petrographic analyses indicated that quartz is the predominant mineral in the samples, with lesser amounts of potassium feldspar, ilmenite, rutile, and micaceous clay minerals. Manganese occurs in ilmenite grains ($[\text{Fe,Mg,Mn,Ti}]\text{O}_3$), as small (<5 µm)

blebs intergrown with clay, as rare Mn-rich grains that are probably an intergrowth of clay, and as Mn-hydroxide minerals that likely resulted from the in situ weathering of ilmenite. The degree of weathering is variable among samples with primary potassium feldspar, ilmenite, and rutile grains scattered amongst more prevalent secondary phases including micaceous clays and iron and manganese oxyhydroxide minerals.

Ilmenite grains appear to be the main primary source of manganese with most grains containing manganese as a trace element. The ilmenite grains appear to have undergone oxidation and hydrolysis to varying degrees, resulting in the precipitation of amorphous iron- and manganese-oxyhydroxides (Attachment 4). These oxyhydroxides appear to precipitate on particles with a high surface area, such as quartz grains and weathered micas and clay minerals. Consequently the manganese-oxyhydroxides appear as finely disseminated coatings that resulted from primary mineral dissolution, migration of dissolved manganese, and subsequent precipitation due to variations in subsurface redox and hydrologic conditions. The presence of manganese-bearing minerals is a natural occurrence and attributed to normal subsurface geochemical processes.

To understand the dissolution and mobility potential of the naturally occurring manganese, the collected soil samples were subjected to a sequential geochemical digestion. This sequential digestion process involves exposing the sample to a series of progressively more aggressive digestants for specified time periods. The digestants are, in order of increasing aggressiveness, neutral salt exchange, acid extractable, organic fraction, amorphous iron oxide fraction, crystalline iron oxide fraction, and residual fraction. Following each step, the digestant is separated from the remaining solid and analyzed for manganese, providing a quantification of manganese in that phase. The remaining solid is then subjected to the next step in the sequence. Using this analysis, the leachability of the naturally occurring manganese can be measured. The leachability of manganese would also directly correlate with the mobility and bioavailability of the manganese in the aquifer. The table below summarizes the results of the sequential digestion of the four collected samples.

Manganese	IS21MW05		IS21MW06		IS21MW07		IS21MW08	
	Mn (ppm)	Mn (%)						
neutral salt exchange	7.34	2.7%	21.08	7.1%	52.34	20.9%	4.04	0.1%
acid extractable	14.37	5.4%	9.75	3.3%	19.48	7.8%	23.72	0.8%
organic fraction	1.46	0.5%	19.8	6.6%	4.8	1.9%	6.18	0.2%
amorphous iron oxide fraction	110.04	41.2%	28.68	9.6%	12.79	5.1%	81.51	2.7%
Crystalline iron oxide fraction	50.71	19.0%	29.96	10.0%	14.39	5.7%	117.27	3.9%
residual fraction	83.48	31.2%	188.93	63.4%	146.8	58.6%	2776.18	92.3%
Total Digest	267.4	100.0%	298.2	100.0%	250.6	100.0%	3008.9	100.0%

A review of the data indicated that the leachability of manganese is variable across the site, with significant amounts of leachable manganese in sample IS21MW05 and the least amounts of leachable manganese in sample IS21MW08. This suggests that the soil in the upgradient monitoring well IS21MW05 location would provide a prime leachable source of manganese. A further review of the table indicates that the most susceptible sample for manganese leaching (i.e., most manganese dissolved at the lowest digestant step) is from the

IS21MW07 location, with about 21% of the manganese being dissolved at the neutral salt exchange process step. This result correlates with the highest dissolved manganese concentration in groundwater detected at the site in the 2008 sampling events (about 6,000 µg/L in monitoring well IS21MW07 as shown on Figure 2).

Based on these analyses, manganese occurs at the site in various forms including as manganese-oxyhydroxide coatings on grains, which occur due to the natural dissolution, migration, and precipitation controlled by the natural geochemical processes. Sequential digestion results show that the leachability of manganese is variable across the site and may account for the variable dissolved manganese concentrations in groundwater. With an understanding that the material in the former landfill area is not preferentially enriched in manganese, the naturally occurring manganese in the soil and aquifer material represents the source of dissolved manganese in the groundwater.

Geochemical Conditions

To understand the geochemical conditions at the site, a review of the processes that affect the various geochemical parameters is provided below, after which the site specific parameters will be discussed.

Background

Most pristine coastal plain aquifers are biogeochemically controlled by microbial processes that impart a unique signature on the water as it migrates down gradient from the recharge area (Chapelle, 1992). This signature is the result of progressive consumption of available terminal electron acceptors (TEA) with the most oxidizing acceptors being consumed first. In general, the most oxidizing acceptor is oxygen, followed by iron and manganese, followed by sulfate, then carbon dioxide (methanogenesis). However, the use of any TEA by the aquifer microbial community is more based on concentration of that TEA than the mere presence or absence (Washington et al. 2004; 2006). Therefore, as the dissolved oxygen in aquifers that contain abundant bioavailable iron and manganese is depleted, the reduction of iron and manganese increases. In other words, these processes overlap as the concentration of dissolved oxygen decreases and falls to the point where bioavailable iron or manganese becomes the dominant TEA in the aquifer, with the result being that the concentration of dissolved iron or manganese increases.

In aquifer systems that contain low concentrations of dissolved oxygen (i.e., < 5 mg/L), the local bioavailability of iron and manganese as electron acceptors becomes the controlling factor. In general, the up gradient areas of recharge which only receive oxygen-saturated rainwater, tend to have the highest dissolved oxygen concentration and the lowest dissolved iron and manganese concentrations. As the water moves down gradient through the aquifer, oxygen is consumed and the concentration of dissolved iron and manganese increases (Chapelle, 1992).

In typical landfill situations, the geochemistry of the downgradient groundwater is distinctly different than the upgradient groundwater, caused by the biochemical processes associated with the landfill contents. Groundwater downgradient from landfills are depleted in oxygen, have low oxidation-reduction potential, and may have elevated anion concentrations (such as chloride). These groundwater conditions are spatially distinct (i.e.,

plume) and temporally consistent with only very minor changes as the groundwater geochemistry equilibrates with the landfill material.

Site Conditions

The Bronson Road landfill area is generally low in dissolved oxygen (Figure 7) and elevated in both dissolved iron and manganese (Figures 8 and 2, respectively). A review of the data shows that the dissolved oxygen and iron/manganese concentrations are variable across the site and are variable through time. The specific concentrations indicate that the dominant TEA processes in the area fall between oxygen reduction and iron/manganese reduction, with naturally elevated manganese concentrations anticipated in the downgradient area. The wells installed upgradient of the Bronson Road landfill (IS21MW04 and IS21MW05) are recharge points and as such generally have the highest dissolved oxygen and lowest dissolved iron and manganese concentrations. Wells installed downgradient of the Bronson Road landfill tend to exhibit lower dissolved oxygen and consequently have the highest dissolved iron and manganese concentrations. Variability in the actual manganese concentrations on the down gradient side of the landfill as observed in the well and the direct push data are due to heterogeneities in the manganese source material as previously discussed.

As discussed above, the dominant TEA is controlled by the concentration of the available electron acceptors. While the dissolved oxygen concentrations are relatively low in the Bronson Road Landfill groundwater well samples, the concentration of bioavailable iron and/or manganese is also variable as demonstrated in the sequential extraction digests. Therefore, in some wells, such as IS21MW07, which have a high concentration of bioavailable manganese in the solid phase, manganese reduction is likely the dominant TEA process even in the presence of measurable dissolved oxygen. Consequently, these wells tend to have elevated dissolved manganese. In contrast, although dissolved oxygen is low in wells such as IS21MW08, the concentration of dissolved oxygen may actually be higher than the concentration of bioavailable manganese as implicated by the sequential extraction data and therefore, the dissolved oxygen is still the dominant TEA.

The chloride concentrations and groundwater oxidation-reduction potentials are shown in Figures 9 and 7, respectively. These figures indicate variable concentrations across the site with no consistent difference between the up gradient and down gradient wells. These results indicate that the geochemical parameters are not typical of groundwater flowing through a landfill area.

Summary of Geochemical Analysis

The occurrence and distribution of manganese in the groundwater at the site is consistent with natural groundwater conditions and processes. Native soil constituents provide a natural source for the manganese, and the natural geochemical processes provide a mechanism to account for the dissolved manganese observed at the site. The geochemical conditions noted are inconsistent with that of a typical landfill situation, indicating that the material in the former landfill is not adversely affecting the groundwater conditions. It is noted that potential reductions in the dissolved oxygen content of the groundwater would result in a more iron/manganese dominated process, which results in elevated dissolved manganese concentrations.

6.0 Human Health Risk Assessment for Groundwater

The Indian Head Site 21 Baseline Human Health Risk Assessment, which was conducted as part of the RI completed in April 2004, concluded that there were potentially unacceptable noncarcinogenic hazards (hazard index [HI] above EPA's target HI of 1) to future adult and child residents using the shallow groundwater as a potable water supply from exposure to the manganese, iron, and thallium detected in the groundwater as summarized below (CH2M HILL, 2004):

Receptor	Land Use	Carcinogenic Risk		Noncarcinogenic Hazard	
		RME	CTE	RME	CTE
Resident (Child)	Future	1.2 × 10 ⁻⁶	NC	94	23
Resident (Adult)	Future			40	1.9

Notes:
 CTE = central tendency exposure
 RME = reasonable maximum exposure
 NC = not calculated

The risk estimates were calculated using the maximum detected concentrations in the groundwater samples due to the limited number of samples (only three groundwater samples were available) [CH2M HILL, 2004]. For example, the maximum concentration of total manganese of 23,100 µg/L detected in September 2000 from well IS21MW02 was used for the risk estimate calculation.

Risk assessment calculations were updated for noncarcinogenic hazard using more recent groundwater sample results, as well as current exposure factors, to calculate daily intake values. Iron and manganese groundwater sample data collected from five wells (IS21MW02, IS21MW03, IS21MW06, IS21MW 07, and IS21MW08) in August and November 2008 were used for the updated risk calculations. Sample location IS21MW01 was included in the human health risk assessment previously completed in 2004 (CH2M HILL, 2004); however, this well was not included in the updated sample data set as the well is not located along a flow path that goes through the landfill materials at the site.

Updated reasonable maximum exposure (RME) exposure point concentrations (EPCs) for iron and manganese were calculated as a 95 percent upper confidence limit (UCL) of the arithmetic mean of the data set, using ProUCL Version 4.0 (Singh, et al., 2007). The arithmetic mean of the dataset calculated using the same method that was used to calculate the 95 percent UCL was used as the central tendency (CTE) EPC. Attachment 5, Tables 3.1.RME and 3.1.CTE present the EPCs and the rationale for the selected EPC.

Exposure parameter values were also updated for this risk assessment. The skin surface areas and exposure/event time for the RME future resident were updated to current values presented in United States Environmental Protection Agency (EPA)'s Risk Assessment Guidance for Superfund (RAGS) Part E. The skin surface area for the adult was changed from 20,000 to 18,000 square centimeters (cm²) and for the child resident from 7,500 to 6,600

cm². The RME exposure/event time for the adult was changed from 12 minutes per event to 34 minutes per event. The RME exposure/event time for the child was changed from 20 minutes per event to 1 hour per event.

The risk assessment calculations are based on the assumption that future residents (including adults and children) would be exposed to shallow groundwater used as a potable water supply.

The updated noncarcinogenic hazards using the recent groundwater sampling data in August and November 2008 and the previous noncarcinogenic hazard calculated in CH2M HILL (2004) is summarized below.

Receptor	Land Use	Noncarcinogenic Hazard - Updated with 2008 Data		Noncarcinogenic Hazard - CH2M HILL (2004)	
		RME	CTE	RME	CTE
Resident (Child)	Future	23	5.4	94	23
Resident (Adult)	Future	9.6	2.2	40	1.9

Notes:
 CTE = central tendency exposure
 RME = reasonable maximum exposure
 NC = not calculated

The noncarcinogenic hazard for the adult resident shows the RME noncarcinogenic hazard (HI = 9.6) exceeds EPA's target HI of 1. Iron contributes an HI = 3.5 and manganese contributes an HI = 6.0 to the total RME HI. The CTE noncarcinogenic hazard (HI = 2.2) also exceeds EPA's target HI of 1. Iron contributes an HI = 1.0 and manganese contributes and HI = 1.2 to the total CTE HI. Additional detail regarding these calculations is presented in Attachment 5, Table 9.1.

The noncarcinogenic hazards for the child resident shows the RME noncarcinogenic hazard (HI = 23) exceeds USEPA's target HI of 1. Iron contributes an HI = 8.3 and manganese contributes an HI = 14 to the total RME HI. The CTE noncarcinogenic hazard (HI = 5.4) also exceeds EPA's target HI of 1. Iron contributes an HI = 1.6 and manganese contributes and HI = 3.8 to the total CTE HI. Additional detail regarding these calculations is presented in Attachment 5, Table 9.2.

Both iron and manganese are essential human nutrients. The recommended daily allowance (RDA) range of iron for children ages 6 month to 8 years is 7-11 mg/day (Institute of Medicine, 2005), and the RDA for adult males and females is 8-11 mg/day and 8-18 mg/day, respectively (EPA, January 1999). The tolerable upper intake level (UL) of iron for children ages 6 months to 8 years is 40 mg/day, and the UL for adult males and females is 45 mg/day. The average daily intake of iron for both a child and adult based on the RME EPC and standard exposure parameters (adult groundwater ingestion rate of 2 liters/day, child groundwater ingestion rate of 1 liter/day) would exceed the RDA ranges and the ULs.

Manganese is an essential human nutrient responsible for activating several enzymes (EPA, 2008). Disease states have been documented in humans associated with both deficiencies and excess intakes of manganese (EPA, 2008). The recommended daily allowance (RDA) range of manganese for children ages 6 month to 8 years is 0.6-1.5 mg/day (Institute of Medicine, 2005), and the RDA for adult males and females is 1.9-2.3 mg/day and 1.6-1.8 mg/day, respectively. The tolerable upper limit (UL) of manganese for children ages 1 year to 8 years is 2-3 mg/day, and the UL for adults is 6-11 mg/day. The average daily intake of manganese for both a child and adult based on the RME EPC groundwater concentration and standard exposure parameters (adult groundwater ingestion rate of 2 liters/day, child groundwater ingestion rate of 1 liter/day) would exceed the RDA ranges and the ULs.

Manganese concentrations in downgradient monitoring wells IS21MW02 and IS21MW07 were above the facility-wide background concentration (824 µg/L) typically by a factor of between 3X and 7X background. Groundwater concentrations of manganese within the other six monitoring wells were typically below the background concentration value of 824 µg/L.

7.0 Summary and Recommendations

7.1 Summary of Information and Interpretations

Groundwater Flow Conditions

Groundwater flow conditions at Site 21 from the August 2008 and November 2008 gauging events are similar to those noted in previous events with a groundwater flow direction toward the southwest and a hydraulic gradient of approximately 0.22 ft/ft.

Based on the groundwater contour maps, monitoring wells IS21MW04 and IS21MW05 are upgradient of the former landfill. Monitoring wells IS21MW02, IS21MW03, IS21MW07, and IS21MW08 are immediately downgradient from a groundwater flow path through the landfill area, whereas monitoring wells IS21MW01 and IS21MW06 area along groundwater flow paths that do not go through the landfill.

The fill associated with Site 21 extends below the groundwater table, which is confirmed with the installation of the piezometer (IS21PZ01) in the fill area. The groundwater flow conditions noted in August and November 2008 support the information that a significant portion of fill is below the groundwater table. The updated groundwater elevation information also demonstrates that perched groundwater conditions do not exist at the site.

Manganese Spatial and Temporal Distribution in Groundwater

The lowest manganese groundwater concentrations are detected in upgradient monitoring wells IS21MW04 and IS21MW05, and in monitoring well IS21MW01, which is hydraulically downgradient of the site boundary, but cross-gradient from the main filled area. Total manganese groundwater concentrations in these three monitoring wells are below both the background concentration (824 µg/L) and RSL-Tap Water (880 µg/L) concentration.

Manganese groundwater concentrations in three downgradient monitoring wells (IS21MW03, IS21MW06, and IS21MW08) located on the southern downgradient side of the site were below both the background concentration and RSL-Tap Water criteria, with the

exception of the November 2008 sampling event where the concentration was 1,680 µg/L at well IS21MW03.

Manganese groundwater concentrations in two downgradient wells (IS21MW02 and IS21MW07) located on the western downgradient side of the site were above the background and RSL-Tap Water criteria, with a maximum detection from the August and November 2008 sampling event of 6,110 µg/L (well IS21MW07).

Temporally, the overall trend for total manganese in groundwater at Site 21 is decreasing from the initial sampling event in September 2000 based on results from the individual wells and the average concentration for each event. The average concentration has decreased from 6,119 µg/L in September 2000 to 1,298 µg/L in November 2008.

Geochemical Analysis

The occurrence and distribution of manganese in the groundwater at the site is consistent with natural groundwater conditions and processes. Native soil constituents provide a natural source for the manganese, and the natural geochemical processes provide a mechanism to account for the manganese observed at the site. The geochemical conditions noted are inconsistent with that of a typical landfill situation, indicating that the material in the former landfill is not adversely affecting the groundwater conditions. It is noted that potential reductions in the dissolved oxygen content of the groundwater would result in a more iron/manganese dominated process, which results in elevated dissolved manganese concentrations.

Human Health Risk Assessment for Groundwater

The results of the updated human health risk assessment indicate that noncarcinogenic hazards are lower than previously estimated in the Site 21 Remedial Investigation (CH2M HILL, 2004) although both CTE and RME hazards are slightly above EPA’s target HI of 1 (under the CTE scenario). Note previous estimates of carcinogenic risk from groundwater exposure at Site 21 to future resident receptor were considered acceptable at 1.2×10^{-6} . The primary contributors to the HI are manganese and iron.

Receptor	Land Use	Noncarcinogenic Hazard - Updated with 2008 Data		Noncarcinogenic Hazard - CH2M HILL (2004)	
		RME	CTE	RME	CTE
Resident (Child)	Future	23	5.4	94	23
Resident (Adult)	Future	9.6	2.2	40	1.9

Notes:
 CTE = central tendency exposure
 RME = reasonable maximum exposure

In addition, the EPCs for manganese used in the updated assessment for both the CTE scenario (2,064 µg/L) and RME scenario (4,665 µg/L) are lower by almost an order of magnitude than the concentration used within the Remedial Investigation (23,100 µg/L)

based on the updated understanding of the distribution and concentration of manganese in groundwater at Site 21.

7.2 Recommendations

Based on the geochemical analysis presented in Section 5 above, the manganese in groundwater at Site 21 is consistent with natural groundwater conditions and processes. Native soil constituents provide a natural source for the manganese, and the natural geochemical processes provide a mechanism to account for the manganese observed at the site. Therefore, as identified within Section 1, no further action for groundwater at Site 21 is warranted based on the decision path defined during the April 2008 IHIRT meeting. As a conservative and protective measure consistent with a landfill setting, institutional controls are recommended for the groundwater at the landfill at Site 21.

The recommendations for remedial action decisions for all media at Site 21 and associated rationale are provided below:

- Groundwater - As identified above, no further action for groundwater is required based on the geochemical analysis indicating manganese in groundwater consistent with natural groundwater conditions and processes. Institutional controls for groundwater at the landfill at Site 21 are recommended as being appropriate for a landfill setting.
- Surface Soil - No further action is required. Estimation of human health risks (carcinogenic risks and noncarcinogenic hazards) from surface soil exposure in the Site 21 Remedial Investigation (CH2M HILL, 2004) are considered acceptable as summarized below. All RME estimates are below or within EPA's target range, with the exception of the future child resident where the RME noncarcinogenic hazard was 3.0 and the CTE noncarcinogenic hazard was 0.78. Furthermore, there were no individual constituents or target organ effects with HI greater than 1 under RME scenario for the future resident child (Arsenic at 1.0).

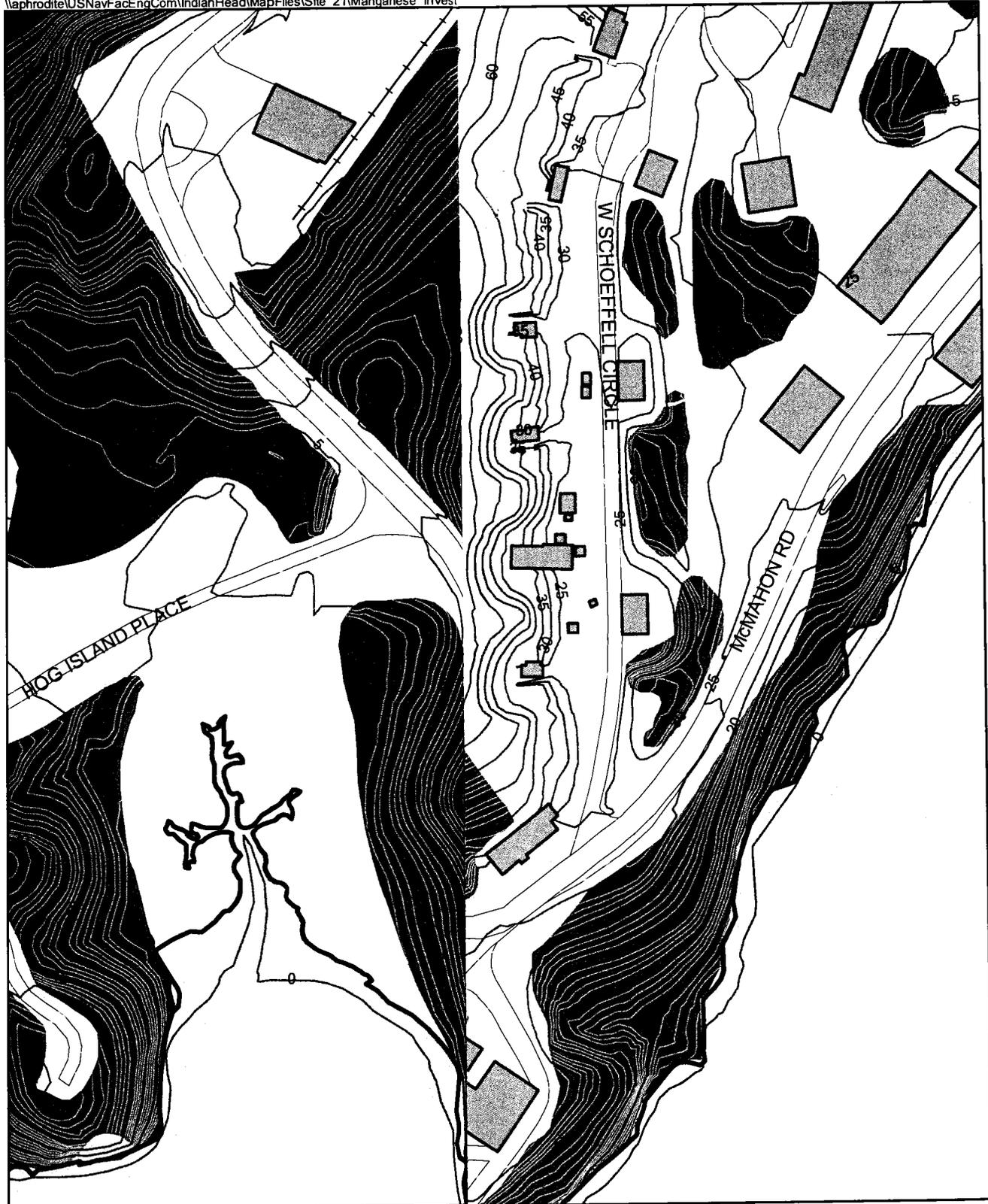
Receptor	Land Use	Surface Soil			
		Carcinogenic Risk		Noncarcinogenic Risk	
		RME	CTE	RME	CTE
Trespasser/Visitor (Adolescent)	Current/Future	1.4x10 ⁻⁶	NC	0.085	NC
Trespasser/Visitor (Adolescent)	Current/Future	2.9x10 ⁻⁶	NC	0.071	NC
Industrial Worker	Current/Future	1.8x10 ⁻⁵	NC	0.50	NC
Resident Child	Future	6.2x10 ⁻⁵	NC	3.0	0.78
Resident Adult	Future			0.65	NC
NC = not calculated; RME carcinogenic risk/noncarcinogenic hazard below/within EPA target level					

- Subsurface Soil – Institutional controls are recommended for the landfill area at Site 21.

8.0 References

- CH2M HILL, 2008. *Final Site 21 (Bronson Road Landfill) Manganese Investigation Work Plan*, CH2M HILL, July 16, 2008.
- CH2M HILL, 2006a. *Final Feasibility Study, Site 21, Bronson Road Landfill*. CH2M HILL. September 2006.
- CH2M HILL, 2006b. *Indian Head Site 21 – Potential Geochemical and Hydraulic Effects of a RCRA Subtitle C Cap at Site 21, Bronson Road Landfill*. December 19, 2006.
- CH2M HILL, 2006c. *Site 21 Manganese Investigation Results, NSF-IH, Indian Head, Maryland*, CH2M HILL, September 15, 2006.
- CH2M HILL, 2004. *Final Remedial Investigation Report, Sites 11, 13, 17, 21, and 25*. CH2M HILL. April 2004.
- EPA, January 1999. *Risk Assessment Issue Paper for Derivation of a Provisional RfD for Iron (CASRN 7439-89-6)*. National Center for Environmental Assessment. January 5, 1999.
- EPA. 2008. *Integrated Risk Information System Database*.
- Institute of Medicine, 2005. *Dietary Reference Intakes (DRIs): Recommended Intakes for Individuals, Elements*.
- Chapelle, F.H., 1992. *Ground-Water Microbiology and Geochemistry*. John Wiley and Sons. New York. 424 pp.
- Washington, J.W., Thomas, R.C., Endale, D.M., Schroer, K.L., Samarkina, L.P., 2006, Groundwater N speciation and redox control of organic N mineralization by O₂ reduction to H₂O₂. *Geochimica et Cosmochimica Acta*, v. 70, p. 3533 – 3548.
- Washington, J.W., Endale, D.M., Samarkina, L.P., Chappell, K.E., 2004, Kinetic control at thermo-buffered potentials in subsurface waters. *Geochimica et Cosmochimica Acta*, v. 68(23), p. 4831-4842.

Figures

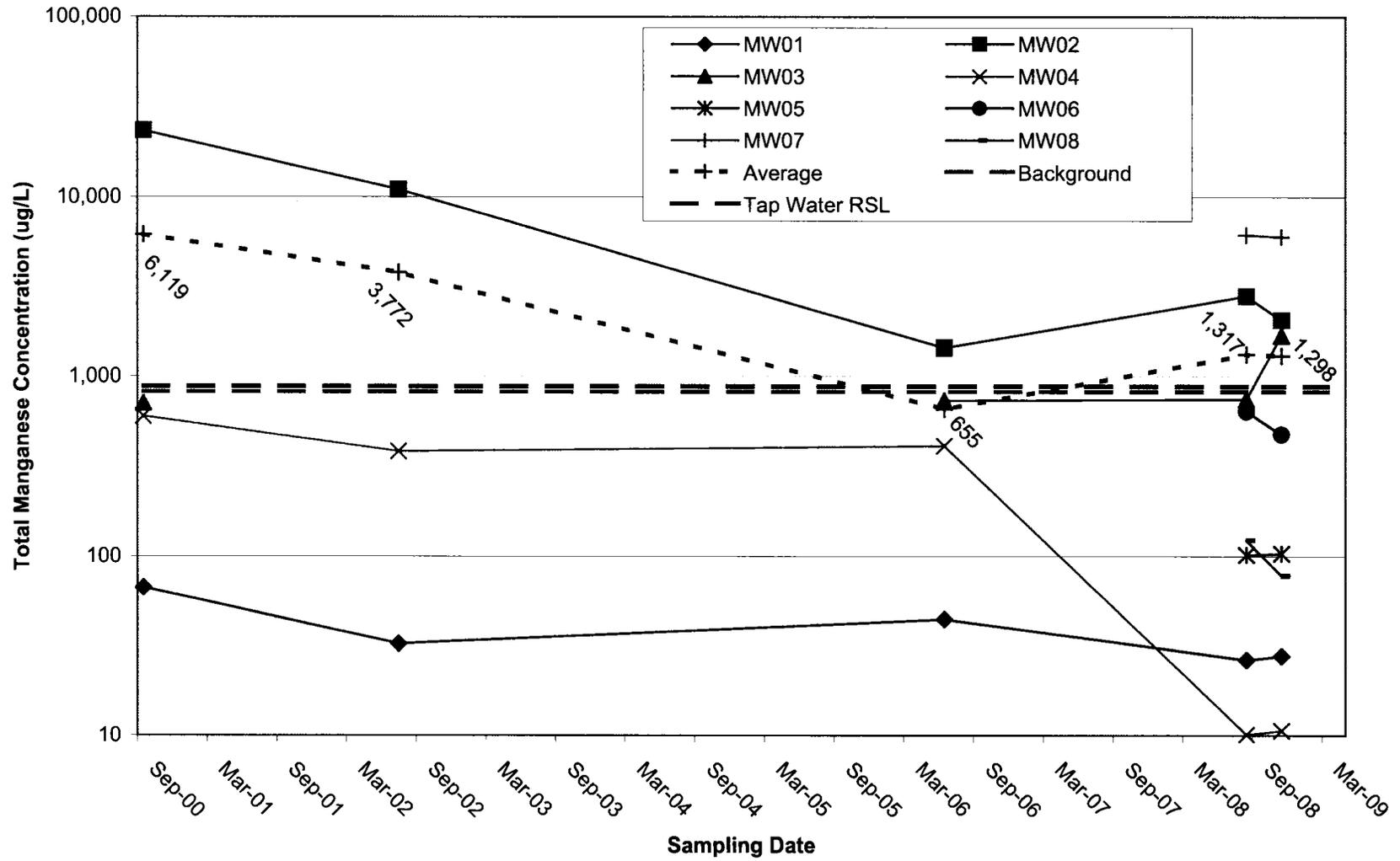


Legend

- | | |
|-------------------|------------------|
| ● Monitoring Well | + Railroad |
| ◆ Piezometer | ■ Buildings |
| — Contours (5ft) | ■ Wooded Area |
| — Contours (1ft) | □ Approximate |
| — Road | □ Installation E |

Figure 1
 Site 21 Monitoring Well/Piezometer Network
 Site 21 Manganese Investigation Technical Memo
 Indian Head, Maryland

Figure 3. Site 21 Monitoring Wells Manganese (Total) Concentrations



Tables

Table 1. Well Construction and Water Level Elevations, Site 21 Monitoring Well Network
 Site 21 Manganese Investigation
 Indian Head, Maryland

Location	Well Construction Information ¹										Water Level Measurements			
	Date Constructed	Diameter (inches)	Casing and Screen Material	Wellhead Completion	Ground Surface Elevation (ft-MSL)	TOC Elevation (ft-MSL)	Depth to Top of Screen (ft-bgs)	Depth to Bottom of Screen (ft-bgs)	Elevation at Top of Screen (ft-MSL)	Elevation at Bottom of Screen (ft-MSL)	August 11, 2008		November 5, 2008	
											DTW (ft-TOC)	Groundwater Elevation (ft-MSL)	DTW (ft-TOC)	Groundwater Elevation (ft-MSL)
IS21MW01	August 3, 2000	2	Sch. 40 PVC (0.010" slot)	Stickup	34.14	36.00	13	18	21.14	16.14	6.98	29.02	7.57	28.43
IS21MW02	August 4, 2000	2	Sch. 40 PVC (0.010" slot)	Stickup	43.65	45.33	15	20	28.65	23.65	16.69	28.64	16.51	28.82
IS21MW03	August 4, 2000	2	Sch. 40 PVC (0.010" slot)	Stickup	35.51	36.70	13	18	22.51	17.51	14.95	21.75	17.67	19.03
IS21MW04	August 3, 2000	2	Sch. 40 PVC (0.010" slot)	Stickup	76.59	78.36	42	48	34.59	28.59	39.79	38.57	40.25	38.11
IS21MW05	July 22, 2008	2	Sch. 40 PVC (0.010" slot)	Stickup	76.69	79.49	42	52	34.69	24.69	46.23	33.26	46.77	32.72
IS21MW06	July 24, 2008	2	Sch. 40 PVC (0.010" slot)	Stickup	37.29	40.46	9	19	28.29	18.29	16.58	23.88	19.11	21.35
IS21MW07	July 25, 2008	2	Sch. 40 PVC (0.010" slot)	Stickup	29.49	32.69	5	15	24.49	14.49	9.45	23.24	9.74	22.95
IS21MW08	July 25, 2008	2	Sch. 40 PVC (0.010" slot)	Stickup	33.45	36.70	14	24	19.45	9.45	14.15	22.55	14.62	22.08
IS21PZ01	July 24, 2008	2	Sch. 40 PVC (0.010" slot)	Stickup	47.31	50.58	14	24	33.31	23.31	20.02	30.56	20.39	30.19

Notes:

ft = feet

TOC = top of well casing

DTW = depth to water

MSL = mean sea level

bgs = below ground surface

¹ Survey performed on all monitoring wells/piezometers in August 2008

Table 2. Soil Samples for Analytical and Geochemical Laboratory Analysis (July 2008)
Site 21 Manganese Investigation
Indian Head, Maryland

Well Location	Sample ID	Sample Interval (ft-bgs)	Date Collected	Analytical Laboratory	Geochemical Laboratory		
				Iron and Manganese	X-Ray Diffraction	Electron Microprobe	Sequential Soil Digestion
IS21MW05	IS21MW05-4547	45 - 47	July 22, 2008	X	X	X	X
IS21MW06	IS21MW06-1719	17 - 19	July 24, 2008	X	X	X	X
IS21MW07	IS21MW07-0911	9 - 11	July 25, 2008	X	X	X	X
IS21MW08	IS21MW08-2224	22 - 24	July 25, 2008	X	X	X	X

Notes:

ft-bgs = feet below ground surface

**Table 3. Groundwater Sample Analyses (August and November 2008)
Site 21 Manganese Investigation
Indian Head, Maryland**

Well Location	Sample ID	Sample Date	Site 21 Manganese Investigation Analytes													Facility-Wide Groundwater Explosives Analytes			
			Total Major Cations: Iron, Manganese, Calcium, Magnesium, Sodium, and Potassium	Filtered (0.45 µm) Major Cations: Iron, Manganese, Calcium, Magnesium, Sodium, and Potassium	Filtered (0.10 µm) Major Cations: Iron, Manganese, Calcium, Magnesium, Sodium, and Potassium	Major Anions: Chloride, Nitrate, Nitrite, Sulfate, Fluoride, and Ortho-Phosphate	Alkalinity	Hardness	Sulfide	Total Dissolved Solids	pH	Total Kjeldahl Nitrogen	Ammonia	Total Organic Carbon	Dissolved Organic Carbon	Nitroaromatics /Nitramines	Nitroaromatics + Nitroguanidine	Perchlorate	
IS21MW01	IS21MW010808	August 5, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
	IS21MW010808A				X														
	IS21MW011108	November 5, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
IS21MW020808	August 5, 2008		X	X		X	X	X	X	X	X	X	X	X	X				
IS21MW02		IS21MW020808A	November 5, 2008	X	X		X	X	X	X	X	X	X	X	X	X			
	IS21MW021108				X														
	IS21MW030808	August 5, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
IS21MW030808A				X															
IS21MW03	IS21MW031108	November 6, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
	IS21MW031108A				X														
	IS21MW040808	August 6, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
IS21MW040808A				X															
IS21MW04	IS21MW041108	November 6, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
	IS21MW041108A				X														
	IS21MW050808	August 6, 2008	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X	X
IS21MW050808P (Duplicate)				X															
IS21MW050808A				X															
IS21MW05	IS21MW051108	November 7, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
	IS21MW051108A				X														
	IS21MW060808	August 6, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
IS21MW060808A				X															
IS21MW06	IS21MW061108	November 6, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
	IS21MW061108A				X														
	IS21MW070808	August 5, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
IS21MW070808P (Duplicate)				X															
IS21MW070808A				X															
IS21MW07	IS21MW070808AP (Duplicate)	November 6, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
	IS21MW071108				X														
	IS21MW071108P				X														
IS21MW08	IS21MW071108AP	August 4, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
	IS21MW080808				X														
	IS21MW080808A				X														
IS21MW08	IS21MW081108	November 6, 2008	X	X		X	X	X	X	X	X	X	X	X	X				
	IS21MW081108A				X														

- Notes:**
- Sample IDs containing an "A" as in "IS21MW010808A" represent the filtered Major Cations fraction at 0.10 micron (µm)
 - Sample IDs containing a "P" on the end as in "IS21MW0808P" represent a duplicate sample
 - As discussed in the Work Plan (CH2M HILL, 2008a), the analysis of explosives was identified for new upgradient monitoring well IS21MW05 to provide facility-wide groundwater explosives data unrelated to the objectives of the Site 21 Manganese Investigation. No further discussion of the explosives results is provided in this technical memo.

**Table 4. Soil Sample Analytical Results (July 2008)
Site 21 Manganese Investigation
Indian Head, Maryland**

Station ID	IS21MW05	IS21MW06	IS21MW07	IS21MW08	
Sample ID	IS21MW054547	IS21MW061719	IS21MW070911	IS21MW082224	IS21MW082224P
Sample Date	07/22/08	07/24/08	07/25/08	07/25/08	07/25/08
Chemical Name					
Total Metals (MG/KG)					
Iron	19,100 J	18,900 J	5,650 J	26,200 J	29,300 J
Manganese	189 L	120 L	95.8 L	1,610 L	1,700 L

Notes:

- J - Analyte present, value may or may not be accurate or precise
- L - Analyte present, value may be biased low, actual value may be higher
- MG/KG - Milligrams per kilogram
- NA - Not analyzed

**Table 5. Water Quality Parameters (November 2008)
Site 21 Manganese Investigation
Indian Head, Maryland**

Well ID	IS21MW01	IS21MW02	IS21MW03	IS21MW04	IS21MW05	IS21MW06	IS21MW07	IS21MW08	IS21PZ01
Sample ID	IS21MW011108	IS21MW021108	IS21MW031108	IS21MW041108	IS21MW051108	IS21MW061108	IS21MW071108	IS21MW081108	IS21PZ010808
Sample Date	11/5/08	11/5/08	11/06/08 ¹	11/6/08	11/7/08	11/06/08 ¹	11/6/08	11/6/08	8/6/2008 ²
Field Parameter Data									
Dissolved Oxygen (mg/L)	1.9	1.98	1.6	3.93	4.5	3.4	0.89	2.69	8.49
Depth to Water (ft-bgs)	8.3	17.4	19.0	40.34	47.1	19.8	9.82	17.2	20.2
Oxidation Reduction Potential (millivolts)	339.8	60.2	-12.6	133.3	188	247.2	-23.5	205.2	-53
Flow Rate (gallons per minute)	0.09	0.03	0.04	0.06	0.05	0.04	0.04	0.03	0.053
Total Gallons	5	2.5	2	5	4	1.5	4	2	4
pH	4.65	5.89	5.75	6.18	5.67	5.18	6.09	5.11	5.4
Specific Conductance (millisiemens per centimeter)	0.168	0.509	1.27	0.586	0.386	0.615	0.787	0.162	1.05
Temperature (°Celsius)	20.64	23.79	21.8	20.88	22.15	19.7	19.19	20.8	19.4
Turbidity (Nephelometric turbidity units)	8.1	43.3	1087.2	37.3	72.7	25.5	104	48.8	14.9

Notes:

mg/L = milligrams per Liter

ft-bgs = feet below ground surface

¹ Well went dry during purging; sample collected following day after recharge

² Groundwater Sample was not collected from piezometer IS21PZ01 for Site 21 Manganese Investigation parameters. Sample was collected to evaluate potential presence of Agent Orange-related constituents as agreed with IHIRT in July 2008. Additional discussion regarding the Agent Orange-related constituents will be provided in a separate technical memo.

Table 6. Groundwater Sampling Analytical Results (August and November 2008)
Site 21 Manganese Investigation
Indian Head, Maryland

Station ID	IS21MW01				IS21MW02				IS21MW03				IS21MW04				IS21MW05		
Sample ID	IS21MW010808	IS21MW010808A	IS21MW011108	IS21MW011108A	IS21MW020808	IS21MW020808A	IS21MW021108	IS21MW021108A	IS21MW030808	IS21MW030808A	IS21MW031108	IS21MW031108A	IS21MW040808	IS21MW040808A	IS21MW041108	IS21MW041108A	IS21MW050808A	IS21MW050808	IS21MW050808D
Sample Date	08/05/08	08/05/08	11/05/08	11/05/08	08/05/08	08/05/08	11/05/08	11/05/08	08/05/08	08/05/08	11/06/08	11/06/08	08/06/08	08/06/08	11/06/08	11/06/08	08/06/08	08/06/08	08/06/08
Chemical Name																			
Total Metals (UG/L)																			
Calcium	2,540 J	NA	2,540 J	NA	0,120	NA	11,900	NA	15,800	NA	42,600	NA	2,890	NA	1,800	NA	NA	597 B	NA
Iron	175 B	NA	455 B	NA	89,100	NA	11,000	NA	1,310	NA	35,100	NA	380	NA	1,200	NA	NA	NA	NA
Magnesium	1,830 J	NA	1,840 J	NA	8,310	NA	10,200	NA	16,800	NA	68,200	NA	1,000	NA	1,000	NA	NA	NA	NA
Manganese	28.2	NA	27.8	NA	2,780	NA	2,640	NA	780	NA	1,680	NA	10.1 B	NA	10.6 B	NA	NA	NA	NA
Potassium	1,890 J	NA	2,210 J	NA	4,540 J	NA	4,890 J	NA	2,180 J	NA	12,900 J	NA	10,800 J	NA	1,800 J	NA	NA	NA	NA
Sodium	20,200	NA	21,800	NA	82,300	NA	84,100	NA	42,700	NA	80,500	NA	84,600	NA	120,000	NA	NA	NA	NA
Dissolved Metals (UG/L)																			
Calcium	2,940 J	2,810 J	2,800 J	2,800 J	8,900	8,850	11,900	12,000	12,300	12,500	12,600	12,600	2,800 J	2,190 B	2,100 J	1,040 B	458 B	817 J	NA
Iron	8.5 U	8.5 U	17.7 U	14.1 B	1,900	1,700	1,700	1,270	280	32.3	1,900	16,800	17.8 B	8.5 U	27.6 J	9.7 U	8.5 U	26.3 B	NA
Magnesium	1,820 J	1,740 J	1,810 J	1,730 J	8,930	7,900	10,800	10,500	16,100	17,100	20,000	20,000	1,100	1,100	2.6 B	NA	NA	NA	NA
Manganese	25.2	24.4	25.2	25.2	2,470	2,400	2,470	2,440	730	1,500	1,500	1,500	10.1 B	10.6 B	10.6 B	NA	NA	NA	NA
Potassium	2,240 J	2,240 J	2,810 J	2,840 J	4,780	4,840 J	5,000 J	5,070	2,300 J	2,600	12,900	12,900	10,800	10,800	1,800	NA	NA	NA	NA
Sodium	20,000	19,900	21,000	22,000	82,800	81,000	83,800	83,800	43,300	48,800	80,600	80,600	84,600	84,600	110,000	110,000	110,000	110,000	110,000
Wet Chemistry (MGL)																			
Alkalinity	10 U	NA	10 U	NA	77.8	NA	62	NA	10 U	NA	11.8	NA	NA	NA	10.3	NA	NA	NA	NA
Ammonia	0.1 U	NA	0.4	NA	0.1 U	NA	0.1 U	NA	NA	NA	0.1 U								
Chloride	37.2	NA	37	NA	80.7	NA	70	NA	80.4	NA	100	NA	80.8	NA	80	NA	NA	NA	47.3
Dissolved organic carbon	5 U	NA	8.1	NA	8.7	NA	8.6	NA	5 U	NA	11	NA	5 U	NA	5 U	NA	NA	NA	5 U
Fluoride	0.2 U	NA	0.5 U	NA	0.2 U	NA	0.5 U	NA	0.2 U	NA	0.5 U	NA	0.2 U	NA	0.5 U	NA	NA	NA	0.2 U
Hardness	18.6	NA	18.7	NA	16.7	NA	16.8	NA	18.6	NA	27.8	NA	18.8	NA	18.2	NA	NA	NA	5 U
Nitrate	0.05 U	NA	0.25 U	NA	0.05 U	NA	0.25 U	NA	0.05 U	NA	0.05 U	NA	0.05 U	NA	0.25 U	NA	NA	NA	0.05 U
Nitrite	0.05 U	NA	0.25 U	NA	0.05 U	NA	0.25 U	NA	0.05 U	NA	0.25 U	NA	0.05 U	NA	0.25 U	NA	NA	NA	0.05 U
Orthophosphate	NA	NA	0.25 U	NA	NA	NA	0.25 U	NA	NA	NA	0.25 U	NA	NA	NA	0.25 U	NA	NA	NA	NA
Phosphate	0.05 U	NA	NA	NA	0.05 U	NA	NA	NA	0.05 U	NA	NA	NA	0.05 U	NA	NA	NA	NA	NA	0.05 U
Sulfate	8.8	NA	18 J	NA	27.3	NA	27	NA	21.2	NA	36	NA	14.8	NA	15.1	NA	NA	NA	18.8
Sulfide	1 U	NA	0.8 J	NA	1 U	NA	NA	NA	1 U										
Total Kjeldahl nitrogen	0.25 U	NA	0.804	NA	0.821	NA	1.32	NA	0.18 J	NA	1.12	NA	0.25 U	NA	1.00	NA	NA	NA	0.25 U
Total dissolved solids (TDS)	129	NA	162	NA	248	NA	275	NA	280	NA	385	NA	280	NA	280	NA	NA	NA	284
Total organic carbon (TOC)	5 U	NA	5 U	NA	3.70 J	NA	3.8 J	NA	5 U	NA	NA	NA	5 U						
pH	8.2	NA	8.26	NA	7.4	NA	8.42	NA	8.17	NA	8.08	NA	7.87	NA	8.80	NA	NA	NA	7.96

Notes:
 B - Analyte not detected above the level reported in blanks
 J - Analyte present, value may or may not be accurate or precise
 K - Analyte present, value may be biased
 High, actual value may be lower
 L - Analyte present, value may be biased low, actual value may be higher
 MGL - Milligrams per liter
 NA - Not analyzed
 U - The material was analyzed for, but not detected
 UGL - Micrograms per liter
 UL - Analyte not detected, quantitation limit is probably higher
 Reading indicates detection

1. Sample IDs containing an "A" as in "IS21MW010808A" represent the filtered Major Cations fraction at 0.10 micron (µm)

Table 6. Groundwater Sampling Analytical Results (August and November 2008)
 Site 21 Manganese Investigation
 Indian Head, Maryland

Station ID Sample ID Sample Date	IS21MW06						IS21MW07						IS21MW08					
	IS21MW051108 11/07/08	IS21MW051108A 11/07/08	IS21MW060808 08/06/08	IS21MW060808A 08/06/08	IS21MW061108A 11/06/08	IS21MW061108 11/16/08	IS21MW070808A 08/05/08	IS21MW070808 08/05/08	IS21MW070808P 08/05/08	IS21MW070808AP 08/05/08	IS21MW071108 11/06/08	IS21MW071108A 11/06/08	IS21MW071108AP 11/06/08	IS21MW071108P 11/06/08	IS21MW080808A 08/04/08	IS21MW080808 08/04/08	IS21MW081108A 11/06/08	IS21MW081108 11/06/08
Chemical Name																		
Total Metals (UG/L)																		
Calcium	979 J	NA	18,700	NA	NA	20,000	NA	23,100	32,900	NA	33,000	NA	NA	18,700	NA	1,100	NA	7,770
Iron	4,360	NA	1,280	NA	NA	1,200	NA	23,800	23,400	NA	32,200	NA	NA	7,200	NA	300	NA	151
Magnesium	966 J	NA	91,900	NA	NA	13,100	NA	16,100	16,000	NA	16,200	NA	NA	16,000	NA	4,200 J	NA	6,600
Manganese	703	NA	838	NA	NA	875	NA	8,030	8,110	NA	5,640	NA	NA	6,670	NA	120	NA	77.8
Potassium	808 J	NA	8,880 J	NA	NA	10,190 J	NA	3,890 J	3,980 J	NA	3,480 J	NA	NA	4,770 J	NA	2,810 J	NA	2,910 J
Sodium	74,200	NA	88,100	NA	NA	72,800	NA	77,180	75,800	NA	79,800	NA	NA	48,700	NA	11,800	NA	53,800
Dissolved Metals (UG/L)																		
Calcium	508 J	502 U	18,600	17,000	18,200	18,900	87,100	34,200	34,200	37,000	37,100	32,000	32,200	38,100	16,700	6,810	7,800	7,800
Iron	17.7 U	9.7 U	73 B	8.5 U	9.7 U	36.2 J	340	23,800	23,800	1,710	26,800	4,400	11,800	33,200	8.5 U	210	170	211
Magnesium	438 J	438 J	11,900	11,100	12,400	12,600	16,300	18,800	18,400	15,700	15,900	10,000	10,000	14,200	6,270	4,000 J	1,800	8,870
Manganese	58.2	60.9	801	853	442	462	8,890	8,200	8,200	3,200	3,400	3,800	3,800	5,500	820	100	78.3	18.4
Potassium	739 J	782 J	10,700 J	10,800 J	11,300 J	11,500 J	4,220 J	4,350 J	4,550 J	4,270	3,820	3,820	3,820	4,790 J	4,200 J	2,710 J	4,770 J	4,810 J
Sodium	67,900	80,300	67,200	85,900	74,700	68,100	76,000	74,800	78,200	78,000	78,500	62,700	62,700	73,800	11,800	11,000	12,400	13,800
Wet Chemistry (MG/L)																		
Alkalinity	68.3	NA	18.4	NA	NA	51.8	NA	130	134	NA	150	NA	NA	100	NA	21.7	NA	12.8
Ammonia	0.1 U	NA	0.1 U	NA	NA	0.1 U	NA	0.60	0.1 U	NA	0.30	NA	NA	6.70	NA	0.1 U	NA	0.1 U
Chloride	63	NA	115	NA	NA	130	NA	123	151	NA	100	NA	NA	100	NA	26.8	NA	30
Dissolved organic carbon	5 U	NA	2.07 J	NA	NA	2.8 J	NA	2.84 J	2.89 J	NA	11	NA	NA	11	NA	5 U	NA	3.8
Fluoride	0.5 U	NA	0.2 U	NA	NA	0.5 U	NA	0.2 U	0.2 U	NA	0.5 U	NA	NA	0.5 U	NA	0.2 U	NA	0.5 U
Hardness	4.72 J	NA	145	NA	NA	102	NA	231	227	NA	307	NA	NA	182	NA	44.3	NA	30.9
Nitrate	0.62	NA	1.5	NA	NA	1.8	NA	0.05 U	0.05 U	NA	0.25 U	NA	NA	0.25 U	NA	0.705	NA	1.07
Nitrite	0.25 UL	NA	0.05 U	NA	NA	0.25 U	NA	0.05 U	0.05 U	NA	0.25 U	NA	NA	0.25 U	NA	0.05 U	NA	0.25 U
Orthophosphate	0.25 UL	NA	NA	NA	NA	0.25 U	NA	NA	NA	NA	0.25 U	NA	NA	0.25 U	NA	NA	NA	0.25 U
Phosphate	NA	NA	0.05 U	NA	NA	NA	NA	0.05 U	0.05 U	NA	NA	NA	NA	NA	NA	0.05 U	NA	NA
Sulfate	11 L	NA	36.3	NA	NA	80	NA	31.5	33.4	NA	30	NA	NA	30	NA	12.2	NA	10.3
Sulfide	0.8 K	NA	1 U	NA	NA	1 U	NA	1 U	1 U	NA	1 U	NA	NA	1 U	NA	1 U	NA	1.2
Total Kjeldahl nitrogen	1.63 K	NA	0.263	NA	NA	1.80	NA	0.798	0.768	NA	1.40	NA	NA	2.25	NA	0.25 U	NA	1.00
Total dissolved solids (TDS)	222	NA	364	NA	NA	364	NA	463	463	NA	381	NA	NA	380	NA	176	NA	100
Total organic carbon (TOC)	5 U	NA	2.55 J	NA	NA	5 U	NA	2.91 J	2.84 J	NA	2.4 J	NA	NA	2.8 J	NA	5 U	NA	2.4 J
pH	6.25	NA	6.33	NA	NA	6.00	NA	7.38	8.81	NA	8.38	NA	NA	8.05	NA	7.94	NA	8.30

Notes:
 B - Analyte not detected above the level reported in blanks
 J - Analyte present, value may or may not be accurate or precise
 K - Analyte present, value may be biased high, actual value may be lower
 L - Analyte present, value may be biased low, actual value may be higher
 MG/L - Milligrams per liter
 NA - Not analyzed
 U - The material was analyzed for, but not detected
 UG/L - Micrograms per liter
 UL - Analyte not detected, quantitation limit is probably higher
 Missing indicates detection

1. Sample IDs containing an "A" as in "IS21MW060808A" represent the filtered Major Cations Fraction at 0.10 micron (µm)

Attachment 1 – Soil Boring Logs



PROJECT NUMBER
358174

BORING NUMBER
IS21MW05

SOIL BORING LOG

PROJECT : Indian Head Site 21

LOCATION : Indian Head, MD

ELEVATION :

DRILLING CONTRACTOR : Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : 4.25" Hollow Stem Auger

WATER LEVELS :

START : 7/22/2008

END : 7/22/2008

LOGGER : A.Bogdanski

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)		RECOVERY (IN)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	USCS	COMMENTS
	0 - 4	44"						
	4 - 8	48"						
4	0 - 4	44"			NA	0-8" Topsoil , dry 8"-17" Fill , black, 10YR 3/1, f-c grained sand, loose, dry 17"-44" Silt , yellowish brown 10YR 5/6 becoming strong brown 7.5YR 5/8 @34", dense, hard, dry	ML	PID = 0
8	4 - 8	48"			NA	4-7' Same as above 7-8' Same as above , except 5YR 4/6	ML	PID = 0
12	8 - 12	48"			NA	8-12' Same as above	ML	PID = 0
15	12 - 15	36"			NA	12-15' Silt , strong brown, 7.5YR 5/8, dense, non-plastic, some sand (10%) @ 14', dry	ML	PID = 0
19	15-19	42"			NA	15-16' Same as above 5/8, dense, f-m grained sand, non plastic fines, dry	ML SM	PID = 0
23	19-23	30"			NA	19-21.5' Silty Sand , brownish yellow, 10YR 6/8, f-m grained, loose to dense, few plastic silty laminations, moist	SM	PID = 0
	23-25	24"			NA	23-25' Gravelly Sand , brownish yellow, 10YR 6/8, f-m grained, dense, moist, gravel Sub-angular up to 1" diameter	SW	PID = 0

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)		RECOVERY (IN)	#/TYPE	STANDARD	SOIL DESCRIPTION	USCS	COMMENTS
	PENETRATION				TEST RESULTS	SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.		
	6"-6"-6" (N)							
25					NA			
26	25-26	12"			NA	25-26' Sandy gravel , brownish yellow, 10YR 6/8, sub angular gravel up to 1", f-m grained	GP	PID = 0
	26-29	NA			NA	Note: Macrocore sampling difficult due to cobbles. Augering advanced to 29' and		
29								
	29-33	36"			NA	29-31.5' Same as above 31.5-32' Silty Gravel , sub angular up to 1" diameter, dense, slightly plastic fines, dry		PID = 0
33								
	33-35	24"			NA	33-33.67' Same as above 33.67-34.6' Silty Sand , strong brown, 7.5 YR 5/8, f-m grained, dense, dry		PID = 0
35						34.6-35' Sandy Clay , 7.5 YR 5/8, stiff, plastic, dry		
	35-39	36"			NA	35-38' Gravelly Sand , yellow, 10YR 7/6, f-m grained, sub angular gravel up to 1.5" diameter, moist		PID = 0
39								
	39-43	36"			NA	39-40.67' Silty Sand , yellowish brown, 10YR 5/6, f-m grained, dense, moist 40.67-42.67, Sandy Gravel , yellowish brown, 10YR 5/6, sub angular up to 1", f-m grained, wet		PID = 0
43								
	43-47	36"			NA	43-46' Silty Sand , brownish yellow, 10YR 6/6, f-m grained, non plastic, dense, some sub angular gravel up to .5" (10%), wet		PID = 0
47								
	47-51	48"			NA	47-47.33' Same as above 47.33-48' Gravel , sub angular up to 1", some silt, wet 48-51' Silty Sand , yellow, 10YR 7/6, f-m grained, non plastic, dense, wet		PID = 0
51	End of Boring							



PROJECT NUMBER 358174	BORING NUMBER IS21MW07
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SOIL BORING LOG

PROJECT : Indian Head Site 21	LOCATION : Indian Head, MD
ELEVATION :	DRILLING CONTRACTOR : Parratt Wolff
DRILLING METHOD AND EQUIPMENT USED : 4.25" Hollow Stem Auger	
WATER LEVELS :	START : 7/24/2008 END : 7/25/2008 LOGGER : A.Bogdanski

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)		RECOVERY (IN)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	USCS	COMMENTS
	INTERVAL (FT)							
	RECOVERY (IN)	#/TYPE						
0 - 4	40"			NA	0-3" Topsoil , organics, rootlets 3-40" Silty Sand , yellowish brown, 10YR 5/8, f-m grained, dense, sub rounded gravel up to 1", dry to moist @ 30"		PID = 0	
4 - 8	24"			NA	4-5.0' Silty Sand , yellowish brown, 10YR 5/6, f-m grained, dense, sub rounded gravel up to 1",		PID = 0	
8 - 10	12"			NA	8-9.0' Same as above		PID = 0	
10 - 14	48"			NA	10-12.5' Same as above 12.5-14' Clayey Silt , yellowish brown, 10YR 5/6, soft to dense, plastic, moist to dry		PID = 0	
14 - 18	48"			NA	14-17.25' Clay , gray, 10YR 6/1, very stiff, slightly plastic, dry 17.25-18' Clayey Silt , greenish gray, 5/5 GY, very stiff, slightly plastic, dry		PID = 0	
18	End of Boring							



PROJECT NUMBER
358174

BORING NUMBER
IS21PZ01

SOIL BORING LOG

PROJECT : Indian Head Site 21

LOCATION : Indian Head, MD

ELEVATION :

DRILLING CONTRACTOR : Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : 4.25" Hollow Stem Auger

WATER LEVELS :

START : 7/23/2008

END : 7/23/2008

LOGGER : A.Bogdanski

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)		RECOVERY (IN)	#/TYPE	STANDARD PENETRATION TEST RESULTS 6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	USCS	COMMENTS
	0 - 4	40"						
4	0 - 4	40"			NA	0-6" Topsoil , dry 6"-40" Clay , light olive brown, 2.5Y 5/3, stiff, plastic, dry, some gravel up to 1" diameter		PID = 0
8	4 - 8	8"			NA	4-4.67' Silt (Fill) , dark gray, 2.5Y 4/1, soft, plastic, moist, pieces of glass mixed in		PID = 0
12	8 - 12	30"			NA	8-8.83' Same as above 8.83-9.0' Fill , pieces of wood 9.0-9.5' Clay (Fill) , dark gray, 2.5Y 4/1, stiff, plastic, dry 9.5-9.6' Fill , pieces of wood 9.6-10.5' Silt (Fill) , brown, 10YR 5/3, stiff, plastic, few sub rounded gravel up to .5"		PID = 0
16	12 - 16	27"			NA	12-12.9' Silt (Fill) , dark gray, 2.5Y 4/1, soft, plastic, moist 12.9-13.6' Same as above , except 10YR 3/1 13.6-14.25' Silt , yellowish brown, 10YR 5/6, hard, dense, 5% rounded gravel up to 1"		PID = 0
20	16-20	24"			NA	16-17' Silt , strong brown, 7.5 YR 5/6, dense, plastic, 10% sub rounded gravel up to 1" diameter, wet 17-18' Sandy Gravel , light yellowish brown, 2.5Y 6/4, sub rounded gravel up to 1" diameter, f-c grained sand, dense, wet		PID = 0
24	20-24	36"			NA	20-20.5' Same as above 20.5-23' Silty Sand , brownish yellow, 10YR 6/8, f-c grained, slightly plastic, wet		PID = 0
26	24-26	24"			NA	24-26' Clay , light yellowish brown, 2.5Y 6/3, mottles 10YR 5/8, very stiff, plastic, dry		PID = 0
26	End of Boring							

Attachment 2 – Well Construction Diagrams



PROJECT NUMBER

358174

WELL NUMBER

IS21MW05

WELL COMPLETION DIAGRAM

PROJECT : Indian Head Site 21

LOCATION : Indian Head, MD

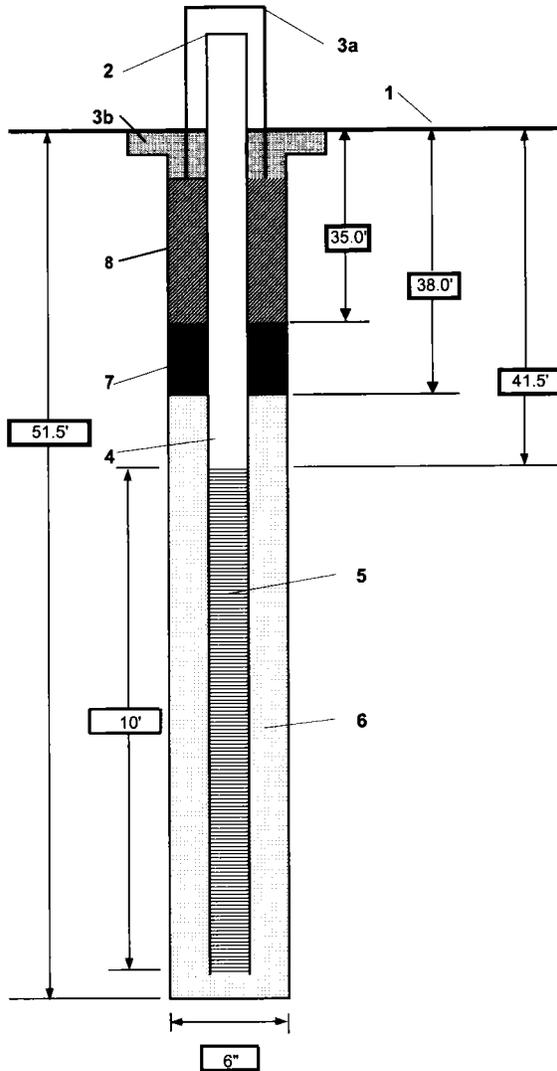
DRILLING METHOD AND EQUIPMENT USED : 4 1/4" HSA

DRILLING CONTRACTOR : Parratt Wolff

START : 7/22/08

END : 7/22/08

GEOLOGIST : A. Bogdanski



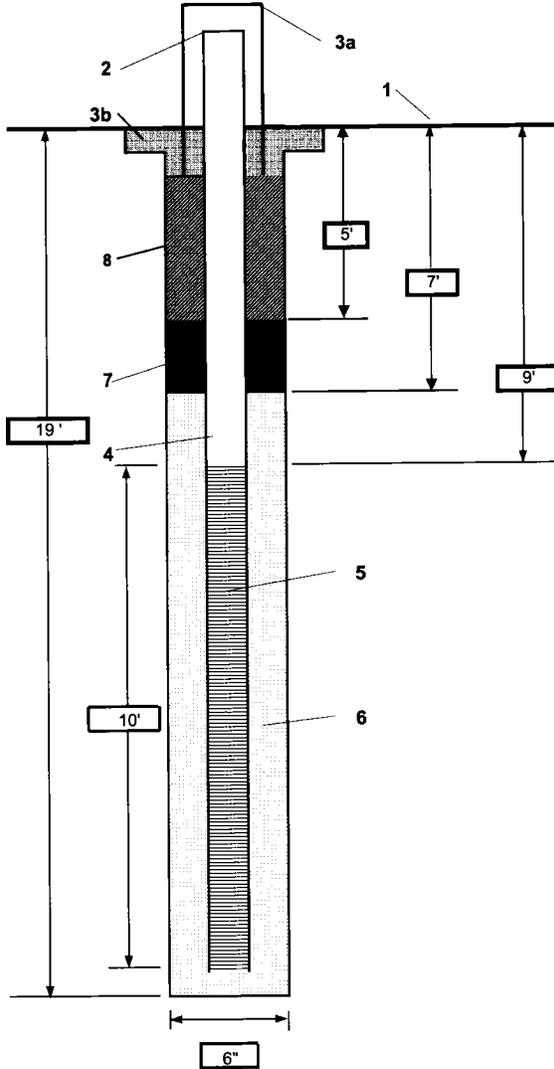
1- Ground elevation at well	76.69' above MSL
2- Top of casing elevation	79.49' above MSL
3- Wellhead protection cover type	J-plug well cap
a) Dia./type of outer casing	4" square steel casing
b) Concrete pad dimensions	2' diameter x 6" deep
4- Dia./type of inner well casing	2" I.D. Sch 40 PVC
5- Type/slot size of screen	2" I.D. PVC Screen (0.010" slot)
6- Type screen filter	#1 Sand
7- Type of seal	Bentonite chips (3/8")
a) Quantity used	1 - 50lb bag
8- Grout	Cement/bentonite grout mix
a) Grout mix used	
Development method	Pump/Surge
Development time	40 Minutes
Estimated purge volume	Approx 15 gal



PROJECT NUMBER 358174 WELL NUMBER IS21MW06

WELL COMPLETION DIAGRAM

PROJECT : Indian Head Site 21
 LOCATION : Indian Head, MD
 DRILLING METHOD AND EQUIPMENT USED : 4 1/4" HSA
 DRILLING CONTRACTOR : Parratt Wolff START : 7/24/08 END : 7/24/08 GEOLOGIST : A. Bogdanski



1- Ground elevation at well	<u>37.29' above MSL</u>
2- Top of casing elevation	<u>40.46' above MSL</u>
3- Wellhead protection cover type	<u>J-plug well cap</u>
a) Dia./type of outer casing	<u>4" square steel casing</u>
b) Concrete pad dimensions	<u>2' diameter x 6" deep</u>
4- Dia./type of inner well casing	<u>2" I.D. Sch 40 PVC</u>
5- Type/slot size of screen	<u>2" I.D. PVC Screen (0.010" slot)</u>
6- Type screen filter	<u>#1 Sand</u>
7- Type of seal	<u>Bentonite chips (3/8")</u>
a) Quantity used	<u>1 - 50lb bag</u>
8- Grout	
a) Grout mix used	<u>Cement/bentonite grout mix</u>
Development method	<u>Pump/Surge</u>
Development time	<u>Approx 40 Minutes</u>
Estimated purge volume	<u>Approx 15 gal</u>



PROJECT NUMBER

358174

WELL NUMBER

IS21MW07

WELL COMPLETION DIAGRAM

PROJECT : Indian Head Site 21

LOCATION : Indian Head, MD

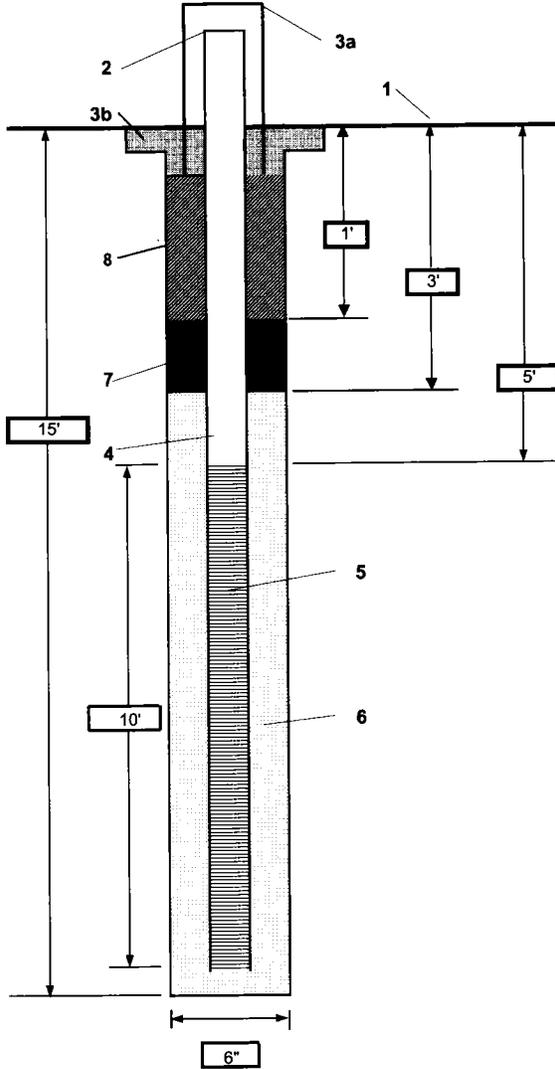
DRILLING METHOD AND EQUIPMENT USED : 4 1/4" HSA

DRILLING CONTRACTOR : Parratt Wolff

START : 7/25/08

END : 7/25/08

GEOLOGIST : A. Bogdanski



1- Ground elevation at well	<u>29.49' above MSL</u>
2- Top of casing elevation	<u>32.69' above MSL</u>
3- Wellhead protection cover type	<u>J-plug well cap</u>
a) Dia./type of outer casing	<u>4" square steel casing</u>
b) Concrete pad dimensions	<u>2' diameter x 6" deep</u>
4- Dia./type of inner well casing	<u>2" I.D. Sch 40 PVC</u>
5- Type/slot size of screen	<u>2" I.D. PVC Screen (0.010" slot)</u>
6- Type screen filter	<u>#1 Sand</u>
7- Type of seal	<u>Bentonite chips (3/8")</u>
a) Quantity used	<u>1 - 50lb bag</u>
8- Grout	
a) Grout mix used	<u>Cement/bentonite grout mix</u>
Development method	<u>Pump/Surge</u>
Development time	<u>Approx 45 Minutes</u>
Estimated purge volume	<u>Approx 20 gal</u>



PROJECT NUMBER

358174

WELL NUMBER

IS21MW08

WELL COMPLETION DIAGRAM

PROJECT : Indian Head Site 21

LOCATION : Indian Head, MD

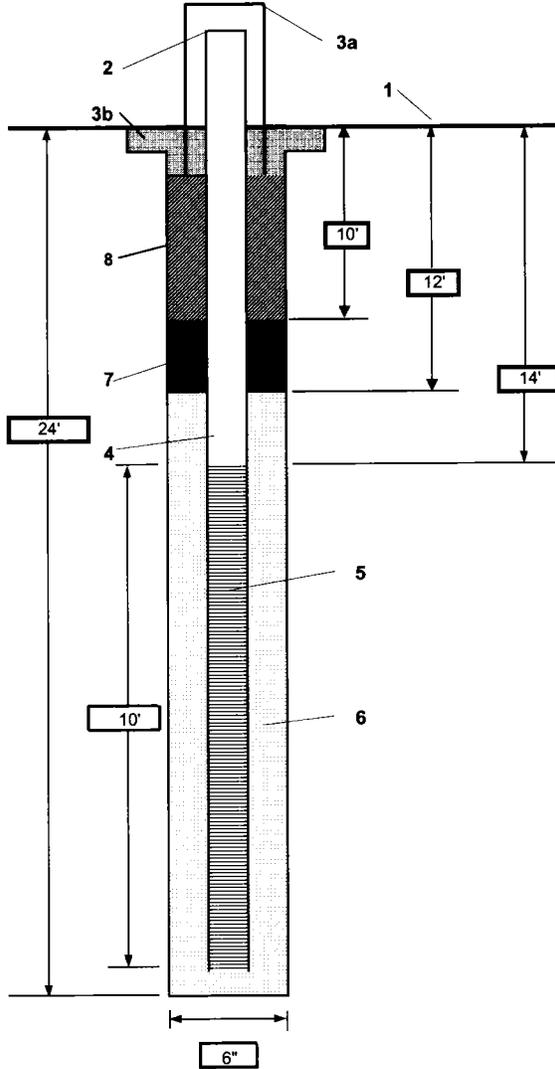
DRILLING METHOD AND EQUIPMENT USED : 4 1/4" HSA

DRILLING CONTRACTOR : Parratt Wolff

START : 7/25/08

END : 7/25/08

GEOLOGIST : A. Bogdanski



1- Ground elevation at well	<u>33.45' above MSL</u>
2- Top of casing elevation	<u>36.70' above MSL</u>
3- Wellhead protection cover type	<u>J-plug well cap</u>
a) Dia./type of outer casing	<u>4" square steel casing</u>
b) Concrete pad dimensions	<u>2' diameter x 6" deep</u>
4- Dia./type of inner well casing	<u>2" I.D. Sch 40 PVC</u>
5- Type/slot size of screen	<u>2" I.D. PVC Screen (0.010" slot)</u>
6- Type screen filter	<u>#1 Sand</u>
7- Type of seal	<u>Bentonite chips (3/8")</u>
a) Quantity used	<u>1 - 50lb bag</u>
8- Grout	
a) Grout mix used	<u>Cement/bentonite grout mix</u>
Development method	<u>Pump/Surge</u>
Development time	<u>Approx 10 Minutes</u>
Estimated purge volume	<u>15 gal</u>



PROJECT NUMBER

358174

WELL NUMBER

IS21PZ01

WELL COMPLETION DIAGRAM

PROJECT : Indian Head Site 21

LOCATION : Indian Head, MD

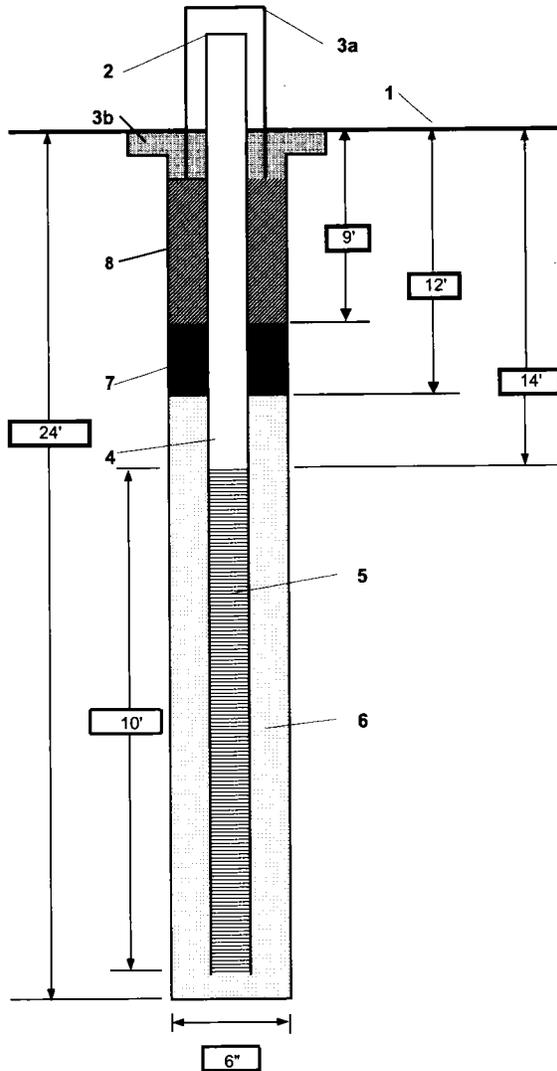
DRILLING METHOD AND EQUIPMENT USED : 4 1/4" HSA

DRILLING CONTRACTOR : Parratt Wolff

START : 7/24/08

END : 7/24/08

GEOLOGIST : A. Bogdanski



1- Ground elevation at well	<u>47.31' above MSL</u>
2- Top of casing elevation	<u>50.58' above MSL</u>
3- Wellhead protection cover type	<u>J-plug well cap</u>
a) Dia./type of outer casing	<u>4" square steel casing</u>
b) Concrete pad dimensions	<u>2' diameter x 6" deep</u>
4- Dia./type of inner well casing	<u>2" I.D. Sch 40 PVC</u>
5- Type/slot size of screen	<u>2" I.D. PVC Screen (0.010" slot)</u>
6- Type screen filter	<u>#1 Sand</u>
7- Type of seal	<u>Bentonite chips (3/8")</u>
a) Quantity used	<u>1 - 50lb bag</u>
8- Grout	
a) Grout mix used	<u>Cement/bentonite grout mix</u>
Development method	<u>Pump/Surge</u>
Development time	<u>Approx 55 Minutes</u>
Estimated purge volume	<u>Approx 15 gal</u>

Attachment 3 – Sequential Extraction Analyses



The University of Georgia

College of Agricultural and Environmental Sciences
Department of Crop and Soil Sciences

UGA Lab for Environmental Analysis
160 Phoenix Road
Athens, GA 30605
<http://www.uga.edu/lea>
(706) 227-7994

29-Sep-08

overall summary of work done on four soils supplied by CH2MHill. project IH-Site-21

four soils for sequential extraction and Fe and Mn analysis for BT Thomas of CH2M Hill.

exchangeable = 0.5 magnesium nitrate (16 hour shake)
acid extractable = 0.44 M acetic acid + 0.5 M magnesium nitrate (8 hour shake)
organic fraction= 0.10 M Na pyrophosphate (24 hour shake)
amorphous Fe oxide= 0.18 M am oxalate + 0.10 M oxalic acid (4 hours in the dark)
crystalline Fe oxides = 0.15 Na citrate, 0.05 citric acid, 2.5 g Na dithionite (6 hours at 60 degrees)
residual= total digestion 3052 minus the sum of the above 5 fractions
total digestion EPA 3052= Microwave digestion using hydrofluoric acid, followed by nitric and hydrochloric acid

soil was crushed and sieved through a 1 mm sieve and dried at 60 deg overnight prior to weighing.

5 g in 40 mL extractant used throughout, with centrifugation and filtration through 42 Whatman filter paper.

samples are identified as follows:

soil 1: IH site 21 IS21 MW07-094 7-25-08 1200 hours
soil 2: IH-site 21 IS21 MW06-1719 7-24-08 1415 hours
soil 3: IH site 21 IS21 MW08-2224 7-25-08 0830 hours
soil 4: IH site 21 IS21 MW05-4547 7-22-08 1350 hours

Mn only

	soil 1	soil 2	soil 3	soil 4	soil 1	soil 2	soil 3	soil 4
	Mn (ppm)	Mn (ppm)	Mn (ppm)	Mn (ppm)	Mn (%)	Mn (%)	Mn (%)	Mn (%)
neutral salt exch	52.34	21.08	4.04	7.34	20.9%	7.1%	0.1%	2.7%
acid extractable	19.48	9.75	23.72	14.37	7.8%	3.3%	0.8%	5.4%
organic fraction	4.80	19.80	6.18	1.46	1.9%	6.6%	0.2%	0.5%
amorphous iron oxide fraction	12.79	28.68	81.51	110.04	5.1%	9.6%	2.7%	41.2%
Crystalline iron oxide fraction	14.39	29.96	117.27	50.71	5.7%	10.0%	3.9%	19.0%
residual fraction	146.80	188.93	2776.18	83.48	58.6%	63.4%	92.3%	31.2%
total of 5 fractions	250.60	298.20	3008.90	267.40	100.0%	100.0%	100.0%	100.0%
total digestion EPA 3052	250.60	298.20	3008.90	267.40				

Fe only

	soil 1	soil 2	soil 3	soil 4	soil 1	soil 2	soil 3	soil 4
	Fe (ppm)	Fe (ppm)	Fe (ppm)	Fe (ppm)	Fe (%)	Fe (%)	Fe (%)	Fe (%)
neutral salt exch	< 8.00	< 8.00	< 8.00	< 8.00	below det	below det	below det	below det
acid extractable	41.4	< 8.00	52.4	< 8.00	0.4%	below det	0.1%	below det
organic fraction	419.3	1004.5	201.5	31.7	4.4%	2.4%	0.4%	0.2%
amorphous iron oxide fraction	263.9	276.3	536.0	141.4	2.7%	0.7%	0.9%	0.8%
Crystalline iron oxide fraction	3041.1	12127.0	1243.4	9110.8	31.6%	28.8%	2.2%	53.0%
residual fraction	5853.5	28631.1	54437.3	7912.5	60.9%	68.1%	96.4%	46.0%
total of 5 fractions	9619.2	42039.0	56470.6	17196.4	100.0%	100.0%	100.0%	100.0%
total Digestion EPA 3052	9619.2	42039.0	56470.6	17196.4				

Gene Weeks, Lab for Environmental Analysis

c:\analresults08\MISC_#2193(summary.1)_CH2MHill_25Sep08.xls

Attachment 4 – XRD and Electron Microprobe Analyses



The University of Georgia

Franklin College of Arts and Sciences
Department of Geology

August 21, 2008

Jeff Woodward, P.G.
CH2M Hill, Inc.,
15010 Conference Center Dr.
Chantilly, VA 20151

Re: X-ray diffraction and Electron microprobe analysis of samples from the IH-site 21

This letter constitutes a report prepared by Paul Schroeder and Chris Fleisher on the subject. Four samples submitted by CH2M were evaluated using X-ray diffraction (XRD) and Electron microprobe analysis (EMPA) to characterize the occurrence of Mn in the samples. EMPA includes backscattered electron imaging (BSEI), semi-quantitative Wavelength Dispersive Spectroscopy (WDS) X-ray analysis, and X-ray mapping. Four samples were received on July 28, 2008 with labels IS21MW05-0911, IS21MW06-1719, IS21MW08-2224, and IS21MW05-4547, respectively (chain of custody form attached). In this report, these samples are referred to as 0911, 1719, 2224, and 4547, respectively. Representative samples for XRD analysis were dried and ground to a particle size of $<10 \mu\text{m}$. Powder mounts were analyzed on a Pan-analytical diffractometer with a Xe proportional counter, using Cu radiation and a scanning rate of $2^\circ 2\theta$ per minute. Only major phases were identified with XRD. Separate cementing of the grains with epoxy and subsequent flat surface polishing made grain mounts for EMPA studies. WDS maps were made specifically for visual purposes to show distributions of Si, Fe, and Mn, which were the elements of interest in this study. It is important to note that the intensities of the image bright spots are relative and apply only within each image. Image to image correlation of brightness is not possible. Semi-quantitative assessment of major elements was performed using WDS. Table 1 contains abundances of common elements in selected grains.

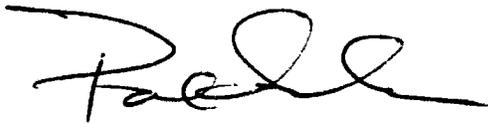
Both EMPA and XRD analyses indicate quartz is the most abundant mineral in all 4 samples, and all contain lesser amounts of K-feldspar, ilmenite, rutile, and micaceous clay minerals (see attached figures). In sample 0911, Mn occurs in ilmenite grains, as small ($<5 \mu\text{m}$) blebs intergrown with clay, and as rare Mn-rich grains that are probably an intergrowth of clay and Mn-hydroxide minerals that likely resulted from the in situ weathering of the ilmenite. In sample 1719, Mn occurs in ilmenite grains and occasional Mn-rich grains. In sample 2224, Mn occurs in ilmenite grains, and also is incorporated in Fe-oxy-hydroxide cements binding aggregates of quartz and k-feldspar grains. Free grains of this material are fairly common in the sample. In sample 4547, Mn occurs in ilmenite grains, Mn-rich particles, and Mn-rich clay coating occasional quartz grains.

In summary, this material appears typical of eastern U.S. coastal plain sediments that have been weathered and transported from their provenance. Hydraulic sorting and post depositional meteoric weathering processes have further modified their composition. Quartz is concentrated and remains relatively insoluble. Feldspars are minor and therefore their common weathering alteration product, kaolin, is also in low abundance. Ilmenite grains contain Mn as a

trace element and they appear to have undergone oxidation and hydrolysis, resulting in the precipitation of poorly ordered (i.e., XRD amorphous) secondary phases such as Fe- and Mn-hydroxides. These secondary phases appear to nucleate on high surface area particles, such as rough quartz grains and weathered micas and clay minerals. Consequently the hydroxide phases appear as finely disseminated coatings that own their origins to primary mineral dissolution and re-mobilization due to variations in subsurface redox and hydrologic conditions. The presence of Mn-bearing phases appears to be natural occurrence and attributed to normal subsurface biogeochemical processes.

You will be invoiced under separate cover as per the bid sheet submitted to you on July 15, 2008. Please feel free to call me if you have any questions.

Sincerely,

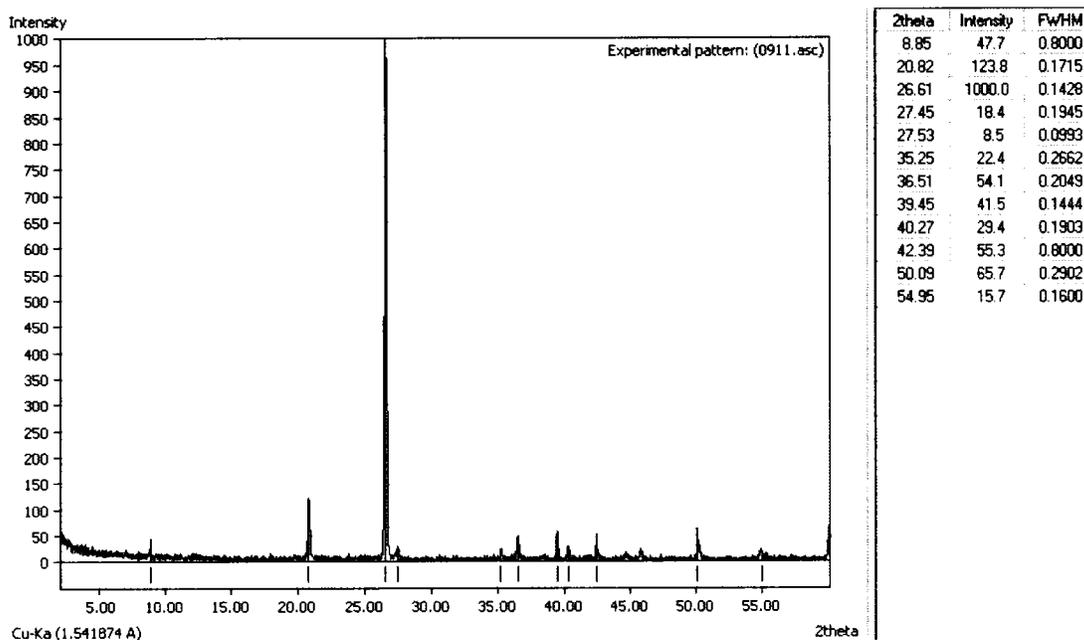
A handwritten signature in black ink, appearing to read "Paul", written in a cursive style.

Dr. Paul A. Schroeder
Professor and Co-Director CAUR

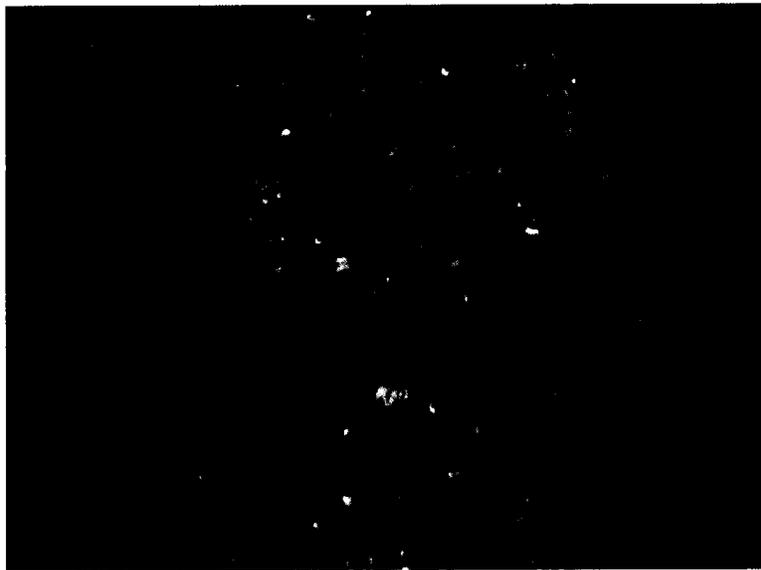
X-ray diffraction and Electron microprobe analysis of samples from the IH-site 21

Prepared for: CH2M Hill, Inc., 15010 Conference Center Dr. Chantilly, VA 20151
Prepared by: Paul Schroeder and Chris Fleisher, UGA Geology, Athens, GA 30602
August 21, 2008

0911 Data Descriptions



X-ray powder diffraction pattern of Sample 0911. Quartz is the major phase. Mica and feldspar are minor phases.



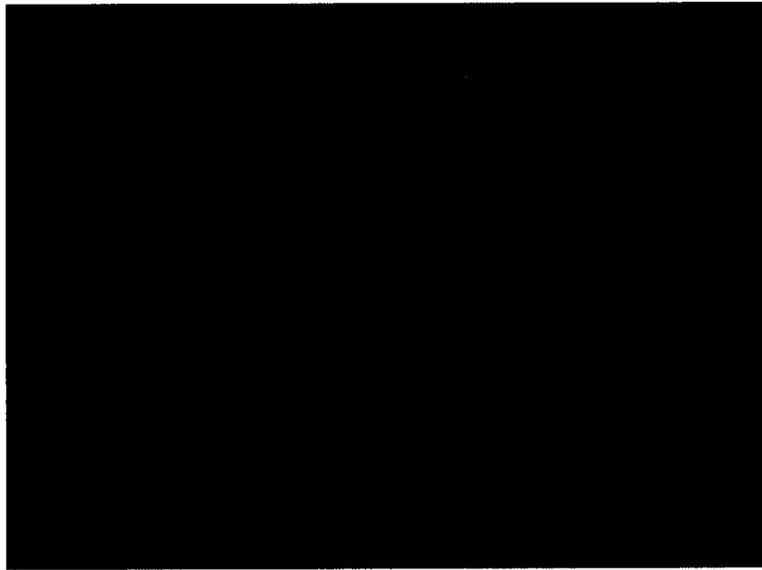
30µm
BEI 0911 Clay_Microlites

0911a Clay particle (Backscatter electron image mode).



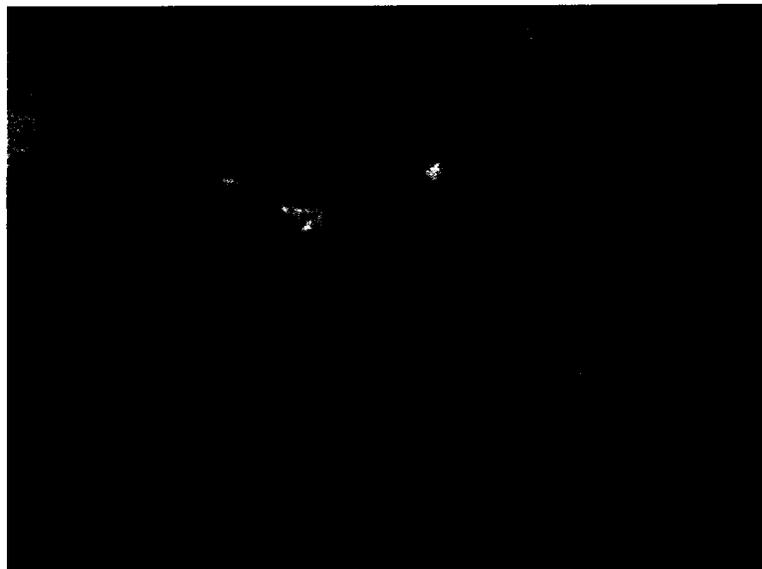
30µm
Fe 0911 Clay_Microlites

0911a Clay particle (Fe -map).



30µm
Mn 0911 Clay_Microlites

0911a Clay particle (Mn – accentuated map).



30µm
Si 0911 Clay_Microlites

0911a Clay particle (Si -map).



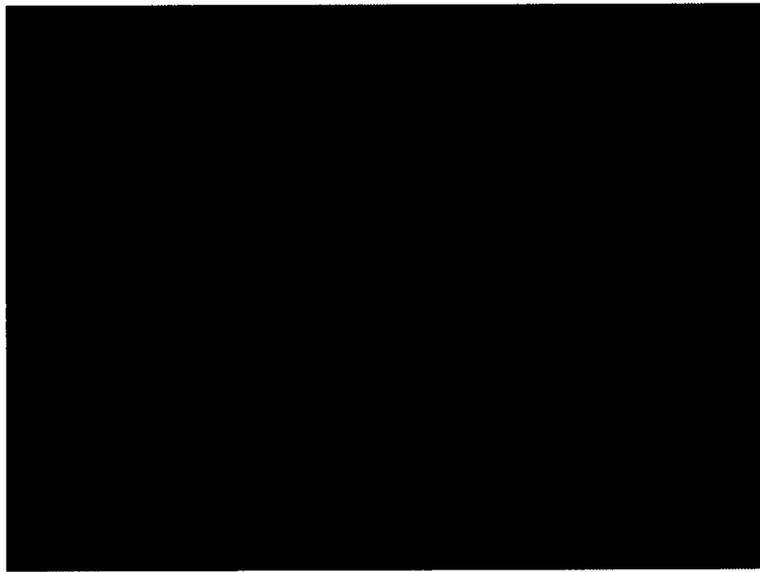
30µm
BEI 0911 Ilmenite

0911 b Representative ilmenite grain. (Backscatter electron image mode).



30µm
Fe 0911 Ilmenite

0911 b Representative ilmenite grain. Clay particle (Fe -map).



30µm
Mn 0911 Ilmenite

0911 b Representative ilmenite grain. (Mn – accentuated map).



30µm
Si 0911 Ilmenite

0911 b Representative ilmenite grain. (Si -map).



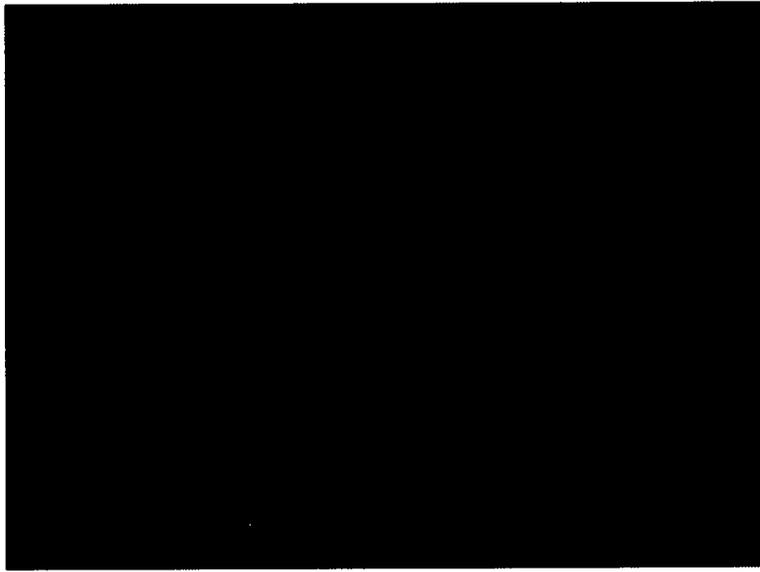
20µm
BEI 0911 Clay_Microlites

0911c Quartz and clay particle. (Backscatter electron image mode).



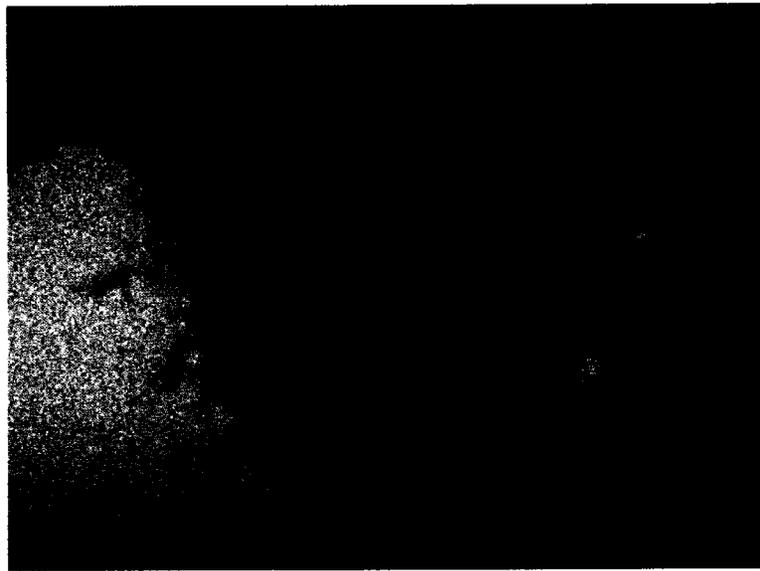
20µm
Fe 0911 Clay_Microlites

0911c Quartz and clay particle. (Fe -map).



20µm
Mn 0911 Clay_Microlites

0911c Quartz and clay particle. (Mn – accentuated map).



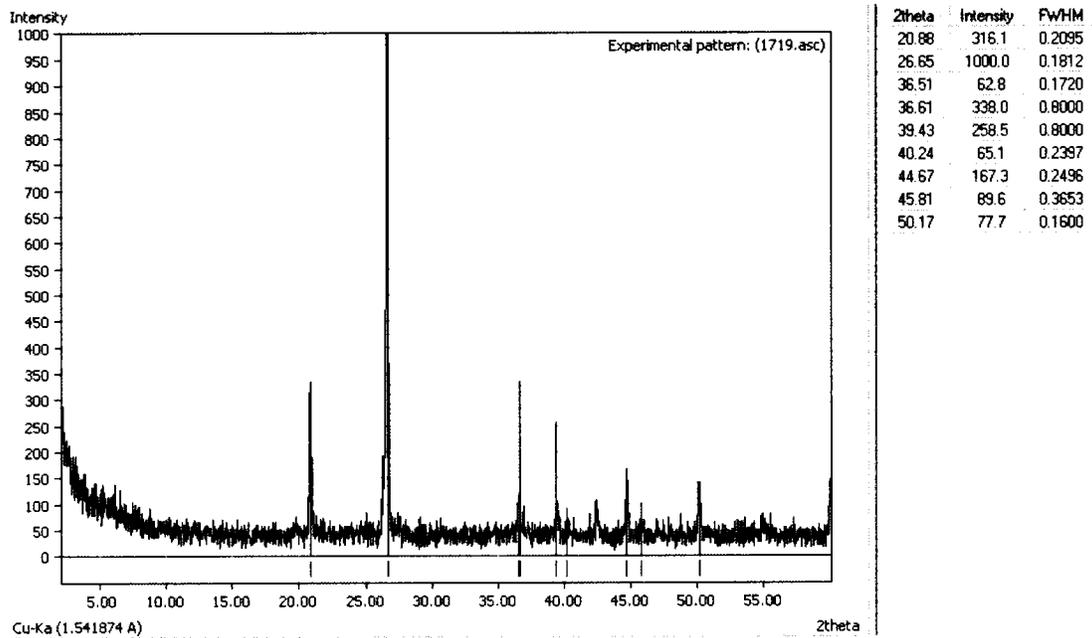
20µm
Si 0911 Clay_Microlites

0911c Quartz and clay particle. (Si -map).

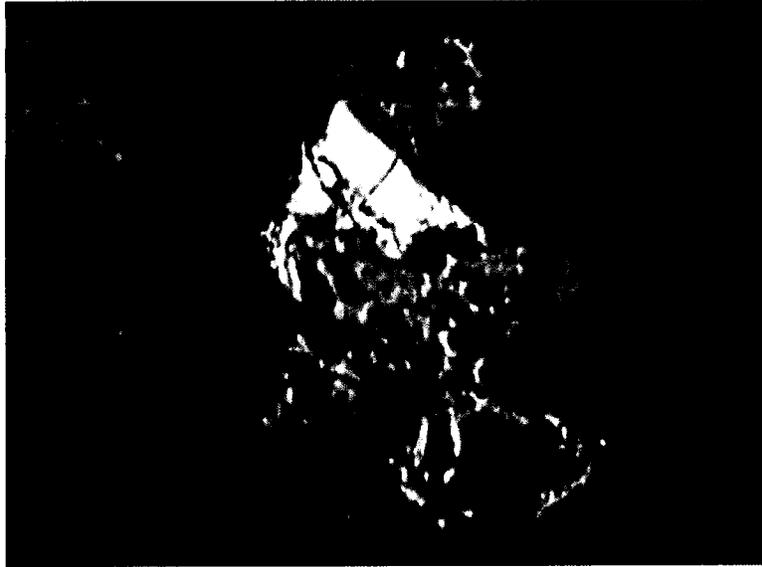
X-ray diffraction and Electron microprobe analysis of samples from the IH-site 21

Prepared for: CH2M Hill, Inc., 15010 Conference Center Dr. Chantilly, VA 20151
Prepared by: Paul Schroeder and Chris Fleisher, UGA Geology, Athens, GA 30602
August 21, 2008

1719 Data Descriptions



X-ray powder diffraction pattern of Sample 1719. Quartz is the major phase. Feldspar is a very minor phase.



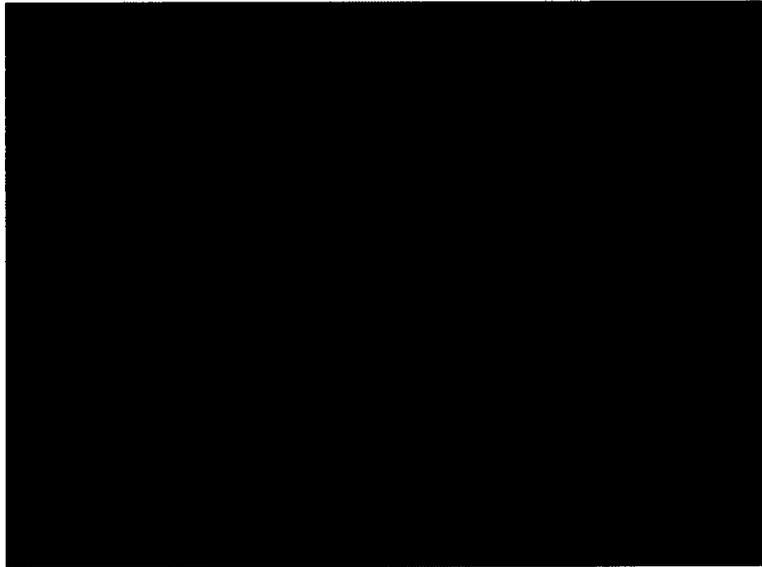
20µm
BEI 1719

1719a Mn-rich particle. (Backscatter electron image mode).



20µm
Fe 1719

1719a Mn-rich particle. (Fe -map).



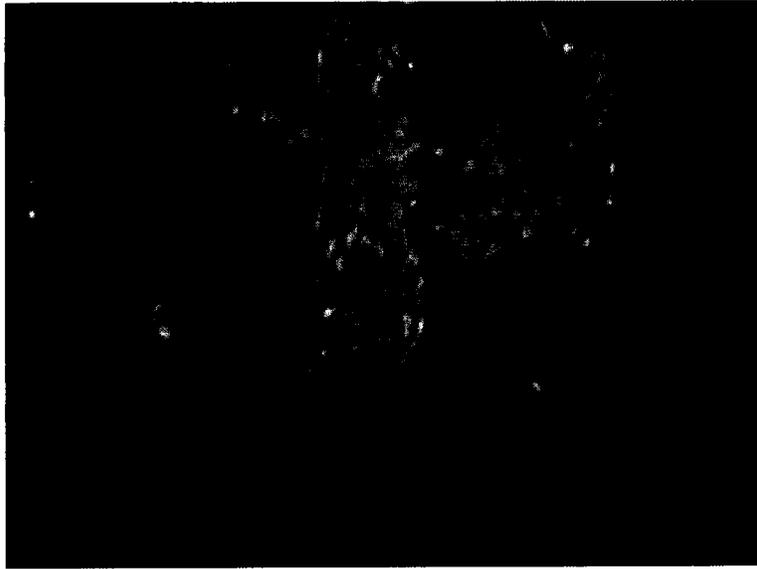
Mn 1719
20 μm

1719a Mn-rich particle. (Mn – accentuated map).



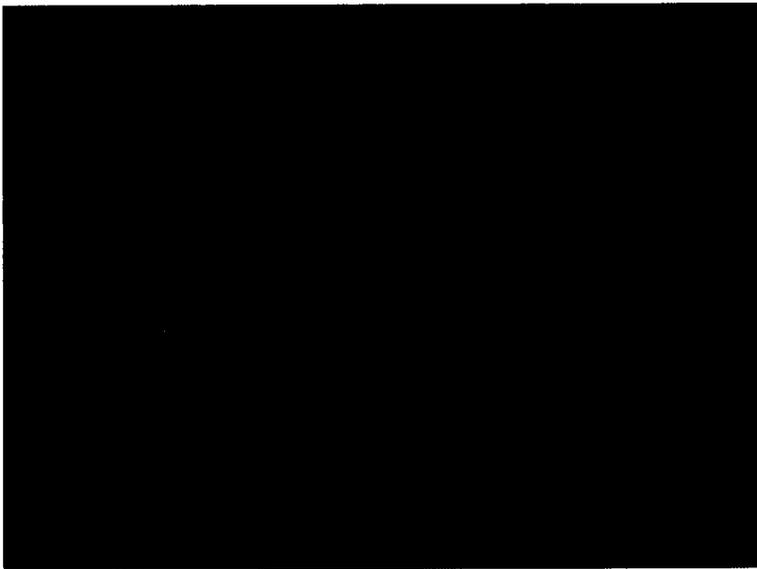
Si 1719
20 μm

1719a Mn-rich particle. (Si -map).



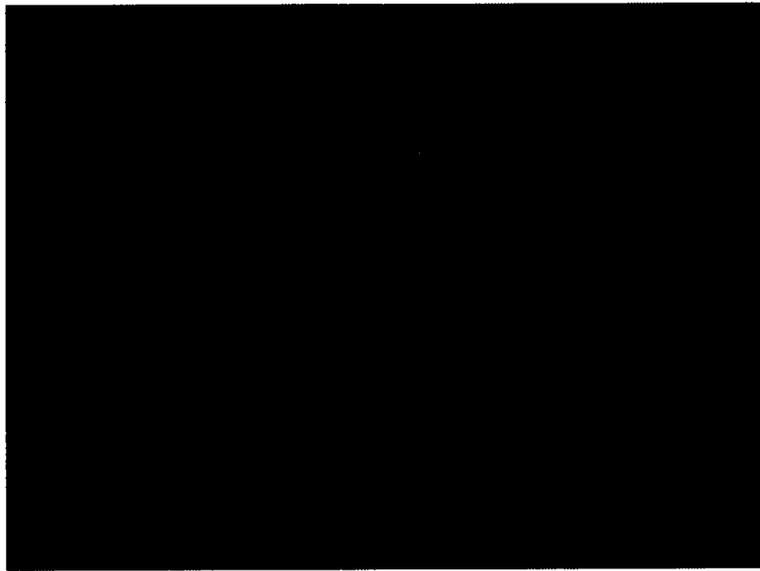
40µm
BEI 1719

1719b Mn-rich particle. (Backscatter electron image mode).



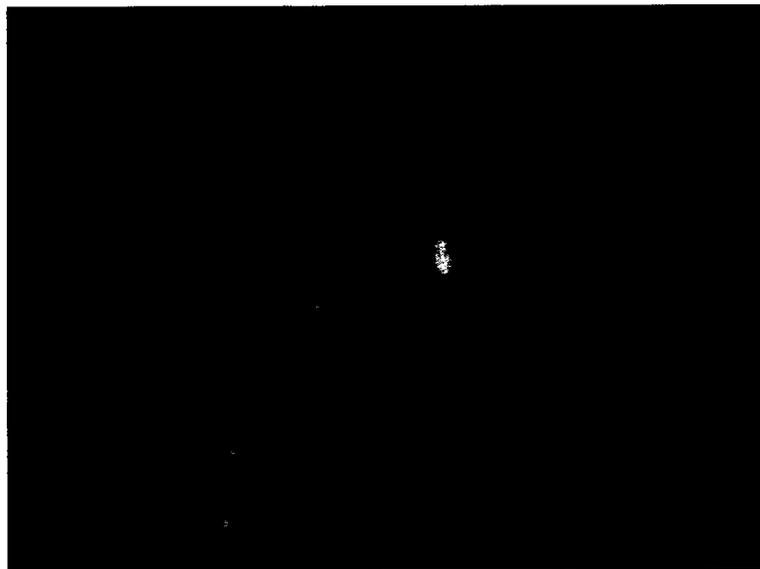
40µm
Fe 1719

1719b Mn-rich particle. (Fe -map).



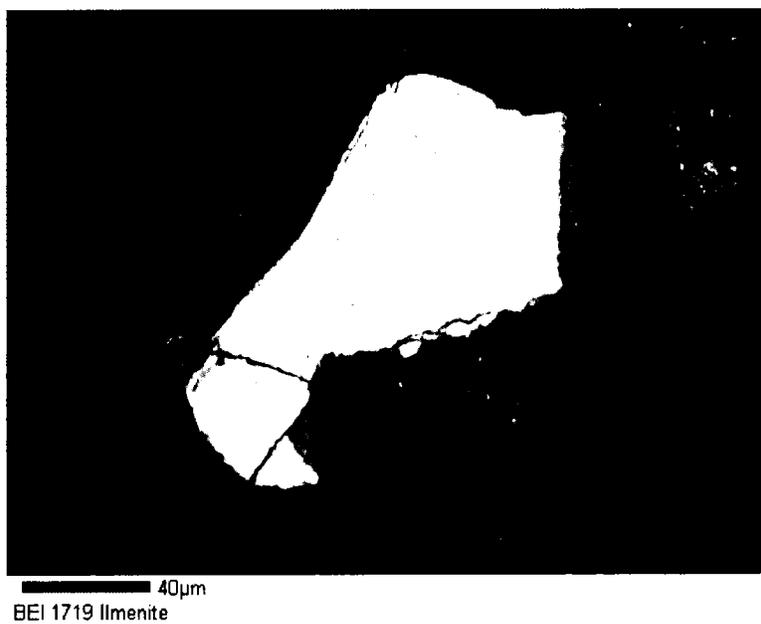
Mn 1719
40 μm

1719b Mn-rich particle. (Mn – accentuated map).

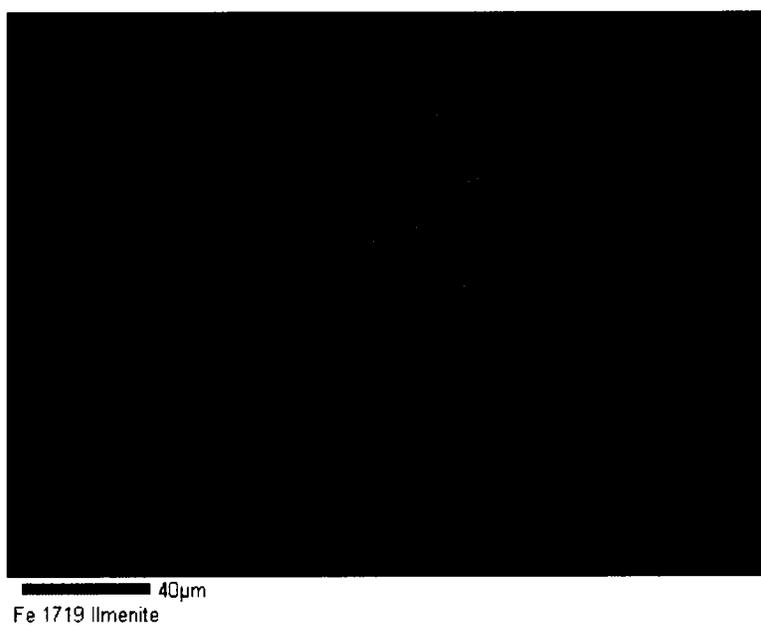


Si 1719
40 μm

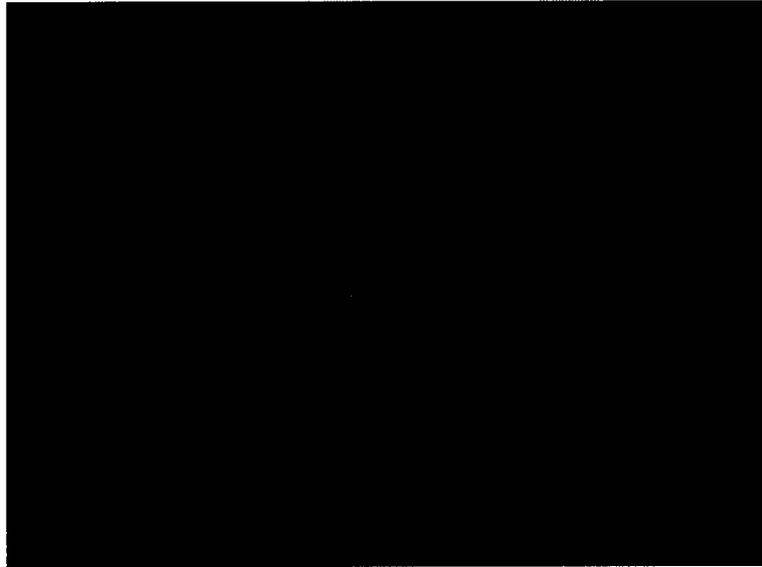
1719b Mn-rich particle. (Si -map).



1719c Ilmenite, quartz, and clay particles. (Backscatter electron image mode).



1719c Ilmenite, quartz, and clay particles. (Fe -map).



40µm
Mn 1719 Ilmenite

1719c Ilmenite, quartz, and clay particles. (Mn – accentuated map).



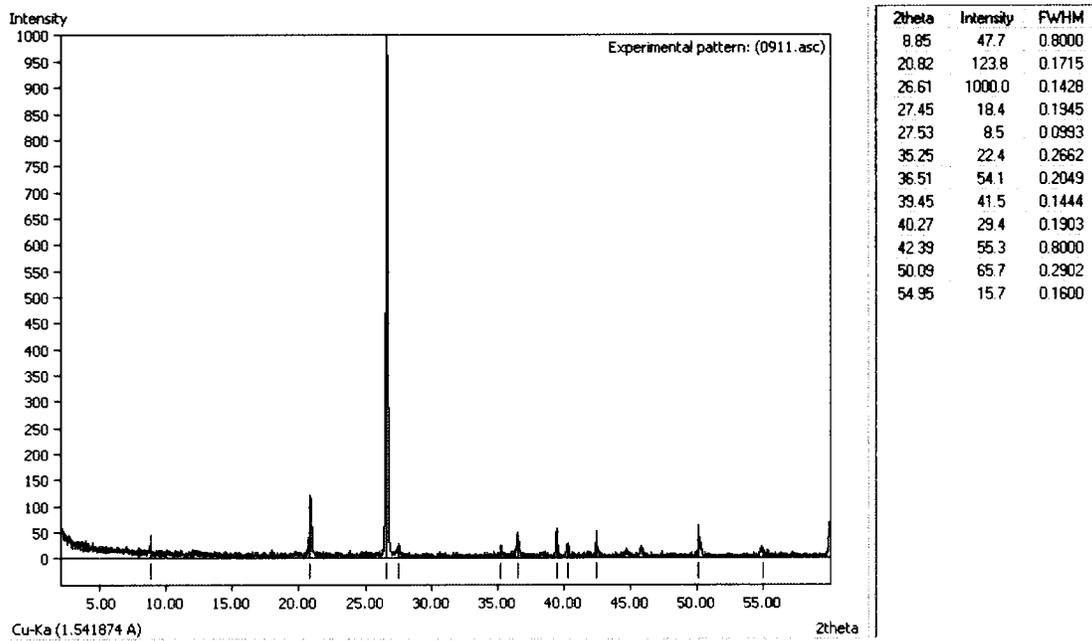
40µm
Si 1719 Ilmenite

1719c Ilmenite, quartz, and clay particles. (Si -map).

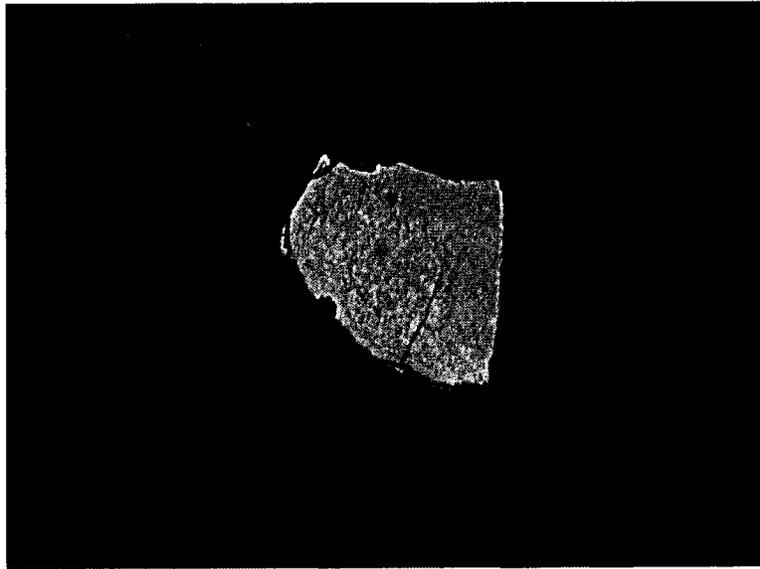
X-ray diffraction and Electron microprobe analysis of samples from the IH-site 21

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Prepared by: Paul Schroeder and Chris Fleisher, UGA Geology, Athens, GA 30602
August 21, 2008

2224 Data Descriptions

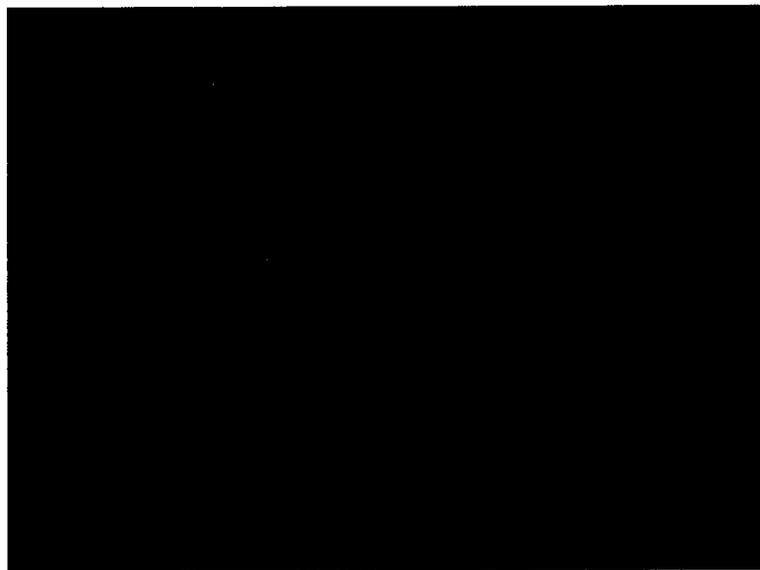


X-ray powder diffraction pattern of Sample 2224. Quartz is the major phase. Feldspar and mica are minor phases.



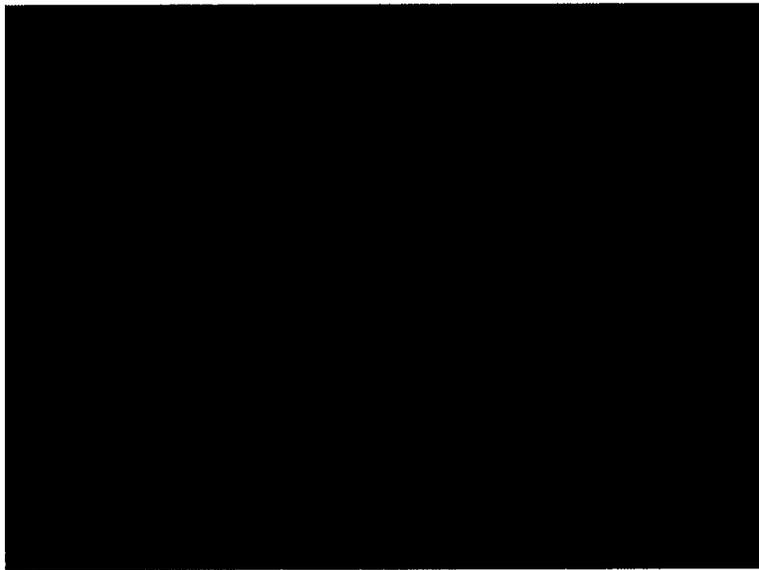
40µm
BEI 2224 aggregate

2224a Fe-oxy-hydroxide cemented aggregate. (Backscatter electron image mode).



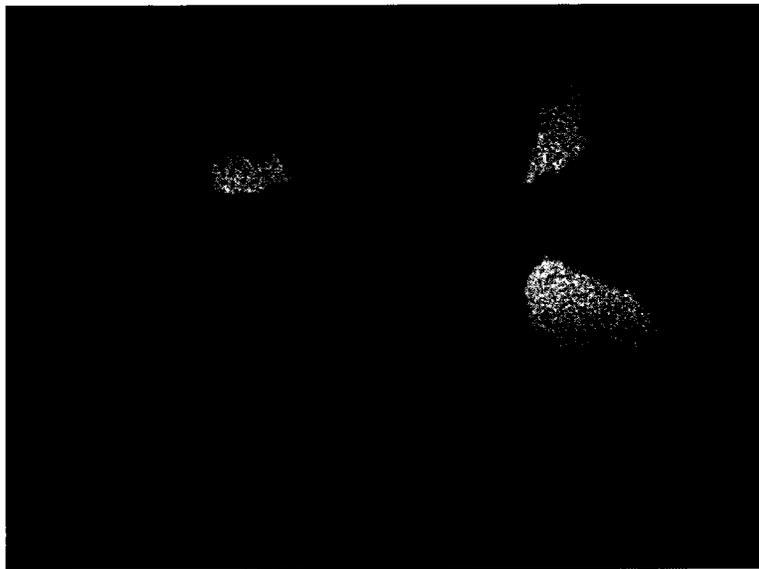
40µm
Fe 2224 aggregate

2224a Fe-oxy-hydroxide cemented aggregate. (Fe -map).



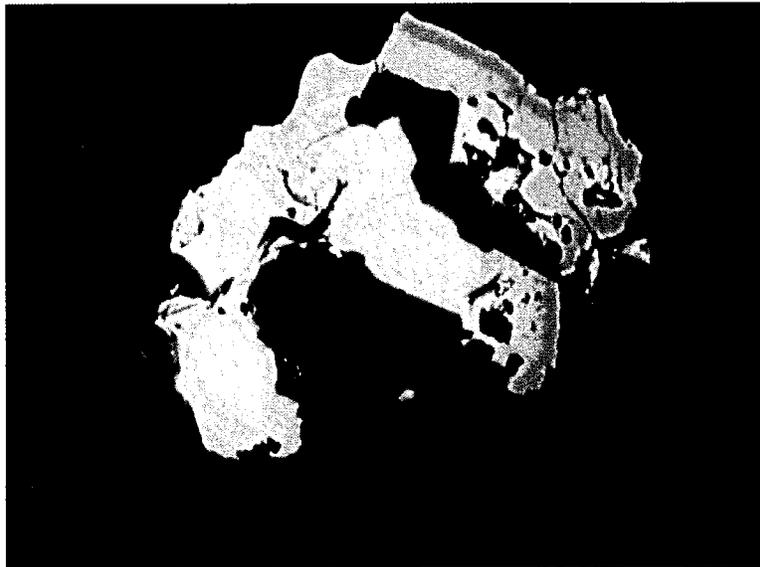
40µm
Mn 2224 aggregate

2224a Fe-oxy-hydroxide cemented aggregate. (Mn – accentuated map).



40µm
Si 2224 aggregate

2224a Fe-oxy-hydroxide cemented aggregate. (Si -map).



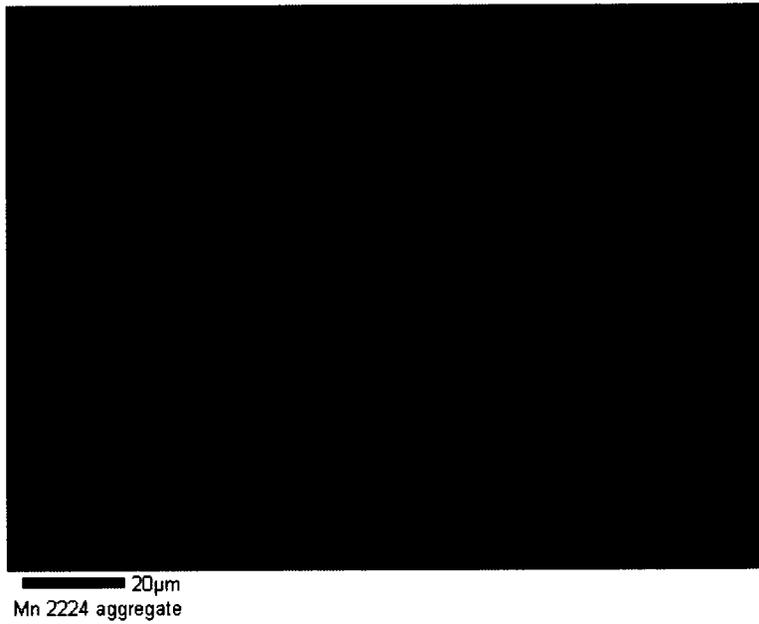
20µm
BEI 2224 aggregate

2224b Fe-oxy-hydroxide cemented aggregate. Grains in the aggregate are quartz, while those below the aggregate are K-feldspar and micas. (Backscatter electron image mode).



20µm
Fe 2224 aggregate

2224b Fe-oxy-hydroxide cemented aggregate. Grains in the aggregate are quartz, while those below the aggregate are K-feldspar and micas. (Fe -map).



2224b Fe-oxy-hydroxide cemented aggregate. Grains in the aggregate are quartz, while those below the aggregate are K-feldspar and micas. (Mn – accentuated map).

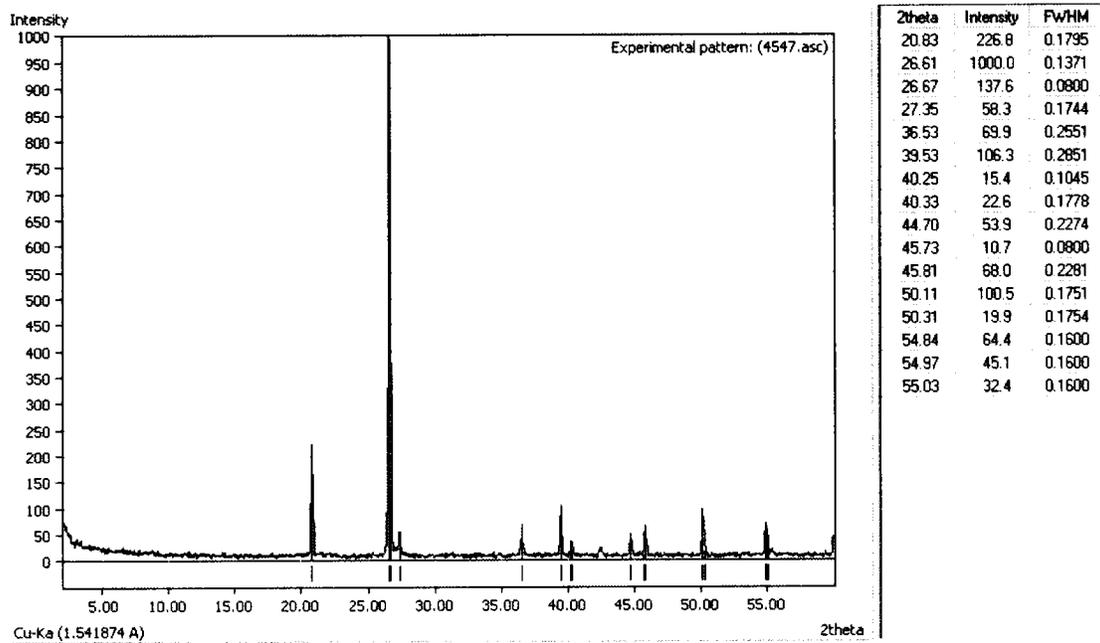


2224b Fe-oxy-hydroxide cemented aggregate. Grains in the aggregate are quartz, while those below the aggregate are K-feldspar and micas. (Si -map).

X-ray diffraction and Electron microprobe analysis of samples from the IH-site 21

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Prepared by: Paul Schroeder and Chris Fleisher, UGA Geology, Athens, GA 30602
August 21, 2008

4547 Data Descriptions



X-ray powder diffraction pattern of Sample 4547. Quartz is the major phase. Feldspar is a minor phase.



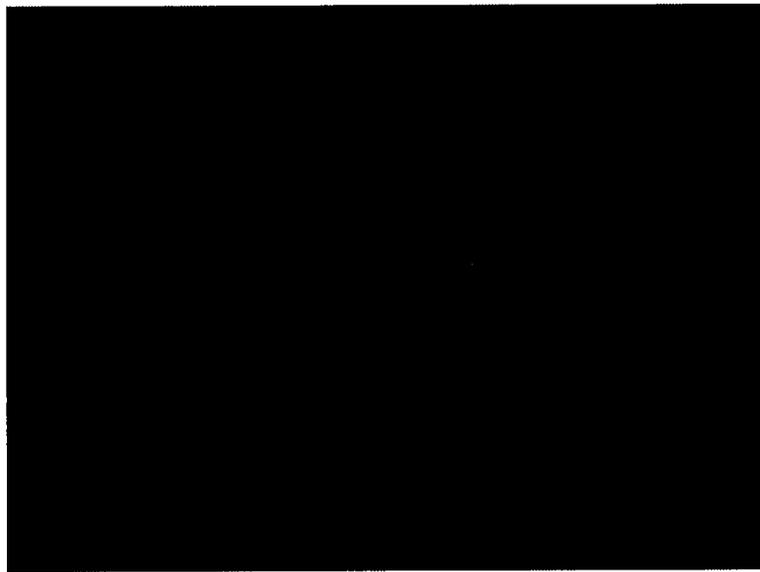
BEI 4547
40µm

4547a Mn-rich grain and silicate minerals. (Backscatter electron image mode).



Fe 4547
40µm

4547a Mn-rich grain and silicate minerals. (Fe -map).



Mn 4547 40µm

4547a Mn-rich grain and silicate minerals. (Mn – accentuated map).



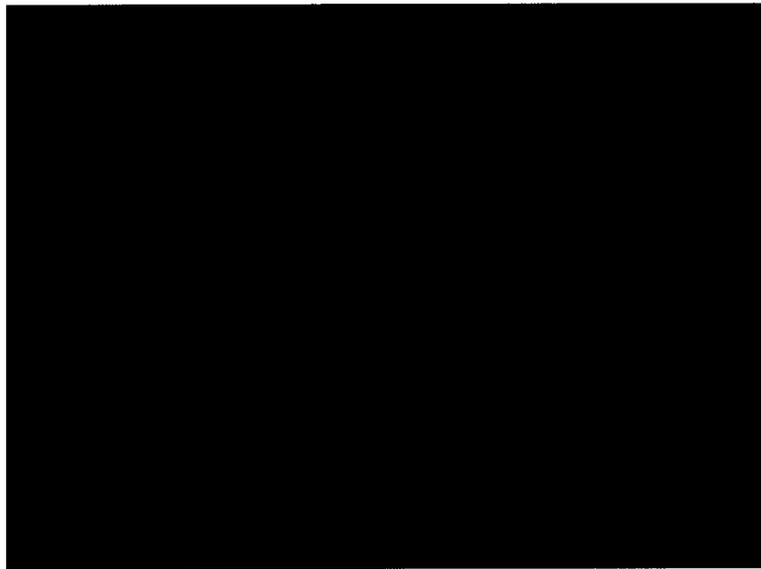
Si 4547 40µm

4547a Mn-rich grain and silicate minerals. (Si -map).



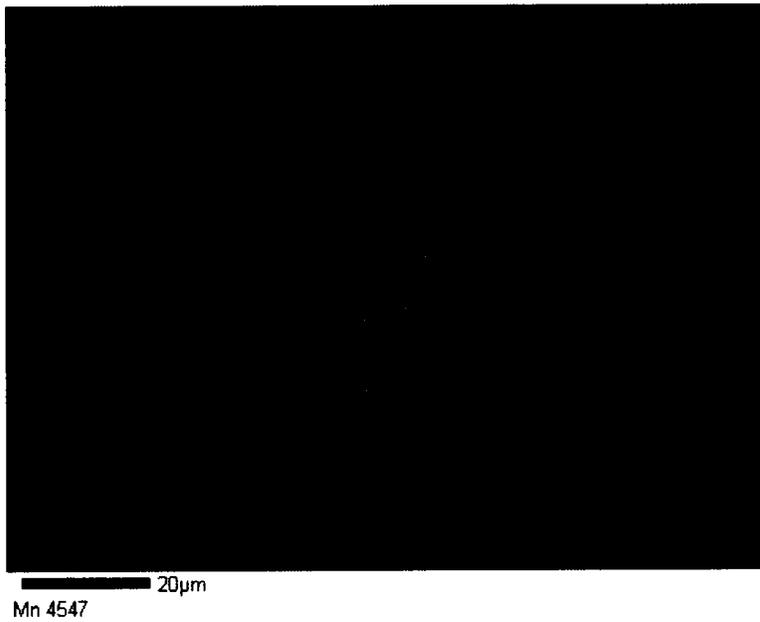
BEI 4547
20µm

4547b Mn-rich grain with quartz and K-feldspar. (Backscatter electron image mode).

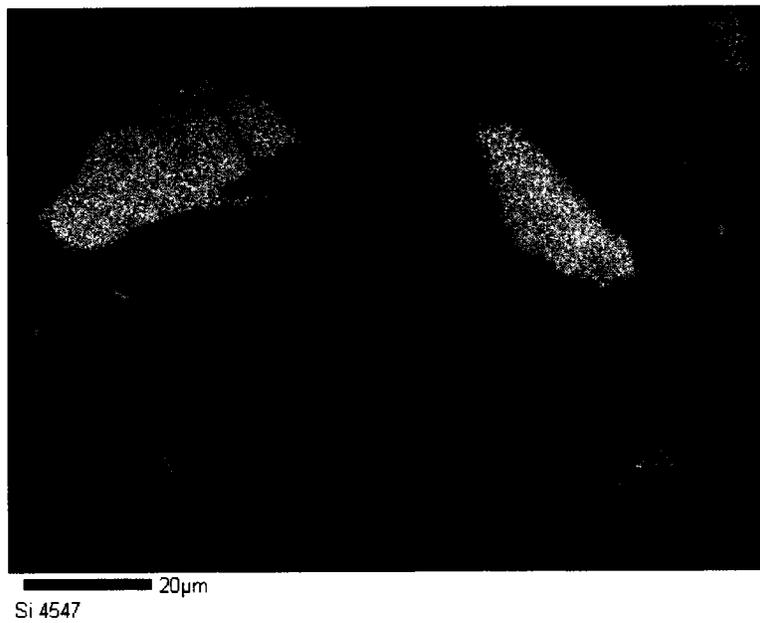


Fe 4547
20µm

4547b Mn-rich grain with quartz and K-feldspar. (Fe -map).



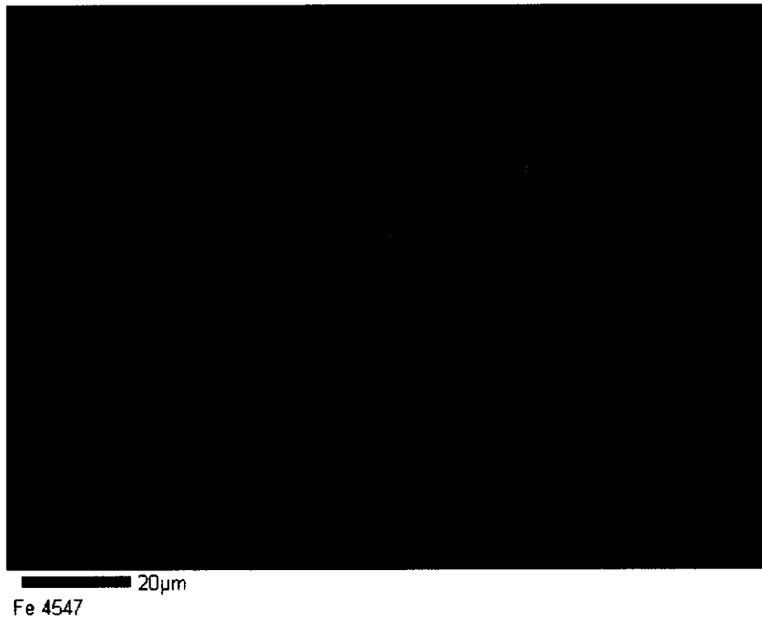
4547b Mn-rich grain with quartz and K-feldspar. (Mn – accentuated map).



4547b Mn-rich grain with quartz and K-feldspar. (Si -map).



4547c Quartz grain with remnant coating of Mn-rich clay particle and Fe-oxyhydroxides. (Backscatter electron image mode).

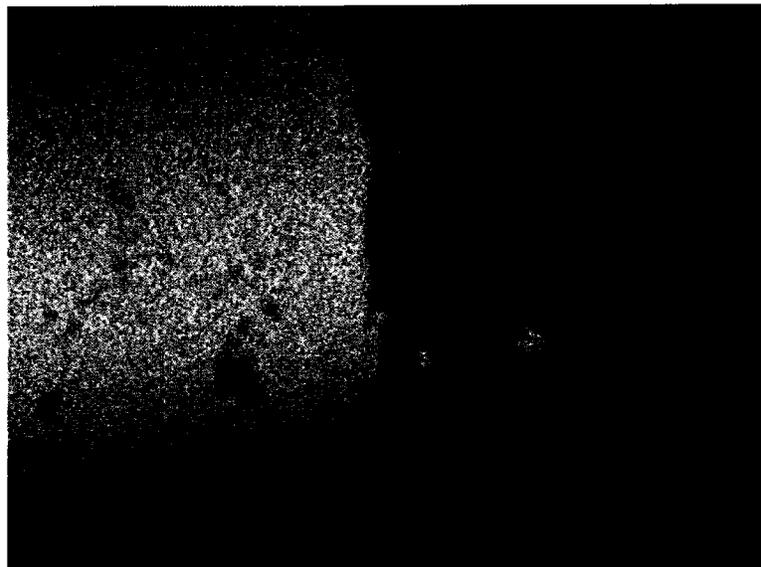


4547c Quartz grain with remnant coating of Mn-rich clay particle and Fe-oxyhydroxides. (Fe -map).



Mn 4547

4547c Quartz grain with remnant coating of Mn-rich clay particle and Fe-oxyhydroxides. (Mn – accentuated map).



Si 4547

4547c Quartz grain with remnant coating of Mn-rich clay particle and Fe-oxyhydroxides. (Si -map).

Table 1. Semi-quantitative compilation of grain analysis using electron microprobe. See figures for reference to label information. Low totals can be ascribed to non-ideal beam geometry, matrix conditions and the presence of a hydrous component

Oxide Weight Percent: Oxide												
Pt#	SiO2	TiO2	Al2O3	MgO	FeO	CaO	MnO	Cr2O3	NiO	K2O	Total	Label
2	0.02	51.30	0.02	0.01	47.19	0.01	1.22				99.77	0911 1 ilmenite
4	0.02	53.10	0.05	0.05	42.88	0.00	2.95				99.06	0911 3 ilmenite
5	34.88	0.55	15.09	0.48	17.53	0.37	1.88				70.79	0911 10 um spot in clay microlite mix
6	34.61	0.56	15.06	0.48	17.50	0.37	1.88	0.31	0.12	2.61	73.50	0911 10 um same spot w/added elements
7	17.72	8.32	6.58	0.38	39.97	0.45	0.56	0.29	0.12	0.29	74.67	0911 small bleb in clay
8	31.75	0.57	15.52	0.58	16.31	0.63	15.44	0.31	0.12	0.64	81.86	0911 3 um bleb in clay
12	0.11	59.25	0.66	0.00	32.48	0.02	1.38				93.90	1719 ilmenite
9	0.05	60.37	0.00	0.02	31.61	0.00	0.98	0.31	0.11	0.02	93.48	1719 ilmenite
10	0.08	99.78	0.03	0.04	0.46	0.04	0.00	0.33	0.11	0.00	100.88	1719 Rutile
11	0.19	60.10	0.22	0.16	31.31	0.02	2.26	0.31	0.11	0.04	94.73	1719 ilmenite
12	30.66	0.73	12.05	0.34	37.22	0.39	0.06	0.29	0.12	0.19	82.05	Clay circa Qtz
14	43.56	0.23	25.51	1.60	7.59	0.37	6.44	0.33	0.12	2.94	88.68	Mn-rich grain
15	0.03	58.59	0.00	0.01	28.78	0.00	2.47	0.31	0.11	0.00	90.30	Ilmenite
16	0.15	61.19	0.14	0.16	31.24	0.02	2.13	0.31	0.11	0.01	95.47	Ilmenite
18	0.86	0.21	0.43	1.01	58.58	0.72	4.54				66.34	2224 Fe oxide cement binding clasts
19	0.08	59.48	0.06	0.08	29.89	0.03	0.86				90.48	2224 Ilmenite grain in same aggregate
20	0.17	60.17	0.05	0.04	31.12	0.06	0.92				92.52	2224 Free Ilmenite grain
21	1.13	0.03	0.82	5.01	46.18	1.85	6.01				61.03	2224 10 um grain
22	5.45	35.29	2.97	0.09	17.86	0.26	1.43				63.35	2224 free grain
23	0.04	0.04	0.05	2.59	45.01	2.29	6.73				56.76	2224 Fe rich pt of aggregate
24	0.51	0.05	0.54	4.76	44.13	1.78	5.63				57.39	2224 small grain
25	0.02	0.04	0.01	4.62	43.47	2.67	6.41				57.24	2224 small grain
26	0.23	0.04	0.15	0.16	56.79	0.50	4.32				62.19	2224 small grain
27	0.08	56.09	0.21	0.04	30.35	0.02	1.74				88.53	2224 small ilmenite
28	2.59	0.04	4.13	0.06	67.88	0.11	0.09				74.89	4547 small grain
8	0.82	0.05	3.02	0.12	3.11	0.18	29.42	0.17	0.17		37.06	4547 Mn-rich grain 5 um
9	1.63	0.13	2.80	0.05	67.97	0.13	0.09	0.05	0.07		72.92	4547 Fe-rich grain for comparison
10	15.85	0.14	15.54	0.93	28.62	0.12	5.30	0.12	0.12		66.75	4547 Mn-rich particle
11	13.26	0.10	12.73	0.29	22.08	0.11	6.21	0.66	0.17		55.60	4547 Mn-rich clay area coating qtz grain

Attachment 5 – HHRA Tables

Table 2
 OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
 Indian Head Site 21

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Site 21	7439-89-6	Iron	3.4E+02	9.0E+04	UG_L	IS21MW031108	10/10	100 - 100	9.0E+04	NA	2.6E+03 N	3.0E+02	SMCL	YES	ASL
	7439-96-5	Manganese	7.8E+01	6.1E+03	UG_L	IS21MW070808P	10/10	10 - 10	6.1E+03	NA	8.8E+01 N	5.0E+01	SMCL	YES	ASL

[1] Minimum/Maximum detected concentration. Used filtered metals data since order of magnitude difference between filtered and unfiltered samples. COPC = Chemical of Potential Concern

[2] Maximum concentration is used for screening. ARAR/TBC = Applicable or Relevant and Appropriate Requirement/

[3] Background values not available. To Be Considered

[4] Oak Ridge National Laboratory (ORNL), September 12, 2008. Regional Screening Levels for Chemical Contaminants at Superfund Sites. [Online]. Available: J = Estimated Value

[5] Rationale Codes

Selection Reason:	Above Screening Levels (ASL)	K = Biased High
Deletion Reason:	No Toxicity Information (NTX)	L = Biased Low
	Essential Nutrient (NUT)	C = Carcinogenic
	Below Screening Level (BSL)	N = Noncarcinogenic
		SMCL = Maximum Contaminant Level, Secondary Drinking Water Standards

Table 3.1.RME
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SUMMARY
Indian Head Site 21

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (Distribution)		Maximum Concentration (Qualifier)	Exposure Point Concentration			
							Value	Units	Statistic	Rationale
Site 21	Iron	UG_L	2.6E+04	1.0E+05	G	9.0E+04	9.0E+04	UG_L	Max	1, 3, 4, 6
	Manganese	UG_L	2.1E+03	4.7E+03	G	6.1E+03	4.7E+03	UG_L	App Gamma	1, 3, 4,

ProUCL, Version 4.00.02 used to determine distribution of data. ProUCL used to calculate the EPC, following recommendations based on distribution and standard deviation in users guide.

Statistics: 95% Approximate Gamma (App Gamma); Maximum Detected Concentration (Max)

- (1) Shapiro-Wilk W Test/Lilliefors test indicates data are log-normally distributed.
- (2) Shapiro-Wilk W Test/Lilliefors indicates data are normally distributed.
- (3) Anderson-Darling Test indicates data are gamma distributed.
- (4) Kolmogorov-Smirnov Test indicates data are gamma distributed.
- (5) Distribution tests are inconclusive (data are not normal, log-normal, or gamma-distributed).
- (6) Max value used because 95% UCL greater than max.

N = Normal	UG_L = micrograms liter
T = Log-Transformed	L = Biased Low
NP = Non-Parametric	J = Estimated Value
G = Gamma	K = Biased High

Table 3.1.CTE
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SUMMARY
Indian Head Site 21

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (Distribution)		Maximum Concentration (Qualifier)	Exposure Point Concentration			
							Value	Units	Statistic	Rationale
Site 21	Iron	UG_L	2.6E+04	1.0E+05	G	9.0E+04	2.6E+04	UG_L	Mean-N	1, 3, 4,
	Manganese	UG_L	2.1E+03	4.7E+03	G	6.1E+03	2.1E+03	UG_L	Mean-N	1, 3, 4,

ProUCL, Version 4.00.02 used to determine distribution of data. ProUCL used to calculate the EPC, following recommendations based on distribution and standard deviation in users guide.

Statistics: Normal Mean (Mean-N)

- (1) Shapiro-Wilk W Test/Lilliefors test indicates data are log-normally distributed.
- (2) Shapiro-Wilk W Test/Lilliefors indicates data are normally distributed.
- (3) Anderson-Darling Test indicates data are gamma distributed.
- (4) Kolmogorov-Smirnov Test indicates data are gamma distributed.
- (5) Distribution tests are inconclusive (data are not normal, log-normal, or gamma-distributed).

N = Normal	UG_L = micrograms liter
T = Log-Transformed	L = Biased Low
NP = Non-Parametric	J = Estimated Value
G = Gamma	K = Biased High

TABLE 4.1.RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
Site 21, Indian Head

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference	Intake Equation/Model Name
Ingestion	Resident	Adult	Tap Water	CW	Chemical Concentration in Water	See Table 3.1.RME	µg/l	See Table 3.1.RME	Chronic Daily Intake (CDI) (mg/kg-day) = $CW \times IR-W \times EF \times ED \times CF2 \times 1/BW \times 1/AT$
				IR-W	Ingestion Rate of Water	2	liters/day	EPA, 1997	
				EF	Exposure Frequency	350	days/year	EPA, 1991	
				ED	Exposure Duration	24	years	EPA, 1991	
				CF2	Conversion Factor 2	0.001	mg/µg	--	
				BW	Body Weight	70	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				AT-N	Averaging Time (Non-Cancer)	8,760	days	EPA, 1989	
				Child	Tap Water	CW	Chemical Concentration in Water	See Table 3.1.RME	
	IR-W	Ingestion Rate of Water	1			liters/day	EPA, 1997		
	EF	Exposure Frequency	350			days/year	EPA, 1991		
	ED	Exposure Duration	6			years	EPA, 1991		
	CF2	Conversion Factor 2	0.001			mg/µg	--		
	BW	Body Weight	15			kg	EPA, 1991		
	AT-C	Averaging Time (Cancer)	25,550			days	EPA, 1989		
	AT-N	Averaging Time (Non-Cancer)	2,190			days	EPA, 1989		
	Child/Adult	Tap Water	CW			Chemical Concentration in Water	See Table 3.1.RME	µg/l	See Table 3.1.RME
			IR-W-A	Ingestion Rate of Water, Adult	2	liters/day	EPA, 1997		
			IR-W-C	Ingestion Rate of Water, Child	1	liters/day	EPA, 1997		
			IR-W-Adj	Ingestion Rate of Water, Age-adjusted	1.09	liter-year/kg-day	calculated		
			EF	Exposure Frequency	350	days/year	EPA, 1991		
			ED-A	Exposure Duration, Adult	24	years	EPA, 1991		
			ED-C	Exposure Duration, Child	6	years	EPA, 1991		
			CF2	Conversion Factor 2	0.001	mg/µg	--		
BW-A			Body Weight, Adult	70	kg	EPA, 1991			
BW-C	Body Weight, Child	15	kg	EPA, 1991					
AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989					

TABLE 4.1 RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
Site 21, Indian Head

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference	Intake Equation/Model Name
Dermal	Resident	Adult	Tap Water	CW	Chemical Concentration in Water	See Table 3.1.RME	µg/l	See Table 3.1.RME	CDI (mg/kg-day) =
		Child	Tap Water	CW	Chemical Concentration in Water	See Table 3.1.RME	µg/l	See Table 3.1.RME	CDI (mg/kg-day) =
				DAevent	Dermally Absorbed Dose per Event	calculated	mg/cm ² -event	calculated	DAevent x SA x EV x EF x ED x 1/BW x 1/AT
				FA	Fraction absorbed water	chemical specific	dimensionless	EPA, 2004	
				Kp	Permeability Coefficient	chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm ² -event) =
				τ	Lag Time	chemical specific	hr/event	EPA, 2004	Kp x CW x t _{event} x CF2 x CF3
				t*	Time to Reach Steady-state Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	dimensionless	EPA, 2004	Organics :
				t _{event}	Event Time	0.58	hr/event	EPA, 2004	t _{event} <t*: DAevent (mg/cm ² -event) =
				SA	Skin Surface Area Available for Contact	18,000	cm ²	EPA, 2004	2 x FA x Kp x CW x (sqrt((6 x τ x t _{event})/π))
				EV	Event Frequency	1	events/day	EPA, 2004	x CF2 x CF3
				EF	Exposure Frequency	350	days/year	EPA, 2004	
				ED	Exposure Duration	24	years	EPA, 2004	t _{event} >t*: DAevent (mg/cm ² -event) =
				BW	Body Weight	70	kg	EPA, 1991	FA x Kp x CW x (t _{event} /(1+B) + 2 x τ x
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	((1 + 3B + 3B ²)/(1+B ²)) x CF2 x CF3
				AT-N	Averaging Time (Non-Cancer)	8,760	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	--	
				CF3	Conversion Factor 3	0.001	l/cm ³	--	
				DAevent	Dermally Absorbed Dose per Event	calculated	mg/cm ² -event	calculated	DAevent x SA x EV x EF x ED x 1/BW x 1/AT
				FA	Fraction absorbed water	chemical specific	dimensionless	EPA, 2004	
				Kp	Permeability Coefficient	chemical specific	cm/hr	EPA, 2004	Inorganics: DAevent (mg/cm ² -event) =
				τ	Lag Time	chemical specific	hr/event	EPA, 2004	Kp x CW x t _{event} x CF2 x CF3
				t*	Time to Reach Steady-state Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	dimensionless	EPA, 2004	Organics :
				t _{event}	Event Time	1.0	hr/event	EPA, 2004	t _{event} <t*: DAevent (mg/cm ² -event) =
				SA	Skin Surface Area Available for Contact	6,600	cm ²	EPA, 2004	2 x FA x Kp x CW x (sqrt((6 x τ x t _{event})/π))
				EV	Event Frequency	1	events/day	EPA, 2004	x CF2 x CF3
				EF	Exposure Frequency	350	days/year	EPA, 2004	
				ED	Exposure Duration	6	years	EPA, 2004	t _{event} >t*: DAevent (mg/cm ² -event) =
				BW	Body Weight	15	kg	EPA, 1991	FA x Kp x CW x (t _{event} /(1+B) + 2 x τ x
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	((1 + 3B + 3B ²)/(1+B ²)) x CF2 x CF3
				AT-N	Averaging Time (Non-Cancer)	2,190	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	--	
				CF3	Conversion Factor 3	0.001	l/cm ³	--	

TABLE 4.1.RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
Site 21, Indian Head

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Dermal	Resident	Child/Adult	Tap Water	CW	Chemical Concentration in Water	See Table 3.1.RME	µg/l	See Table 3.1.RME	$CDI \text{ (mg/kg-day)} = DA\text{-}Adj \times EF \times 1/AT$ $DA\text{-}Adj = (DA\text{-}event\text{-}A \times SA\text{-}A \times ED\text{-}A \times 1/BW\text{-}A) + (DA\text{-}event\text{-}C \times SA\text{-}C \times ED\text{-}C \times 1/BW\text{-}C)$ Inorganics: $DA\text{-}event \text{ (mg/cm}^2\text{-event)} = Kp \times CW \times t_{\text{event}} \times CF2 \times CF3$ Organics : $t_{\text{event}} < t^*$: $DA\text{-}event \text{ (mg/cm}^2\text{-event)} = 2 \times FA \times Kp \times CW \times (\text{sqrt}((6 \times \tau \times t_{\text{event}})/\pi)) \times CF2 \times CF3$ $t_{\text{event}} > t^*$: $DA\text{-}event \text{ (mg/cm}^2\text{-event)} = FA \times Kp \times CW \times (t_{\text{event}}/(1+B)) + 2 \times \tau \times ((1 + 3B + 3B^2)/(1+B^2)) \times CF2 \times CF3$
				DAevent-A	Dermally Absorbed Dose per Event, Adult	calculated	mg/cm ² -event	calculated	
DAevent-C				Dermally Absorbed Dose per Event, Child	calculated	mg/cm ² -event	calculated		
DA-Adj				Dermally Absorbed Dose, Age-adjusted	calculated	mg-year/event-kg	calculated		
FA				Fraction absorbed water	chemical specific	dimensionless	EPA, 2004		
K _p				Permeability Coefficient	chemical specific	cm/hr	EPA, 2004		
τ				Lag Time	chemical specific	hr/event	EPA, 2004		
t*				Time to Reach Steady-state Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	hours	EPA, 2004		
B				Epidermis	chemical specific	dimensionless	EPA, 2004		
t _{event} -A				Event Time, Adult	0.58	hr/event	EPA, 2004		
t _{event} -C				Event Time, Child	1.0	hr/event	EPA, 2004		
SA-A				Skin Surface Area, Adult	18,000	cm ²	EPA, 2004		
SA-C				Skin Surface Area, Child	6,600	cm ²	EPA, 2004		
EV				Event Frequency	1	events/day	EPA, 2004		
EF				Exposure Frequency	350	days/year	EPA, 2004		
ED-A				Exposure Duration, Adult	24	years	EPA, 2004		
ED-C				Exposure Duration, Child	6	years	EPA, 2004		
BW-A				Body Weight, Adult	70	kg	EPA, 1991		
BW-C				Body Weight, Child	15	kg	EPA, 1991		
AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989					
CF2	Conversion Factor 2	0.001	mg/µg	--					
CF3	Conversion Factor 3	0.001	l/cm ³	--					
Construction Worker	Adult	Adult	Water in Excavation Pit	CW	Chemical Concentration in Water	See Table 3.5.RME	µg/l	See Table 3.5.RME	$CDI \text{ (mg/kg-day)} = DA\text{-}event \times SA \times EV \times EF \times ED \times 1/BW \times 1/AT$ Inorganics: $DA\text{-}event \text{ (mg/cm}^2\text{-event)} = Kp \times CW \times t_{\text{event}} \times CF2 \times CF3$ Organics : $t_{\text{event}} < t^*$: $DA\text{-}event \text{ (mg/cm}^2\text{-event)} = 2 \times FA \times Kp \times CW \times (\text{sqrt}((6 \times \tau \times t_{\text{event}})/\pi)) \times CF2 \times CF3$ $t_{\text{event}} > t^*$: $DA\text{-}event \text{ (mg/cm}^2\text{-event)} = FA \times Kp \times CW \times (t_{\text{event}}/(1+B)) + 2 \times \tau \times ((1 + 3B + 3B^2)/(1+B^2)) \times CF2 \times CF3$
				DAevent	Dermally Absorbed Dose per Event	calculated	mg/cm ² -event	calculated	
				FA	Fraction absorbed water	chemical specific	dimensionless	EPA, 2004	
				K _p	Permeability Coefficient	chemical specific	cm/hr	EPA, 2004	
				τ	Lag Time	chemical specific	hr/event	EPA, 2004	
				t*	Time to Reach Steady-state Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	hours	EPA, 2004	
				B	Epidermis	chemical specific	dimensionless	EPA, 2004	
				t _{event}	Event Time	8	hr/day	(1)	
				SA	Skin Surface Area Available for Contact	5,700	cm ²	EPA, 2004, (3)	
				EV	Event Frequency	1	events/day	EPA, 2004	
				EF	Exposure Frequency	125	days/year	(2)	
				ED	Exposure Duration	1	years	EPA, 1991	
				BW	Body Weight	70	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				AT-N	Averaging Time (Non-Cancer)	365	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	--	
				CF3	Conversion Factor 3	0.001	l/cm ³	--	

TABLE 4.1.RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
Site 21, Indian Head

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference	Intake Equation/Model Name
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- (1) Professional judgment based on construction activities that would occur 8 hrs per day for the RME.
- (2) Assumed contact with groundwater during construction project would be 125 days/year.
- (3) Skin surface area in contact with groundwater assumed to be hands, forearms, lower legs, and feet.

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund. Vol.1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.

EPA, 1991: Risk Assessment Guidance for Superfund. Vol.1: Human Health Evaluation Manual - Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER Directive 9285.6-03.

EPA, 1997: Exposure Factors Handbook. EPA/600/P-95/002Fa.

EPA, 2004 . Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment (Final). EPA/540/R/99/005. July 2004.

TABLE 4.1.CTE
VALUES USED FOR DAILY INTAKE CALCULATIONS
CENTRAL TENDENCY EXPOSURE
Site 21, Indian Head

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Ingestion	Resident	Adult	Tap Water	CW	Chemical Concentration in Water	See Table 3.1.CTE	µg/l	See Table 3.1.CTE	Chronic Daily Intake (CDI) (mg/kg-day) = CW x IR-W x EF x ED x CF2 x 1/BW x 1/AT
				IR-W	Ingestion Rate of Water	1.4	liters/day	EPA, 1993	
				EF	Exposure Frequency	234	days/year	EPA, 1993	
				ED	Exposure Duration	9	years	EPA, 1993	
				CF2	Conversion Factor 2	0.001	mg/µg	--	
				BW	Body Weight	70	kg	EPA, 1991	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				AT-N	Averaging Time (Non-Cancer)	3,285	days	EPA, 1989	
				Child	Tap Water	CW	Chemical Concentration in Water	See Table 3.1.CTE	
	IR-W	Ingestion Rate of Water	1			liters/day	EPA, 1997		
	EF	Exposure Frequency	234			days/year	EPA, 1993		
	ED	Exposure Duration	6			years	EPA, 1991		
	CF2	Conversion Factor 2	0.001			mg/µg	--		
	BW	Body Weight	15			kg	EPA, 1991		
	AT-C	Averaging Time (Cancer)	25,550			days	EPA, 1989		
	AT-N	Averaging Time (Non-Cancer)	2,190			days	EPA, 1989		
	Child/Adult	Tap Water	CW			Chemical Concentration in Water	See Table 3.1.CTE	µg/l	See Table 3.1.CTE
			IR-W-A	Ingestion Rate of Water, Adult	1.4	liters/day	EPA, 1993		
			IR-W-C	Ingestion Rate of Water, Child	1	liters/day	EPA, 1997		
			IR-W-Adj	Ingestion Rate of Water, Age-adjusted	0.58	liter-year/kg-day	calculated		
			EF	Exposure Frequency	234	days/year	EPA, 1993		
			ED-A	Exposure Duration, Adult	9	years	EPA, 1993		
	ED-C	Exposure Duration, Child	6	years	EPA, 1991				
	CF2	Conversion Factor 2	0.001	mg/µg	--				
BW-A	Body Weight, Adult	70	kg	EPA, 1991					
BW-C	Body Weight, Child	15	kg	EPA, 1991					
AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989					

TABLE 4.1.CTE
VALUES USED FOR DAILY INTAKE CALCULATIONS
CENTRAL TENDENCY EXPOSURE
Site 21, Indian Head

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name		
Dermal	Resident	Adult	Tap Water	CW	Chemical Concentration in Water	See Table 3.1.CTE	µg/l	See Table 3.1.CTE	$CDI (mg/kg\text{-}day) = DA_{event} \times SA \times EV \times EF \times ED \times 1/BW \times 1/AT$ $DA_{event} \times SA \times EV \times EF \times ED \times 1/BW \times 1/AT$ Inorganics: $DA_{event} (mg/cm^2\text{-}event) = K_p \times CW \times t_{event} \times CF_2 \times CF_3$ Organics : $t_{event} < t^*$: $DA_{event} (mg/cm^2\text{-}event) = 2 \times FA \times K_p \times CW \times (\sqrt{t^* \times t_{event}}/t^*) \times CF_2 \times CF_3$ $t_{event} > t^*$: $DA_{event} (mg/cm^2\text{-}event) = FA \times K_p \times CW \times (t_{event}/(1+B) + 2 \times t \times ((1 + 3B + 3B^2)/(1+B)^2)) \times CF_2 \times CF_3$		
				DAevent	Dermally Absorbed Dose per Event	Calculated	mg/cm ² -event	calculated			
				FA	Fraction absorbed water	Chemical specific	dimensionless	EPA, 2004			
				K _p	Permeability Coefficient	Chemical specific	cm/hr	EPA, 2004			
				τ	Lag Time	Chemical specific	hr/event	EPA, 2004			
				t*	Time to Reach Steady-state Ratio of Permeability of Stratum Corneum to Epidermis	Chemical specific	hours	EPA, 2004			
				B		Chemical specific	dimensionless	EPA, 2004			
				t _{event}	Event Time	0.25	hr/event	EPA, 2004			
				SA	Skin Surface Area Available for Contact	18,000	cm ²	EPA, 2004			
				EV	Event Frequency	1	events/day	EPA, 2004			
		EF	Exposure Frequency	234	days/year	EPA, 1993					
		ED	Exposure Duration	9	years	EPA, 2001					
		BW	Body Weight	70	kg	EPA, 1991					
		AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989					
		AT-N	Averaging Time (Non-Cancer)	3,285	days	EPA, 1989					
		CF2	Conversion Factor 2	0.001	mg/µg	--					
		CF3	Conversion Factor 3	0.001	l/cm ³	--					
				Child	Tap Water	CW	Chemical Concentration in Water	See Table 3.1.CTE	µg/l	See Table 3.1.CTE	$CDI (mg/kg\text{-}day) = DA_{event} \times SA \times EV \times EF \times ED \times 1/BW \times 1/AT$ $DA_{event} \times SA \times EV \times EF \times ED \times 1/BW \times 1/AT$ Inorganics: $DA_{event} (mg/cm^2\text{-}event) = K_p \times CW \times t_{event} \times CF_2 \times CF_3$ Organics : $t_{event} < t^*$: $DA_{event} (mg/cm^2\text{-}event) = 2 \times FA \times K_p \times CW \times (\sqrt{t^* \times t_{event}}/t^*) \times CF_2 \times CF_3$ $t_{event} > t^*$: $DA_{event} (mg/cm^2\text{-}event) = FA \times K_p \times CW \times (t_{event}/(1+B) + 2 \times t \times ((1 + 3B + 3B^2)/(1+B)^2)) \times CF_2 \times CF_3$
						DAevent	Dermally Absorbed Dose per Event	Calculated	mg/cm ² -event	calculated	
						FA	Fraction absorbed water	Chemical specific	dimensionless	EPA, 2004	
K _p	Permeability Coefficient					Chemical specific	cm/hr	EPA, 2004			
τ	Lag Time					Chemical specific	hr/event	EPA, 2004			
t*	Time to Reach Steady-state Ratio of Permeability of Stratum Corneum to Epidermis					Chemical specific	hours	EPA, 2004			
B						Chemical specific	dimensionless	EPA, 2004			
t _{event}	Event Time					0.33	hr/event	EPA, 2004			
SA	Skin Surface Area Available for Contact					6,800	cm ²	EPA, 2004			
EV	Event Frequency					1	events/day	EPA, 2004			
EF	Exposure Frequency	234	days/year	EPA, 1993							
ED	Exposure Duration	6	years	EPA, 2001							
BW	Body Weight	15	kg	EPA, 1991							
AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989							
AT-N	Averaging Time (Non-Cancer)	2,190	days	EPA, 1989							
CF2	Conversion Factor 2	0.001	mg/µg	--							
CF3	Conversion Factor 3	0.001	l/cm ³	--							

TABLE 4.1.CTE
VALUES USED FOR DAILY INTAKE CALCULATIONS
CENTRAL TENDENCY EXPOSURE
Site 21, Indian Head

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name					
Dermal	Resident	Child/Adult	Tap Water	CW	Chemical Concentration in Water	See Table 3.1.CTE	µg/l	See Table 3.1.CTE	$CDI \text{ (mg/kg-day)} = DA\text{-Adj} \times EF \times 1/AT$ $DA\text{-Adj} = (DA\text{event-A} \times SA\text{-A} \times ED\text{-A} \times 1/BW\text{-A}) + (DA\text{event-C} \times SA\text{-C} \times ED\text{-C} \times 1/BW\text{-C})$ Inorganics: $DA\text{event} \text{ (mg/cm}^2\text{-event)} = Kp \times CW \times t_{\text{event}} \times CF2 \times CF3$ Organics: $t_{\text{event}} < t^*$: $DA\text{event} \text{ (mg/cm}^2\text{-event)} = 2 \times FA \times Kp \times CW \times (\text{sqrt}((6 \times \tau \times t_{\text{event}})/\pi)) \times CF2 \times CF3$ $t_{\text{event}} > t^*$: $DA\text{event} \text{ (mg/cm}^2\text{-event)} = FA \times Kp \times CW \times (t_{\text{event}}/(1+B) + 2 \times \tau \times ((1 + 3B + 3B^2)/(1+B^2))) \times CF2 \times CF3$					
				DAevent-A	Dermally Absorbed Dose per Event, Adult	Calculated	mg/cm ² -event	calculated						
				DAevent-C	Dermally Absorbed Dose per Event, Child	Calculated	mg/cm ² -event	calculated						
				DA-Adj	Dermally Absorbed Dose, Age-adjusted	Calculated	mg-year/event-kg	calculated						
				FA	Fraction absorbed water	Chemical specific	dimensionless	EPA, 2004						
				K _p	Permeability Coefficient	Chemical specific	cm/hr	EPA, 2004						
				τ	Lag Time	Chemical specific	hr/event	EPA, 2004						
				t*	Time to Reach Steady-state	Chemical specific	hours	EPA, 2004						
				B	Ratio of Permeability of Stratum Corneum to Epidermis	Chemical specific	dimensionless	EPA, 2004						
				t _{event} -A	Event Time, Adult	0.25	hr/event	EPA, 2004						
				t _{event} -C	Event Time, Child	0.33	hr/event	EPA, 2004						
				SA-A	Skin Surface Area, Adult	18,000	cm ²	EPA, 2004						
				SA-C	Skin Surface Area, Child	6,600	cm ²	EPA, 2004						
				EV	Event Frequency	1	events/day	EPA, 2004						
				EF	Exposure Frequency	234	days/year	EPA, 1993						
				ED-A	Exposure Duration, Adult	9	years	EPA, 2001						
				ED-C	Exposure Duration, Child	6	years	EPA, 2001						
				BW-A	Body Weight, Adult	70	kg	EPA, 1991						
				BW-C	Body Weight, Child	15	kg	EPA, 1991						
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989						
				CF2	Conversion Factor 2	0.001	mg/µg	--						
				CF3	Conversion Factor 3	0.001	l/cm ³	--						
					Construction Worker	Adult	Water in Excavation Pit	CW		Chemical Concentration in Water	See Table 3.5.CTE	µg/l	See Table 3.5.CTE	$CDI \text{ (mg/kg-day)} = DA\text{event} \times SA \times EV \times EF \times ED \times 1/BW \times 1/AT$ Inorganics: $DA\text{event} \text{ (mg/cm}^2\text{-event)} = Kp \times CW \times t_{\text{event}} \times CF2 \times CF3$ Organics: $t_{\text{event}} < t^*$: $DA\text{event} \text{ (mg/cm}^2\text{-event)} = 2 \times FA \times Kp \times CW \times (\text{sqrt}((6 \times \tau \times t_{\text{event}})/\pi)) \times CF2 \times CF3$ $t_{\text{event}} > t^*$: $DA\text{event} \text{ (mg/cm}^2\text{-event)} = FA \times Kp \times CW \times (t_{\text{event}}/(1+B) + 2 \times \tau \times ((1 + 3B + 3B^2)/(1+B^2))) \times CF2 \times CF3$
								DAevent		Dermally Absorbed Dose per Event	Calculated	mg/cm ² -event	calculated	
								FA		Fraction absorbed water	Chemical specific	dimensionless	EPA, 2004	
								K _p		Permeability Coefficient	Chemical specific	cm/hr	EPA, 2004	
τ	Lag Time	Chemical specific	hr/event					EPA, 2004						
t*	Time to Reach Steady-state	Chemical specific	hours					EPA, 2004						
B	Ratio of Permeability of Stratum Corneum to Epidermis	Chemical specific	dimensionless					EPA, 2004						
t _{event}	Event Time	4	hr/day					(1)						
SA	Skin Surface Area Available for Contact	5,700	cm ²					EPA, 2001, (3)						
EV	Event Frequency	1	events/day					EPA, 2001						
EF	Exposure Frequency	125	days/year					(2)						
ED	Exposure Duration	1	years					EPA, 1991						
BW	Body Weight	70	kg					EPA, 1991						
AT-C	Averaging Time (Cancer)	25,550	days					EPA, 1989						
AT-N	Averaging Time (Non-Cancer)	365	days					EPA, 1989						
CF2	Conversion Factor 2	0.001	mg/µg					--						
CF3	Conversion Factor 3	0.001	l/cm ³					--						

TABLE 4.1.CTE
VALUES USED FOR DAILY INTAKE CALCULATIONS
CENTRAL TENDENCY EXPOSURE
Site 21, Indian Head

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
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- (1) Professional judgement assuming 1/2 RME value for CT.
- (2) Assumed contact with groundwater during construction project would be 125 days/year.
- (3) Skin surface area in contact with groundwater assumed to be hands, forearms, lower legs, and feet.

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund. Vol.1: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA, 1991: Risk Assessment Guidance for Superfund. Vol.1: Human Health Evaluation Manual - Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER Directive 9285.6-03.
EPA, 1993: Superfund's Standard Default Exposure Factors for the Central Tendency and Reasonable Maximum Exposure.
EPA, 1997: Exposure Factors Handbook. EPA/600/P-95/002Fa.
EPA, 2001: Risk Assessment Guidance for Superfund. Vol.1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Interim. EPA/540/R/99/005.
EPA, 2004. Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment (Final)). EPA/540/R/99/005. July 2004.

TABLE 5.1
NON-CANCER TOXICITY DATA – ORAL/DERMAL
Site 21
Indian Head

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Oral to Dermal Adjustment Factor (1)	Adjusted Dermal RfD (2)	Units	Primary Target Organ	Combined Uncertainty/Modifying Factors	Sources of RfD: Target Organ	Dates of RfD: Target Organ (3) (MM/DD/YY)
Iron	Chronic	7.0E-01	mg/kg-day	N/A	7.0E-01	mg/kg-day	Gastrointestinal	1.5	PPRTV	9/11/2006
	Subchronic	7.0E-01	mg/kg-day	N/A	7.0E-01	mg/kg-day	Gastrointestinal	1.5	PPRTV	9/11/2006
Manganese	Chronic Subchronic	2.4E-02 N/A	mg/kg-day	4%	9.6E-04	mg/kg-day	Central Nervous System	1/1	IRIS	01/13/09

(1) Source: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment). Final.

Section 4.2 and Exhibit 4-1. USEPA recommends that the oral RfD should not be adjusted to estimate the absorbed dose for compounds when the absorption efficiency is greater than 50%.

Constituents that do not have oral absorption efficiencies reported on this table were assumed to have an oral absorption efficiency of 100%.

(2) Adjusted Dermal RfD = RfD (oral) x Absorption Efficiency or ABS_{DI}

(3) For IRIS values, provide the date IRIS was searched.

Definitions: IRIS = Integrated Risk Information System

TABLE 5.2
NON-CANCER TOXICITY DATA – INHALATION
Site 21
Indian Head

Chemical of Potential Concern	Chronic/ Subchronic	Value Inhalation RfC	Units	Adjusted Inhalation RfD (1)	Units	Primary Target Organ	Combined Uncertainty/Modifying Factors	Sources of RfC:RfD: Target Organ	Dates (2) (MM/DD/YY)
Iron	Chronic Subchronic	N/A N/A							
Manganese	Chronic Subchronic	5.0E-05 N/A	mg/m ³	1.4E-05	mg/kg-day	CNS	1000/1	IRIS	12/22/2008

N/A = Not Applicable

- (1) Provide equation used for derivation in text.
(2) For IRIS values, the date IRIS was searched.

Definitions: IRIS = Integrated Risk Information System

TABLE 6.1
 CANCER TOXICITY DATA -- ORAL/DERMAL
 Site 21
 Indian Head

Chemical of Potential Concern	Oral Cancer Slope Factor	Oral to Dermal Adjustment Factor	Adjusted Dermal Cancer Slope Factor (1)	Units	EPA Carcinogen Group	Source	Date (2) (MM/DD/YY)
Iron	N/A						
Manganese	N/A						

N/A-Not available

IRIS = Integrated Risk Information System

HEAST= Health Effects Assessment Summary Tables

NCEA = National Center for Environmental Assessment

PPRTV = Provisional Peer-Reviewed Toxicity Value

EPA Carcinogen Group:

A - Human carcinogen

B1 - Probable human carcinogen - indicates that limited human data are available

B2 - Probable human carcinogen - indicates sufficient evidence in animals and inadequate or no evidence in humans

C - Possible human carcinogen

D - Not classifiable as a human carcinogen

E - Evidence of noncarcinogenicity

(1) Refer to RAGS, Part E. July 2004.

(2) For IRIS values, provide the date IRIS was searched.

For HEAST values, provide the date of HEAST.

For NCEA values, provide article date provided by NCEA.

For RBC values, provide the date of last change in the Tables.

TABLE 6.2
 CANCER TOXICITY DATA -- INHALATION
 Site 21
 Indian Head

Chemical of Potential Concern	Unit Risk	Units	Adjustment (1)	Inhalation Cancer Slope Factor	Units	Weight of Evidence/ Cancer Guidance Description	Source	Date (2) (MM/DD/YY)
Iron	N/A							
Manganese	N/A							

IRIS = Integrated Risk Information System

HEAST= Health Effects Assessment Summary Tables

NCEA = National Center for Environmental Assessment

PPRTV = Provisional Peer-Reviewed Toxicity Value

N/A = Not Available

(1) Adjustment Factor applied to Unit Risk to calculate Inhalation Slope Factor =
 $70\text{kg} \times 1/20\text{m}^3/\text{day} \times 1000\text{ug}/\text{mg}$

(2) For IRIS values, provide the date IRIS was searched.

For HEAST values, provide the date of HEAST.

For NCEA values, provide the date of the article provided by NCEA.

For RBC values, provide the date of last change in the Tables.

EPA Group:

A - Human carcinogen

B1 - Probable human carcinogen - indicates that limited human data are available

B2 - Probable human carcinogen - indicates sufficient evidence in animals and inadequate or no evidence in humans

C - Possible human carcinogen

D - Not classifiable as a human carcinogen

E - Evidence of noncarcinogenicity

TABLE 7.1.RME
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 REASONABLE MAXIMUM EXPOSURE
 Site 21, Indian Head

Scenario Timeframe: Future
 Receptor Population: Resident
 Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Tap Water	Ingestion	Iron	9.0E+04	ug/L	N/A	N/A	N/A	N/A	N/A	2.5E+00	mg/kg/day	7.0E-01	mg/kg/day	3.5E+00
				Manganese	4.7E+03	ug/L	N/A	N/A	N/A	N/A	N/A	1.3E-01	mg/kg/day	2.4E-02	mg/kg/day	5.3E+00
			Exp Route Total						N/A						8.9E+00	
			Dermal Absorption	Iron	9.0E+04	ug/L	N/A	N/A	N/A	N/A	N/A	1.3E-02	mg/kg/day	7.0E-01	mg/kg/day	1.8E-02
				Manganese	4.7E+03	ug/L	N/A	N/A	N/A	N/A	N/A	6.7E-04	mg/kg/day	9.6E-04	mg/kg/day	6.9E-01
			Exp Route Total												7.1E-01	
			Exposure Point Total													9.6E+00
			Exposure Medium Total													9.6E+00
			Medium Total													9.6E+00
			Total of Receptor Risks Across All Media										N/A	Total of Receptor Hazards Across All Media		

Notes-
 N/A = Not applicable.
 DAevent for exposure to groundwater while showering is calculated on Table 7.1.RME Supplement A.

TABLE 7.1 CTEE
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 CENTRAL TENDENCY EXPOSURE
 Site 21, Indian Head

Scenario Timeframe: Future
 Receptor Population: Resident
 Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Tap Water	Ingestion	Iron	2.6E+04	ug/L	N/A	N/A	N/A	N/A	N/A	7.3E-01	mg/kg/day	7.0E-01	mg/kg/day	1.0E+00
				Manganese	2.1E+03	ug/L	N/A	N/A	N/A	N/A	N/A	2.6E-02	mg/kg/day	2.4E-02	mg/kg/day	1.1E+00
			Exp. Route Total					N/A							2.1E+00	
			Dermal Absorption	Iron	2.6E+04	ug/L	N/A	N/A	N/A	N/A	N/A	1.1E-03	mg/kg/day	7.0E-01	mg/kg/day	1.6E-03
				Manganese	2.1E+03	ug/L	N/A	N/A	N/A	N/A	N/A	8.5E-05	mg/kg/day	9.6E-04	mg/kg/day	8.9E-02
			Exp. Route Total						N/A							9.0E-02
Exposure Point Total														2.2E+00		
Medium Total															2.2E+00	
Total of Receptor Risks Across All Media										N/A	Total of Receptor Hazards Across All Media					2.2E+00

Notes-
 N/A = Not applicable.

TABLE 7.2.RME
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 REASONABLE MAXIMUM EXPOSURE
 Site 21, Indian Head

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations					
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient	
							Value	Units	Value	Units		Value	Units	Value	Units		
Groundwater	Groundwater	Tap Water	Ingestion	Iron	9.0E+04	ug/L	N/A	N/A	N/A	N/A	N/A	5.8E+00	mg/kg/day	7.0E-01	mg/kg/day	8.2E+00	
				Manganese	4.7E+03	ug/L	N/A	N/A	N/A	N/A	N/A	3.0E-01	mg/kg/day	2.4E-02	mg/kg/day	1.2E+01	
			Exp. Route Total					N/A							2.1E+01		
			Dermal Absorption	Iron	9.0E+04	ug/L	N/A	N/A	N/A	N/A	N/A	3.8E-02	mg/kg/day	7.0E-01	mg/kg/day	5.4E-02	
				Manganese	4.7E+03	ug/L	N/A	N/A	N/A	N/A	N/A	2.0E-03	mg/kg/day	9.6E-04	mg/kg/day	2.1E+00	
			Exp. Route Total												2.1E+00		
			Exposure Point Total													2.3E+01	
			Exposure Medium Total													2.3E+01	
			Medium Total														2.3E+01
			Total of Receptor Risks Across All Media										N/A	Total of Receptor Hazards Across All Media			

Notes-
 N/A = Not applicable.
 DAevent for exposure to groundwater while bathing is calculated on Table 7.2.RME Supplement A.

TABLE 7.2.CTE
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 CENTRAL TENDENCY EXPOSURE
 Site 21, Indian Head

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations					
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient	
							Value	Units	Value	Units		Value	Units	Value	Units		
Groundwater	Groundwater	Tap Water	Ingestion	Iron	2.6E+04	ug/L	N/A	N/A	N/A	N/A	N/A	1.1E+00	mg/kg/day	7.0E-01	mg/kg/day	1.6E+00	
				Manganese	2.1E+03	ug/L	N/A	N/A	N/A	N/A	N/A	8.6E-02	mg/kg/day	2.4E-02	mg/kg/day	3.7E+00	
				Exp. Route Total							N/A						5.3E+00
			Dermal Absorption	Iron	2.6E+04	ug/L	N/A	N/A	N/A	N/A	N/A	1.9E-03	mg/kg/day	7.0E-01	mg/kg/day	2.7E-03	
				Manganese	2.1E+03	ug/L	N/A	N/A	N/A	N/A	N/A	1.5E-04	mg/kg/day	9.6E-04	mg/kg/day	1.5E-01	
				Exp. Route Total							N/A						1.5E-01
				Exposure Point Total							N/A						5.4E+00
				Exposure Medium Total							N/A						5.4E+00
				Medium Total							N/A						5.4E+00
			Total of Receptor Risks Across All Media										N/A	Total of Receptor Hazards Across All Media			

Notes-

N/A = Not applicable.

DAevent for exposure to groundwater while bathing is calculated on Table 7.2.CTE Supplement A.

TABLE 7.3.RME
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 REASONABLE MAXIMUM EXPOSURE
 Site 21, Indian Head

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations						
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient		
							Value	Units	Value	Units		Value	Units	Value	Units			
Groundwater	Groundwater	Tap Water	Ingestion	Iron	9.0E+04	ug/L	1.3E+00	mg/kg/day	N/A	1/mg/kg/day	N/A	N/A	N/A	N/A	N/A	N/A		
				Manganese	4.7E+03	ug/L	7.0E-02	mg/kg/day	N/A	1/mg/kg/day	N/A	N/A	N/A	N/A	N/A	N/A		
				Exp. Route Total							0.0E+00						N/A	
			Dermal Absorption	Iron	9.0E+04	ug/L	7.7E-03	mg/kg/day	N/A	1/mg/kg/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
				Manganese	4.7E+03	ug/L	4.0E-04	mg/kg/day	N/A	1/mg/kg/day	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
				Exp. Route Total									0.0E+00					N/A
				Exposure Point Total									0.0E+00					N/A
	Exposure Medium Total									0.0E+00					N/A			
Medium Total										0.0E+00					N/A			
Total of Receptor Risks Across All Media											0.0E+00	Total of Receptor Hazards Across All Media				N/A		

Notes-

N/A = Not applicable.

DAevent for exposure to groundwater while showering and bathing are calculated on Tables 7.1.RME Supplement A and 7.2.RME Supplement A.

TABLE 7.3.CTE
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 CENTRAL TENDENCY EXPOSURE
 Site 21, Indian Head

Scenario Timeframe: Future
 Receptor Population: Construction Worker
 Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations								
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient				
							Value	Units	Value	Units		Value	Units	Value	Units					
Groundwater	Groundwater	Water in Excavation Pit	Dermal Absorption	Iron	2.6E+04	ug/L	2.9E-04	mg/kg/day	N/A		N/A	3.0E-03	mg/kg/day	7.0E-01	mg/kg/day	4.2E-03				
				Manganese	2.1E+03	ug/L	3.3E-06	mg/kg/day	N/A		N/A	2.3E-04	mg/kg/day	9.6E-04	mg/kg/day	2.4E-01				
			Exp. Route Total														0.0E+00	2.4E-01		
			Exposure Point Total															0.0E+00	2.4E-01	
		Exposure Medium Total																0.0E+00	2.4E-01	
Medium Total																	0.0E+00	2.4E-01		
Total of Receptor Risks Across All Media																		0.0E+00	Total of Receptor Hazards Across All Media	2.4E-01

Notes-

N/A = Not applicable.

DAevent for exposure to groundwater during excavation activities calculated on Table 7.3.CTE Supplement A.

TABLE 7.4.RME
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 REASONABLE MAXIMUM EXPOSURE
 Site 21, Indian Head

Scenario Timeframe: Future
 Receptor Population: Construction Worker
 Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations						
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient		
							Value	Units	Value	Units		Value	Units	Value	Units			
Groundwater	Groundwater	Water in Excavation Pit	Dermal Absorption	Iron	9.0E+04	ug/L	2.9E-04	mg/kg/day	N/A		N/A	2.0E-02	mg/kg/day	7.0E-01	mg/kg/day	2.9E-02		
				Manganese	4.7E+03	ug/L	1.5E-05	mg/kg/day	N/A		N/A	1.0E-03	mg/kg/day	9.6E-04	mg/kg/day	1.1E+00		
			Exp. Route Total														1.1E+00	
			Exposure Point Total															1.1E+00
			Exposure Medium Total															
Medium Total																	1.1E+00	
Total of Receptor Risks Across All Media										0.0E+00	Total of Receptor Hazards Across All Media					1.1E+00		

Notes-

N/A = Not applicable.

DAevent for exposure to groundwater during excavation activities calculated on Table 7.4.RME Supplement A.

TABLE 9.1.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE

Site 21
Indian Head

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient					
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
Groundwater	Groundwater	Tap Water	Iron	N/A	N/A	N/A	0.0E+00	Gastrointestinal	3.5E+00	NA	1.8E-02	3.5E+00	
			Manganese	N/A	N/A	N/A	0.0E+00		Central Nervous System	5.3E+00	NA	6.9E-01	6.0E+00
			Chemical Total	0.0E+00	0.0E+00	0.0E+00	0.0E+00		8.9E+00	N/A	7.1E-01	9.6E+00	
			Exposure Point Total					0.0E+00					9.6E+00
Exposure Medium Total						0.0E+00					9.6E+00		
Medium Total												0.0E+00	9.6E+00
Receptor Total												0.0E+00	Receptor HI Total 9.6E+00

Total Gastrointestinal HI Across All Media = 3.5E+00
Total Neurological HI Across All Media = 6.0E+00

TABLE 9.1.CTE
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
CENTRAL TENDENCY EXPOSURE
Site 21
Indian Head

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient					
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
Groundwater	Groundwater	Tap Water	Iron	N/A	N/A	N/A	0.0E+00	Gastrointestinal	1.0E+00	NA	1.1E+00	2.2E+00	
			Manganese	N/A	N/A	N/A	0.0E+00		Central Nervous System	1.1E+00	NA	8.9E-02	1.2E+00
			Chemical Total	0.0E+00	0.0E+00	0.0E+00	0.0E+00		2.1E+00	N/A	1.2E+00	3.4E+00	
			Exposure Point Total					0.0E+00					3.4E+00
		Exposure Medium Total					0.0E+00					3.4E+00	
Medium Total								0.0E+00					3.4E+00
Receptor Total								0.0E+00	Receptor HI Total				3.4E+00

Total Gastrointestinal HI Across All Media =	2.2E+00
Total Neurological HI Across All Media =	1.2E+00

TABLE 9.2.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
Site 21
Indian Head

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient					
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
Groundwater	Groundwater	Tap Water	Iron	N/A	N/A	N/A	0.0E+00	Gastrointestinal	8.2E+00	NA	5.4E-02	8.3E+00	
			Manganese	N/A	N/A	N/A	0.0E+00		Central Nervous System	1.2E+01	NA	2.1E+00	1.4E+01
			Chemical Total	0.0E+00	0.0E+00	0.0E+00	0.0E+00		2.1E+01	N/A	2.1E+00	2.3E+01	
			Exposure Point Total					0.0E+00					2.3E+01
			Exposure Medium Total					0.0E+00					2.3E+01
Medium Total					0.0E+00					2.3E+01			
Receptor Total					0.0E+00					Receptor HI Total	2.3E+01		

Total Gastrointestinal HI Across All Media =	8.3E+00
Total Neurological HI Across All Media =	1.4E+01

TABLE 9.2.CTE
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
CENTRAL TENDENCY EXPOSURE
Site 21
Indian Head

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Tap Water	Iron	N/A	N/A	N/A	0.0E+00	Gastrointestinal	1.6E+00	NA	2.7E-03	1.6E+00
			Manganese	N/A	N/A	N/A	0.0E+00		Central Nervous System	3.7E+00	NA	1.5E-01
			Chemical Total	0.0E+00	0.0E+00	0.0E+00	0.0E+00		5.3E+00	N/A	1.5E-01	5.4E+00
			Exposure Point Total					0.0E+00				
Exposure Medium Total						0.0E+00					5.4E+00	
Medium Total						0.0E+00					5.4E+00	
Receptor Total						0.0E+00	Receptor HI Total				5.4E+00	

Total Gastrointestinal HI Across All Media =	1.6E+00
Total Neurological HI Across All Media =	3.8E+00

TABLE 9.3.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE

Site 21
Indian Head

Scenario Timeframe: Future
Receptor Population: Resident
Receptor Age: Child/Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient					
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
Groundwater	Groundwater	Tap Water	Iron	N/A	N/A	N/A	0.0E+00	Gastrointestinal Central Nervous System	N/A	NA	N/A	0.0E+00	
			Manganese	N/A	N/A	N/A	0.0E+00		N/A	NA	N/A	0.0E+00	
			Chemical Total	0.0E+00	0.0E+00	0.0E+00	0.0E+00		0.0E+00	N/A	0.0E+00	0.0E+00	
			Exposure Point Total					0.0E+00					0.0E+00
		Exposure Medium Total					0.0E+00					0.0E+00	
Medium Total								0.0E+00					0.0E+00
Receptor Total								0.0E+00	Receptor HI Total				0.0E+00

TABLE 9.3.CTE
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
CENTRAL TENDENCY EXPOSURE
Site 21
Indian Head

Scenario Timeframe: Future
Receptor Population: Construction Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Tap Water	Iron	N/A	N/A	N/A	0.0E+00	Gastrointestinal	N/A	NA	4.2E-03	4.2E-03
				N/A	N/A	N/A	0.0E+00		Central Nervous System	N/A	NA	2.4E-01
			Chemical Total	0.0E+00	0.0E+00	0.0E+00	0.0E+00		0.0E+00	N/A	2.4E-01	2.4E-01
			Exposure Point Total					0.0E+00				
Exposure Medium Total						0.0E+00					2.4E-01	
Medium Total							0.0E+00					2.4E-01
Receptor Total							0.0E+00	Receptor HI Total				2.4E-01

Total Gastrointestinal HI Across All Media =	4.2E-03
Total Neurological HI Across All Media =	2.4E-01

TABLE 9.4.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
Site 21
Indian Head

Scenario Timeframe: Future
Receptor Population: Construction Worker
Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient					
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
Groundwater	Groundwater	Tap Water	Iron	N/A	N/A	N/A	0.0E+00	Gastrointestinal	N/A	NA	2.9E-02	2.9E-02	
			Manganese	N/A	N/A	N/A	0.0E+00						Central Nervous System
			Chemical Total	0.0E+00	0.0E+00	0.0E+00	0.0E+00		0.0E+00	N/A	1.1E+00	1.1E+00	
			Exposure Point Total					0.0E+00					1.1E+00
Exposure Medium Total						0.0E+00					1.1E+00		
Medium Total												0.0E+00	
Receptor Total												0.0E+00	
												Receptor HI Total	1.1E+00

Total Gastrointestinal HI Across All Media =	2.9E-02
Total Neurological HI Across All Media =	1.1E+00