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JEB FORT STORY, VA
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E-MAIL TRANSMITTING REVISED RESPONSES TO VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY COMMENTS 80TH DIVISION RESERVE SITE REMEDIAL INVESTIGATION REPORT FORT STORY VA
5/27/2008
MALCOLM PIRNIE

file: 6C.16

NO comments from FE.

Called Tony on 30 MAY 08 and approved Submission of RTCs

Bateman, Joanna G Ms CIV USA IMCOM

From:	Pace, Tony [TPace@PIRNIE.COM]
Sent:	Tuesday, May 27, 2008 2:19 PM
To:	Bateman, Joanna G Ms CIV USA IMCOM
Cc:	Michel, Amber A Miss CTR USA IMCOM
Subject:	80th DRS revised RI and RTCs
Attachments:	Responses to VDEQ Comments - 80th DRS RI.doc; Final Section 6.doc; Final Section 8.doc

Responses to VDEQ Comments - 8...

Final Section 6.doc (489 KB)

Final Section 8.doc (486 KB)

Joanna,

We have attached the revised responses to VDEQ comments and Sections 6 and 8 of the 80th DRS RI Report based on your concerns about the vapor intrusion model and the text in the recommendations section. We ran the model and included it in the revised text. TCE and PCE risk fell within the EPA target remedial goal of 10-4 to 10-6.

Take a look and get back to us with any additional comments so that we can address them and forward the package onto VDEQ.

Anthony Pace

Associate

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by target organ and formalizing the background comparison may help with risk management decisions for this site.

Response:

It is expected that land use controls will be implemented at the site since there are exceedences of the MCLs in groundwater at the site; albeit, in only one well (MW-9) during the most recent sampling event in 2004. This will be discussed in detail in the Decision Document to be prepared for the site.

It is noted that VDEQ has an antidegradation policy for groundwater (9 VAC 25-280-30), and this policy will be discussed in the Decision Document for the site; however, since there are no current or reasonably anticipated users for groundwater at the site, no further analysis in the risk assessment related to the consumption of groundwater as drinking water is warranted. The purpose of the risk assessment is to identify and characterize current or reasonability anticipated users of the site, not a worst case scenario such as use of the groundwater as a potable water source. The antidegradation policy is not a consideration during the risk assessment but is more related to ultimate control and use of the site which the subsequent Decision Document will address.

A previous removal action has been completed at the site which included the excavation of approximately 3,500 tons of petroleum-contaminated soils and 30 tons of PCE-contaminated soils. Based on the removal of the source area for the contaminated groundwater and the low concentrations of VOCs in groundwater, it is expected that natural recovery will continue at the site and these concentrations should decrease to below MCLs over time. It should be noted that MCL exceedences were only identified in one well (MW-9) during the 2004 sampling event with only TCE (7.5 µg/L) and PCE (6.3 µg/L) slightly exceeding their respective MCLs of 5 µg/L. It should be noted that the 95th UCL for these compounds is below their respective MCL. A long-term monitoring program will be presented in the Decision Document that describes how the contaminant trends will be tracked at the site.

Some additional text has been added to the end of Section 8.4 to discuss future actions at the site.

Specific Comments:

2. (Page 1-3, Section 1.2.2)
Since there was an antifreeze storage tank at the site, did any of the sampling events include analysis for antifreeze ingredients such as ethylene glycol or propylene glycol?

Response: No.

The response indicates that antifreeze ingredients were not sampled for in the area of the antifreeze tank. Samples should be collected or a rationale should be presented for not doing so.

Additional Response:

The antifreeze AST was installed on a raised, bermed concrete platform with a valved outlet for draining any collected stormwater. There are no records of any spills or leaks from the secondary containment area around the UST, therefore, investigations of potential impacts from this AST has not been warranted.

4. (Page 6-1, Section 6.1)
The final version of RAGS, Part E (EPA, 2004) should be cited rather than the interim version.

Response: Text revised.

The date was changed on the reference but "interim" should be changed to "final".

Response:

"Interim" has been changed to "final".

6. (Page 6-17, Section 6.4.2)
The exposure assessment should also consider the potential for vapor intrusion into buildings from contaminated groundwater.

Response: Additional text added to Section 6.4.1 assessing the vapor intrusion scenario.

The comment requested an assessment of the potential for vapor intrusion into buildings. The revision indicates that since there are no buildings currently located at the site, the scenario would not be evaluated for current land use. However, the response does not address future buildings. If the pathway is not assessed, a prohibition on future building will be needed.

Response:

The vapor intrusion model and associated potentially exposed population (future commercial/industrial workers within structures) has been included and assessed in the revised Section 6.

Additional Comments:

Table 6-12:
For future assessments note that the equation for dermal exposure to groundwater is different for organics and inorganics. RAGS, Part E should be consulted for the organic equations.

Response:

Comment noted.

Section 8.4:
DEQ cannot concur with a no further action decision. Additional evaluation of groundwater risk needs to be conducted, as noted above. Also, LUCs will be needed since a residential evaluation was not conducted. LUCs are considered a remedial action.

Response:

The additional evaluation of groundwater as it relates to vapor intrusion has been discussed above. LUC issues were also discussed above. Text stating no further action has been deleted since additional action in the form of LTM and LUCs are anticipated. These will be discussed in the Decision Document to be prepared for the site.

6.1 INTRODUCTION

This human health risk assessment (HHRA) presents an assessment of potential human health risks associated with constituents detected at the 80th DRS at Fort Story, Virginia. The objectives of the assessment are (1) to provide an analysis of baseline risk, currently and in the future, in the absence of any major action to control or mitigate site contamination, and (2) to assist in determining the need for remediation. It provides a basis for comparing a variety of remedial alternatives, and determining, which will be the most protective of human health.

The HHRA presents an assessment of potential human health risks associated with exposure to constituents detected at or migrating from the site. The HHRA follows guidance provided in the following documents:

- *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part A)*, EPA, 1989a
- *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual (Part B)*, EPA, 1989b
- *Risk Assessment Guidance for Superfund, Volume I: Human Health. Supplemental Guidance. "Standard Default Exposure Factors"*, EPA, 1991a
- *Selecting Exposure Routes and Contaminants of Concern by Risk-based Screening*, EPA Region III, 1993a
- *Human Health Evaluation Manual. Supplemental Guidance: Standard Default Exposure Factors.* U.S. Environmental Protection Agency, 1995.
- *Assessing Dermal Exposure from Soil.* U.S. Environmental Protection Agency, Region III, 1995.
- *Risk-Based Concentration Table*, EPA Region III, April 2003.
- *Exposure Factors Handbook*, EPA, 1997
- *Guidance for Data Usability in Risk Assessment, Part 2*, EPA, 1992a
- *RAGS; Part E, Supplemental Guidance for Dermal Risk Assessment, Final Report*, USEPA, 2004

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- *Soil Screening Levels* and *Supplements* (EPA, 1996 and 2001b).

- *Virginia Voluntary Remediation Program Risk Assessment Guidance,* VDEQ, June 2003.
- *Updated Dermal Exposure Assessment Guidance.* U.S. Environmental Protection Agency, Region III, 2003.
- *Groundwater Resources of the Four Cities Area, Virginia.* Commonwealth of Virginia State Water Control Board (SWCB), 1981.
- *Arsenic in ground water of the United States.* USGS, et al, 2003. http://co.water.usgs.gov/trace/arsenic/

6.1.1 Objectives

The goal of the HHRA process is to provide a framework for developing the risk information necessary to assist decision-making at the site. Specific objectives include:

- Provide an analysis of baseline human health risks and help determine the need for remedial action at the site.
- Provide a basis for determining levels of chemicals that can remain at the site and still be adequately protective of public and Fort Story personnel health.
- Provide a basis for comparing potential health impacts of various remedial alternatives at the site.
- Provide a consistent process for evaluating and documenting public health threats at the site.

6.1.2 HHRA Components

There are four components to the HHRA process: (1) hazard identification; (2) exposure assessment; (3) toxicity assessment; and (4) risk characterization. Each step is described briefly as follows:

- **Hazard identification** involves gathering and analyzing the site data relevant to the human health evaluation and identifying the chemicals of potential concern (COPC) at the site that are the focus of the risk assessment process. The selection of such chemicals is based on a number of parameters, including the frequency of detection and concentration in each environmental medium, environmental fate and transport characteristics, intrinsic toxicity and the likelihood of human exposure via significant exposure routes.

- **Exposure assessments** are conducted to estimate the magnitude of actual and/or potential human exposures, the frequency and duration of these exposures, and the pathways by which humans are exposed. In the exposure assessment, reasonable maximum estimates of exposure are developed for both current and future land-use assumptions. Conducting an exposure assessment involves analyzing constituent releases, identifying exposed populations, identifying all potential pathways of exposure, estimating exposure point concentrations for specific pathways and estimating contaminant intakes for specific pathways. The results of this assessment are pathway-specific intakes for current and future exposures to individual substances.

- **Toxicity assessments** consider the types of adverse health effects associated with chemical exposures, the relationship between magnitude of exposure and adverse effects and related uncertainties such as the weight of evidence of a particular chemical's carcinogenicity in humans. Qualitative and quantitative toxicity data for each COPC are summarized, and appropriate guidance levels with which to characterize risks are identified.

- **Risk characterization** summarizes and combines outputs of the exposure and toxicity assessments to characterize baseline risk, both in quantitative expressions and qualitative statements. The likelihood and magnitude of adverse health risks are estimated in this step, in the form of noncancer hazard quotients and cancer risks.

The selection of COPCs will be made based on the methodology established in to EPA Region III's guidance document entitled *Selecting Exposure Routes and Contaminants of Concern by Risk-Based Screening*. The process includes the following steps:

- Data Quality Evaluation which includes assessing the appropriateness of the analytical methods and qualifiers, the significance of blank contamination, and if special analysis is required for TICs.

- Reducing the data set using a risk-based concentration screen such as comparing data to EPA Region III Risk Based Concentrations (RBCs) and USEPA Maximum Contaminant Levels (MCLs). The risk-based screen will be used as follows:

    - The maximum concentration of each chemical in each medium will be compared against the EPA RBC/MCL. If the concentration exceeds the RBC/MCL, the constituent will be retained for the risk assessment. If the constituent concentration is lower than the RBC/MCL than the constituent is dropped for that medium. However, if no screening criteria is available, the constituent will be retained for further analysis. If no toxicity values are available for this compound, then the chemical will be evaluated qualitatively.

- If a specific constituent does not exceed its risk-based concentration for any medium, it is dropped from the risk assessment.
- If no constituent in a specific medium exceeds its risk-based concentration, the medium is dropped from the risk assessment.
- All constituents and exposure routes that are dropped are kept on a sub-list and considered for re-inclusion, based on special properties.

- Consideration of re-including eliminated chemicals based on factors such as ARAR exceedances, special exposure routes, and historical information for the site or area.

- Further reductions in the data set based on evaluations of essentiality, frequency of detection and comparison to background; however, it should be noted that the frequency of detection and comparison to background assessments will be discussed after the quantitative risk assessment in the uncertainty section. In other words, chemicals will not be eliminated based on their infrequent detection or comparison to background, but their significance will be discussed in the uncertainty section. A summary of the background metals data for soils was presented in Section 3.1.4 while the source of the background data, the Montgomery Watson Fort Story PA/SI, is presented in **Appendix J**.

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6.2 DATA QUALITY EVALUATION

Prior to the initiation of the hazard identification process, a data quality evaluation will be conducted to determine if analytical methods, quantitation limits, and qualifiers are appropriate, to assess any blank contamination, to assess duplicates and state how they will be utilized in the risk assessment, and assess sampling methodologies. In addition, a comparison of inorganic concentrations to background and assessment of essential nutrients will also be conducted. This information is provided in the following subsections.

6.2.1 Evaluation of Analytical Methods

All analytical data collected at the site during the performance of the Site Inspection Report were analyzed using appropriate SW-846 methods as follows:

- Volatile Organic Compounds (VOCs) SW846 Method 8260B
- Semi Volatile Organic Compounds (SVOCs) SW846 Method 8270C
- Polychlorinated Biphenyls (PCBs)/Pesticides SW846 Method 8081A/8082
- Metals (Total and Dissolved) SW846 Method 6010B/7470A/7471A
- Total Dissolved Solids (TDS) SW846 Method 160.1
- Total Suspended Solids (TSS) SW846 Method 160.2

- Total Organic Carbon (TOC) Lloyd Kahn Method

6.2.2 Data Quality

URS Corporation performed manual data validation of all soil and groundwater analytical results for the RI. The validation was performed in accordance with *Region III Modifications to the National Functional Guidelines for Organic Data Review (September 1994), Region III Modifications to the Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analysis (April 1993), and Region III Innovative Approaches to Data Validation (June 1995).*

2003 Sampling Event Data

Based on the data validation results, the data generated for the site were considered acceptable. However, two major problems associated with severe QC exceedences from the analytical methods were encountered, which have a serious effect on the usability of some of the data. The major problems and their overall impact on the data usability are discussed below.

- *Major Problem 1*: The VOC continuing calibrations (CCAL) associated with the groundwater samples (plus field QC blank) exhibited a low (i.e., <0.05) relative response factor for acetone. The non-detect acetone results for all groundwater samples (except GW-MW-117) and field QC blanks were rejected ("R"), while the detected acetone result for GW-MW-117 was qualified as biased low ("L").
    - *Impact on RI Outcome: Minimal.* The Method Detection Limit and Sample Quantitation Limit for Acetone are two to three orders of magnitude below screening criteria. Furthermore, acetone was not a target constituent of concern prior to beginning the investigation.
- *Major Problem 2*: The SVOC CCAL associated with several soil and groundwater samples exhibited a low (i.e., <0.05) relative response factor for atrazine. The non-detect atrazine results for all affected soil, groundwater, and equipment rinsate blank samples were rejected ("R").
    - *Impact on RI Outcome: Minimal.* Atrazine was not a target constituent of concern prior to beginning the investigation, and there is no reason to suspect its presence.

In addition, several minor problems were also identified and are summarized in the QCS/AR Report for the 80th DRS. However, no data was rejected for the minor problems.

2004 Sampling Event Data

Based on the data validation results, the data generated for the site were considered acceptable.

However, one major problem associated with severe QC exceedences from the analytical methods was encountered, which have a serious effect on the usability of some of the data. The major problem and its overall impact on the data usability are discussed below.

- *Major Problem*: The VOC continuing calibration (CCAL) performed on 6/23/04 exhibited a low (i.e., <0.05) relative response factor for acetone. The non-detect acetone results for all groundwater samples (except for MW-03 and MW-07 which were not associated with this CCAL) were rejected ("R").
    - *Impact on RI Outcome: Minimal.* The Method Detection Limit and Sample Quantitation Limit for Acetone are two to three orders of magnitude below screening criteria. Furthermore, acetone was not a target constituent of concern prior to beginning the investigation.

In addition, several minor problems were also identified and are summarized in the QCS/AR Report for the 80[th] DRS. However, no data was rejected for the minor problems.

6.2.3 Statistical Evaluation Data

The 95th percent Upper Confidence Limit (UCL) of the arithmetic mean was calculated for COPCs in the onsite soils and groundwater. A detailed description of the methodology used to calculate background and on-site data is provided in **Section 6.4.5**. The statistical analysis of each metal is also provided in **Appendix D**.

6.2.4 Evaluation of Essential Nutrients

A screening process to reduce the list of chemicals of potential concern is the evaluation of essential human nutrients. Chemicals that are essential nutrients, present at low concentrations (e.g., only slightly above background), and are toxic only at very high doses need not be considered further in the quantitative risk assessment. Chemicals typically considered as essential nutrients include calcium, iron, magnesium, potassium, and sodium. Nutritional requirements, typical intakes, and toxic levels for the five identified essential nutrients are presented below.

Calcium

Calcium is the most abundant mineral in the human body. Ninety nine percent of the body's calcium is located in the teeth and bones. Calcium is needed to form bones and teeth and is also required for blood clotting, transmission of signals in nerve cells, and muscle contraction. The important of calcium for preventing osteoporosis is probably its most well-known role. The National Academy of Sciences has established guidelines for calcium that are 25 to 50 percent higher than previous recommendations. For ages 19 to 50, calcium intake is recommended to be 1,000 mg daily; for adults over age 51, the recommendation is 1,200 mg daily.

Constipation, bloating, and gas are sometimes reported with the use of calcium supplements. People with hyperparathyroidism or chronic kidney disease should not supplement with calcium without consulting a physician. High doses of calcium can inhibit the absorption of iron, zinc, phosphorus, and magnesium. Toxicity data for high-level consumption or exposure to calcium is not well defined. However, for safety sake, the upper limit is set at 2,500 mg daily.

Iron

Iron is part of hemoglobin, the oxygen-carrying component of the blood. Iron-deficient people tire easily because their bodies are starved for oxygen. Iron is also part of myoglobin, which helps muscle cells store oxygen. Without enough iron, ATP (the fuel the body runs on) cannot be properly synthesized. As a result, some iron-deficient people become fatigued even when their hemoglobin levels are normal. If a physician diagnoses iron deficiency, iron supplementation is essential. A common recommended amount for an adult is 100 mg daily. The recommended daily intake for the average person (without an iron deficiency) is 10 mg for children ages 1 to 10: 12 mg for males ages 11 to 18: 10 mg for males ages 19 and over; 15 mg for females ages 11 to 50; and 10 mg for females ages 51 and over.

Iron (ferrous sulfate) is the leading cause of accidental poisonings in children. Death in children has occurred from ingesting as little as 200 mg to as much as 5.85 grams of iron. Some researchers have linked excess iron to diabetes, cancer, heart disease, systemic lupus, and increased risk of infection.

Magnesium

Magnesium is needed for bone, protein, and fatty acid formation, making new cells, activating B vitamins, relaxing muscles, clotting blood, and forming ATP. Insulin secretion and function also require magnesium. Magnesium also acts in a way related to calcium channel blocker drugs and this may be responsible for the fact that under certain circumstances, magnesium has been found to potentially improve vision in people with glaucoma and to lower blood pressure. Most people do not consume enough magnesium. Many doctors recommended 250 to 350 mg daily for adults.

Taking too much magnesium often leads to diarrhea. For some people, this can happen with amounts as low as 350 to 500 mg per day. Problems that are more serious can develop with excessive magnesium intake from laxatives.

Potassium

Potassium is needed to regulate water balance, levels of acidity, blood pressure, and neuromuscular function, including a critical role in transmission of electrical impulses in the heart. Potassium is also required for carbohydrate and protein metabolism. The recommended daily dose of potassium for ages 4 to adults is 3,500 mg.

High potassium intake (several hundred milligrams at one time in tablet form) can produce stomach irritation. However, a diet rich in potassium from food is unlikely to be a problem for healthy individuals because excesses are typically eliminated from your body. However, individuals with kidney disease may have to watch the amount of potassium in their diet.

Sodium

Sodium is the principal cation in the extracellular fluid and assists in regulating the membrane potential across cells. A comprehensive review of the evidence suggests that, as part of a overall healthy diet, no more than 2,400 mg of sodium should be consumed daily. A diet high in sodium increases the risk of heart disease-related mortality in overweight individuals.

With the exception of Iron, none of the essential nutrients will be carried forward and evaluated further in this HHRA, as they are not considered hazardous to human health. Iron, however, will be carried forward into this report and evaluated further due to its potentially health affects in children.

6.3 HAZARD IDENTIFICATION

Twenty-two, groundwater, ten surface soil, and twenty subsurface soil samples were collected from this site and analyzed for TCL VOCs, TCL SVOCs, TCL organochlorine pesticides/PCBs, and TAL metals. The data are presented in **Tables 4-3 through 4-7**.

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Also provided are the Hazard Assessment tables (**Tables 6-1 through 6-3**), which contain a summary of the data including the frequency and the range of detections for each chemical with detections over the method detection limit. Also included in **Tables 6-1 through 6-3** is a comparison of the detections with selected screening criteria [i.e., EPA Region III RBCs and USEPA drinking water Maximum Contaminant Levels (MCLs)], and the USEPA weight-of-evidence classification for known or suspected human carcinogens, to facilitate the hazard identification.

The EPA Region III RBCs for industrial soils, residential soils and tap water for non-carcinogenic compounds have been adjusted to a hazard quotient of 0.1 by dividing them by a factor of ten. The RBCs were established for single contaminant exposure situations, however, because multiple contaminants have been detected for each matrix (groundwater and soil), the RBCs have been adjusted. Chemicals of potential concern (COPCs) are identified on the hazard identification tables through the following two annotations:

- **Yes** indicates that the maximum concentration of the compound exceeded the screening criteria and will be retained for further quantitative analysis, and

- **Qual** indicates that the compound was detected but no screening criteria are available and it will be evaluated qualitatively in the risk assessment.

Emphasis is given in the ensuing evaluation to chemical contamination in the soil throughout the site, and groundwater underlying the site as these environmental media are regarded as having the greatest potential for human contact. Chemicals and metals in subsurface soils are discussed in the context of the potential for exposure from future excavation of these soils and potential degradation of groundwater from leaching.

6.3.1 Surface Soils

Surface soil samples were collected from 10 locations at the site and site periphery to evaluate potential exposure to surface soils. Surface soil analytical data were compared to EPA Region III RBCs for industrial and residential soils, as shown in **Tables 4-3 through 4-6**.

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Surface (0-.5 feet bgs) soil samples were from various locations around the site. The locations are summarized on **Table 2-2**.

VOCs

Twenty-one VOCs were detected in Site surface soil samples. Of these 21 compounds, the three most common compounds detected were methylene chloride (detected in 9 of 10 samples), toluene (detected in 8 of 10 samples), and acetone (detected in 6 of 10 samples); however, the EPA Region III RBCs for all the detected VOCs were not exceeded in the samples and therefore, they have not been selected as COPCs.

SVOCs

Twenty-three SVOCs were detected in surface soil samples from the site. Of these 23 constituent detections, the more frequently detected compounds included: bis(2-EH)phthalate detected in 8 of 10 samples; as well as benzo(a)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, and fluoranthene each detected in 7 of 10 samples. Of these detected constituents, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenzo(a,h)anthracene exceeded both EPA Residential and Industrial Soil RBCs in several samples; and indeno(1,2,3-cd)pyrene exceeded the Residential Soil RBC; therefore, these five SVOCs are retained as COPCs.

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Pesticides

Eleven pesticides were detected in surface soil samples from the site. Of these 11 constituent detections, the more frequently detected compounds included: endrin ketone, detected in 5 of 10 samples; as well as endosulfan sulfate and 4,4'-DDT each detected in 3 of 10 samples. Of these detected constituents, only aldrin exceeded the EPA Residential Soil RBC in 1 of 10 samples; and is therefore retained as a COPC.

PCBs

No PCBs were detected in surface soil samples.

Inorganics

Twenty inorganic constituents were detected in surface soil samples from the site. However, only three of these inorganic constituent's (arsenic, iron, and vanadium) concentrations exceeded screening criteria; and are discussed below.

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- Arsenic exceeded the residential soil criteria in 7 of 10 samples, but did not exceed the industrial screening criteria. Arsenic will be retained as a COPC at this time.

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- Iron exceeded the residential RBC of 2,300 mg/kg in 6 of the 10 surface soil samples collected at the site. Iron will be retained as a COPC at this time.

- Vanadium exceeded the residential RBC of 7.8 mg/kg in 3 of the 10 surface soil samples collected at the site. Vanadium will be retained as a COPC at this time.

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6.3.2 Combined Surface and Subsurface Soils

Thirty soil samples were collected from 10 soil borings at the site to evaluate potential exposure to surface and subsurface soils (i.e., future excavation activities for development would potentially involve subsurface soils becoming exposed to the surface). Surface/subsurface soil analytical data were compared to EPA Region III RBCs for industrial and residential soils, as shown in **Table 6-2**.

Surface (0-0.5 feet bgs) and subsurface (1-3 feet and 4-6 feet bgs) soil samples were from the following 10 borings around the site. The locations are summarized on **Table 2-2**.

VOCs

Twenty-one VOCs were detected in Site soil samples. Of these 21 compounds, the three most common compounds detected were toluene (detected in 28 of 30 samples), methylene chloride (detected in 26 of 30 samples), and acetone (detected in 26 of 30 samples); however, the EPA Region III RBCs for all the detected VOCs were not exceeded in the samples and therefore, they have not been selected as COPCs.

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SVOCs

Twenty-six SVOCs were detected in soil samples from the site. Of these 26 constituent detections, the more frequently detected compounds included: bis(2-EH)phthalate, detected in 27 out of 30 samples; fluoranthene, detected in 21 of 30 samples; as well as benzo(g,h,i)perylene, phenanthrene, and pyrene, each detected in 20 of 30 samples. Of these detected constituents, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenzo(a,h)anthracene exceeded both EPA Residential and Industrial Soil RBCs in several samples; and indeno(1,2,3-cd)pyrene exceeded the Residential Soil RBC; therefore, these five SVOCs are retained as COPCs.

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Pesticides

Sixteen pesticides were detected in soil samples from the site. Of these 16 constituent detections, the more frequently detected compounds included: endrin ketone, detected in 17 of 30 samples; 4,4'-DDT, detected in 8 of 30 samples; as well as endosulfan sulfate, detected in 7 of 30 samples. Of these detected constituents, only aldrin exceeded the EPA Residential Soil RBC in 1 of 30 samples; and is therefore retained as a COPC.

PCBs

Only one PCB (Aroclor 1260) was detected in 2 of the 30 soil samples obtained from the site. However, the concentrations of Aroclor 1260 did not exceed the screening criteria, and therefore it was not retained as a COPC.

Inorganics

Twenty-two inorganic constituents were detected in soil samples from the site. However, only three of these inorganic constituent's (arsenic, iron, and vanadium) concentrations exceeded screening criteria; and are discussed below.

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- Arsenic exceeded the residential soil criteria in 8 of 30 samples, but did not exceed the industrial screening criteria. Arsenic will be retained as a COPC at this time.

- Iron exceeded the residential RBC of 2,300 mg/kg in 6 of the 30 soil samples collected at the site. Iron will be retained as a COPC at this time.

- Vanadium exceeded the residential RBC of 7.8 mg/kg in 3 of the 30 surface soil samples collected at the site. Vanadium will be retained as a COPC at this time.

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6.3.3 Groundwater

Groundwater quality data are summarized in **Table 6-3** along with EPA Maximum Contaminant Levels (MCLs) and Action Levels, and EPA RBC for Tap Water. Groundwater samples were collected from 10 monitoring wells in 2003 and from 12 monitoring wells (10 existing and 2 new wells) in 2004 to assess the lateral and vertical extent of contamination in the Columbia Aquifer (water table aquifer). The groundwater samples were analyzed for VOCs, SVOCs, pesticides, PCBs, as well as total and dissolved metals.

Several constituents were detected in the groundwater samples collected at the site. **Table 6-3** provides the analytical results for the groundwater samples collected at the site. A combined VOC dataset (2003 plus 2004 data) of 22 samples for the VOCs is presented in **Table 6-3**. Only those constituents detected are presented.

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VOCs

Five VOCs were detected in groundwater samples from the site: cis 1,2-dichloroethene ([cis 1,2-DCE] detected in 3 of 22 samples), tetrachloroethene ([PCE] detected in 7 of 22 samples), toluene (detected in 10 of 22 samples), trichloroethene ([TCE] detected in 5 of 22 samples), and 1,2,4-trichlorobenzene (detected in 1 of 22 samples). PCE and TCE were both detected above both their EPA RBCs and MCLs while cis 1,2-DCE was detected above its RBC only. Therefore, cis 1,2-DCE, PCE, and TCE will be retained as COPCs for further evaluation.

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Semivolatile Organic Compounds

Bis(2-ethylhexyl)phthalate was detected in one of ten samples at a concentration above its RBC. Therefore, bis(2-ethylhexyl)phthalate will be retained as a COPC for further evaluation.

Pesticides

No pesticides were detected over the detection limit in the groundwater samples collected.

Polychlorinated Biphenyls

No polychlorinated biphenyls (PCBs) were detected over the detection limit.

Total Metals

- Total metals were detected in all the groundwater samples collected at the site. A summary of the total metal results detected above EPA screening criteria is discussed below.
- Total antimony exceeded its MCL of 6 ug/l in 1 out of 10 samples while it exceeded its EPA tap water RBC of 1.5 ug/l in 8 out of 10 samples. Thus, total antimony is retained as a COPC.

- Total arsenic exceeded the EPA RBC of 0.045 ug/l in 3 of 10 samples but did not exceed its MCL of 10 ug/l in any samples. No other samples exceeded the detection limit for arsenic. However, to maintain a conservative approach, total arsenic will be retained as a COPC at this time.

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- Total iron was detected in all groundwater samples. While total iron has no primary MCL, the EPA RBC of 1,100 ug/l was exceeded in 4 of 10 samples. Thus, total iron is retained as a COPC.

- Total manganese was detected in all groundwater samples, and it exceeded the EPA RBC of 73 ug/l in 2 of the 10 samples. Thus, to maintain a conservative approach, total manganese will be retained as a COPC at this time.

- Total vanadium was detected in 9 of 10 groundwater samples, and it exceeded the EPA RBC of 3.7 ug/l in 3 of the 10 samples. Thus, to maintain a conservative approach, total vanadium will be retained as a COPC at this time.

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Dissolved Metals

Dissolved metals were detected in all the groundwater samples collected at the site. A summary of the dissolved metal results detected above EPA screening criteria is discussed below.

- Dissolved arsenic exceeded the EPA RBC of 0.045 ug/l in 2 of 10 samples but did not exceed its MCL in any samples. In addition, no other samples exceeded the detection limit for arsenic. Thus, dissolved arsenic will be retained as a COPC at this time.

- Dissolved iron was detected in all groundwater samples, and while dissolved iron has no primary MCL, the EPA RBC of 1,100 ug/l was exceeded in 3 out of 10 samples. Thus, dissolved iron will be retained as a COPC at this time.

- Dissolved manganese was detected in all groundwater samples, and it exceeded the EPA RBC of 73 ug/l in 2 of the 10 samples. Thus, to maintain a conservative approach, dissolved manganese will be retained as a COPC at this time.
- Dissolved vanadium was detected in 10 of 10 groundwater samples, and it exceeded the EPA RBC of 3.7 ug/l in only 1 of the 10 samples. Thus, to maintain a conservative approach, dissolved vanadium will be retained as a COPC at this time.

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The detections of total and dissolved metal above the EPA MCLs or RBCs are presented on **Table 6-3.**

6.3.4 Chemicals of Potential Concern

COPC identified during the hazard identification are provided in **Table 6-1** (surface soil), **6-2** (combined soil), and **6-3** (groundwater). Potential risk associated with the COPC will be further evaluated in the exposure assessment section.

6.4 EXPOSURE ASSESSMENT

The objective of the exposure assessment is to estimate the type and magnitude of exposures to the COPCs that are present at or migrating from the site.

6.4.1 Potentially Exposed Populations

As part of the exposure assessment, it is important to characterize the potentially exposed populations at or near the site with regard to the current situation and potential future conditions.

Current Situation

The 80th DRS area contains a 50-foot by 70-foot concrete pad surrounded by asphalt on the west, south, and east sides. The north side is bordered by sand that was used as the DRS staging area. Over time, this staging area apparently became contaminated with by-products (primarily petroleum products) of the washing and maintenance operations. A 1,000 gallon used oil UST, 250-gallon antifreeze aboveground storage tank (AST), and a former drum storage area were located west of the wash pad. While Fort Story has numerous residential dwellings, there are no residential sites within one mile of the 80th DRS. Additionally; the land use in the immediate vicinity is best classified as industrial usage.

Soil

The majority of the site is covered with asphalt pavement; however, smaller portions of the site consist of bare sandy soil. Thus, there is a potential for a site worker to contact soil; therefore, in keeping with the conservative nature of this document, the Fort Story Site Worker will be retained for further evaluation. Furthermore, it will be assumed that the worker will be exposed to surface soils only in order to reflect current site conditions.

During construction, both surface and subsurface soils would be disturbed exposing the construction worker to the constituents present in the soils, therefore, a construction worker exposure scenario will be retained for further evaluation.

Groundwater

At present, there are no potable wells or irrigation wells in the immediate vicinity of the site. As discussed in Section 3.1.5, there are several off-post residential communities that may be utilizing groundwater as potable water; however they are located over 1 mile west of the site and groundwater at the site flows northward towards the Chesapeake Bay. Under the current situation, because there are no nearby drinking water wells and groundwater does not appear to be impacting any surface water, exposure to contaminated groundwater from residential populations will not be evaluated.

Because there are no buildings located over the groundwater plume, vapor intrusion is not a reasonable exposure scenario at this site and will not be evaluated further for current land use.

During construction, there is the potential for exposing the construction worker to the constituents present in the groundwater; therefore, a construction worker exposure scenario will be retained for further evaluation.

Future Land Use

Based on master planning issues for Fort Story, as well as its unique location and subsequent training environs, the facility is expected to remain government property. The potential for future development of the land as commercial, residential, or recreational properties is not expected as the base will remain open and the area will continued to identified as industrial usage; however, If development of the site occurred in the future, commercial/industrial worker exposure to groundwater would be possible via inhalation only, where indirect exposure to VOC vapors could occur through migration from groundwater into structures. This scenario has been retained to maintain a conservative approach.

If land use conditions change in the future, possible exposure scenarios (e.g., residential exposure to soils and groundwater if residential development was planned) will be re-evaluated.

The 95th UCL for the detected VOCs with hits above EPA RBCs for tap water including cis 1,2-DCE (3.1 µg/L), PCE (2.9 µg/L), and TCE (2.5 µg/L) were all below these compounds respective MCLs. Based on the low concentrations of VOCs detected at the site, it is highly unlikely that a risk would result from vapor intrusion; therefore, an assessment of the potential for vapor intrusion into buildings

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that may be constructed at the site in the future is not warranted at this time.

Figure 6-1 presents a conceptual site model that demonstrates the current and potential future uses of the site and shows the complete exposure pathways.

Potential Exposed Populations Summary

The following potentially exposed populations to the contaminated media at the site have been identified:

- Fort Story Site Workers exposure (adults only) to contaminated surface soils during Site maintenance. Identified as a current and future land use population.
- Construction worker exposure (adults only) to contaminated surface/subsurface soils. Identified as a current and future land use population.
- Construction worker exposure (adults only) to contaminated groundwater. Identified as a current and future land use population.
- Commercial/industrial worker exposure to vapors in structured from groundwater via volatization.

However, for this HHRA, as the exposure scenarios are so similar, site industrial workers and Fort Story site workers will be considered as the same receptor population. This scenario will consider exposure to surface soils at the site only. As the COPC exposure concentrations in surface soils are greater than, or equal to, the exposure concentrations of the combined surface/subsurface data set, this is a conservative assumption.

Because only industrial exposure scenarios (site and construction worker) are to be evaluated for site soils, several originally identified COPCs including indeno(1,2,3-cd)pyrene, aldrin, aluminum, arsenic, iron, and vanadium will not be retained because they only exceeded the residential soil RBCs and did not exceed the industrial soil RBCs.

6.4.2 Exposure Pathways

The potential exposure pathways of concern at the site include:

Industrial Site Workers (Adults)

- Ingestion of chemicals in surface/subsurface soil
- Dermal contact with chemicals in surface/subsurface soil
- Inhalation of particulates from surface/subsurface soil

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In the event that the Site is redeveloped for either industrial, residential, or recreational uses, several potentially exposed populations on the site may exist.¶
¶
<#>During construction, both surface and subsurface soils would be disturbed exposing the construction worker to the constituents present in the soils. Once construction is complete at the site and the site is occupied the potential for industrial or residential exposure exists depending on the intended use for the property. However, if the site were left in its current state in the future (i.e., no construction activities), or converted for recreational use (e.g., a ball field), then trespassers or recreational users would be exposed to surface soils only. ¶
¶
<#>If the Site were used for an Industrial purpose, the exposed population would include the industrial workers tasked with maintaining the grounds (mowing, landscaping, etc.). ¶
¶ ... [1]

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<#>Trespasser exposure (adults only) to contaminated surface soils,¶
<#>Recreational exposure (adu ... [2]

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<#>Dermal contact with chemicals in surface soil¶
¶ ... [3]

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Residential Populations (Adults and Children)¶
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<#>Ingestion of chemicals in surface/subsurface soil¶
<#>Dermal contact with chemicals in surface/subsurface soil¶ ... [4]

Construction Workers (Adults)

- Ingestion of chemicals in surface/subsurface soil
- Dermal contact with chemicals in surface/subsurface soil
- Inhalation of particulates from surface/subsurface soil
- Ingestion of chemicals in groundwater
- Dermal contact with chemicals in groundwater
- Inhalation of volatile chemicals in groundwater

Commercial/Industrial Workers (Adults)

- Inhalation of volatile chemicals in groundwater

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6.4.3 Data Limitations and Uncertainties

The limitations and uncertainties associated with the analytical data for the site were reviewed during data validation to ensure that appropriate and reliable data are selected for use in estimating human exposure.

Samples and their duplicates are not considered as separate sampling events. Rather a chemical-specific value representing the maximum value of the sample and its duplicate is used. This may result in a conservative estimate of exposure. However, since relatively few duplicate samples were collected, the overall impact on risk estimates should be minimal.

For purposes of this HHRA, if a COPC was not detected in a sample, it is assumed to be present at 1/2 the sample quantitation limit (SQL). Adjusting non-detects by assigning values at 1/2 the chemical-specific SQL is a highly conservative approach that assumes a chemical is present at concentrations typically greater than the method detection limit (MDL), even though the constituent has not been detected above the MDL. This approach would tend to greatly overestimate the risk.

In this evaluation, data which were qualified by indicating that the numerical values are estimated quantities (those organics with a "J" qualifier and those metals with a "B" qualifier) are treated in this evaluation the same as data without this qualifier.

6.4.4 Estimates of Constituent Intake

Evaluation of the exposure pathways described above involves the estimation of several parameters such as skin surface area available for contact; skin permeability factors; exposure time, frequency, and duration; soil-to-skin adherence factors; ingestion rates; as well as the constituent concentrations in the specific media of concern. **Table 6-4** represents a general equation for calculating chemical intakes (chronic daily intakes or CDI) and defines the intake variables in terms of chemical-related, population-related, and evaluation-determined parameters.

6.4.5 Estimates of Reasonable Maximum Exposures

The USEPA recommends that estimates of constituent intake be developed to portray reasonable maximum exposures (RME), which might be expected to occur under current and future site conditions. Accordingly, the highest exposure that might reasonably be expected to occur at the site, one that is well above the average case of exposure but within the range of possibility, should be considered.

The sample data obtained are only "snapshots" of contamination over the site and its surroundings. In order to determine the constituent concentrations to which one might be exposed over many years, it is necessary to evaluate the entire data set in order to develop "representative" concentrations. In many instances, environmental data sets are skewed such that the normal distribution is not a suitable model for estimating parameters such as means, proportions, confidence limits, etc. The USEPA (USEPA 1989a) recommends that the upper confidence limit [i.e., the upper confidence limit (UCL)] on the mean of all the data should be used for evaluating RMEs. The 95th UCL of the arithmetic mean will be calculated and used as the reasonable concentration.

Three types of confidence limits are available: parametric, log-normal, and non-parametric. The type of confidence limit that will be applied depends upon the data distribution of the constituent being evaluated (e.g., normal [parametric], log-normal, and non-normal [non-parametric]). Statistical limits for each constituent data set were employed as detailed below by the following procedures.

1. Initially, all data sets are assumed normally distributed, and the following steps were completed.

   - The assumption of normality of the data was tested using the Shapiro-Wilk Test of Normality.

   - If the data set was determined to be normally distributed (by passing the normality test), a Parametric Confidence Limit was calculated using the ProUCL data program.

2. If the data set initially failed the Test of Normality, the following steps were followed.

   - All data was converted to natural logarithms.

   - The log-adjusted data was then tested for normality using the Shapiro-Wilk Test of Normality.

   - If the log-adjusted data was determined to be normally distributed (by passing the normality test), the data set was said to be log-normally distributed.

   - A lognormal confidence limit was applied to the lognormal data sets using the ProUCL program, selecting the highest calculated UCL from three different methods (95% H-UCL, 95% Chebyshev, and 99% Chebyshev) as the final UCL.

3. If the data set was neither normally distributed nor log-normally distributed the following steps were followed.

- The data set was said to be distribution-free (non-parametric or non-normal).
- A non-parametric confidence limit was applied to the distribution-free data sets.
- The ProUCL data program was utilized to determine the 95th percentile non-parametric UCL using five different methodologies (CLT, Jacknife, Standard Bootstrap, Bootstrap t, and Chebyshev). The highest of the five 95th non-parametric UCLs calculated was then selected as the final UCL established (provided this value was less than the maximum, if not, the second highest UCL was selected as the final UCL).

As described previously, for all samples in which the COPC is not detected, a value of 1/2 the SQL for that chemical was assigned. Depending upon the number of non-detects and variability in measured concentrations, the UCL on the mean concentration may exceed the maximum detected value. Since exposure to chemicals having concentrations greater than the maximum detected value is not feasible, the maximum concentration is used to determine the exposure when the UCL concentration is greater than the maximum concentration. This approach is also consistent with USEPA guidance (USEPA, 1989a) and may be considered a conservative approach to exposure assessment. As reported in the USEPA document, "Supplemental Guidance to RAGS: Calculating the Concentration Term", data sets with fewer than 10 samples per exposure area provide poor estimates of the mean concentration, however, EPA Region III has stated through reviews of previous risk assessments conducted at USACE sites that UCL calculations can be conducted for data sets of three samples or greater. The calculated UCLs are provided in **Appendix D**.

Soil Exposure Estimations

Only surface soil data (0- to 0.5-foot depth) was utilized for the site worker exposures while a combination of surface (0- to 0.5-foot depth) and subsurface (data from 1- to 6-foot depth) were combined and used to estimate exposures for the construction worker population (both current and future) identified in **Sections 6.4.1 and 6.4.2**, as if the site were developed, surface and subsurface soils could be mingled and brought to the surface. Additionally, COPCs in both surface and subsurface soils were selected based on detections greater than the EPA RBCs for industrial soils since only industrial and construction workers were identified as potentially exposed populations. The COPCs in soils include benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, and dibenzo(a,h)anthracene. The estimated exposure concentrations for surface soils and combined surface/subsurface soils are summarized in the following tables:

Deleted: To maintain the conservative approach of this risk assessment, surface soil (0 to 0.5-foot depth) data was used to estimate exposures to populations with limited site contact (i.e., trespassers and recreational users). Additionally,

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SUMMARY OF SURFACE SOIL EXPOSURE ESTIMATIONS		
COPC	**95 Percentile UCL or Maximum**	**Estimated Exposure Concentration (mg/kg) (Surface Soil)**
Benzo(a)anthracene	UCL	4.83
Benzo(a)pyrene	UCL	4.81
Benzo(b)fluoranthene	UCL	6.24
Dibenzo(a,h)anthracene	UCL	1.03

SUMMARY OF COMBINED SOIL EXPOSURE ESTIMATIONS		
COPC	**95 Percentile UCL or Maximum**	**Estimated Exposure Concentration (mg/kg) (Combined Soils)**
Benzo(a)anthracene	UCL	3.42
Benzo(a)pyrene	UCL	3.32
Benzo(b)fluoranthene	UCL	4.41
Dibenzo(a,h)anthracene	UCL	0.55

Groundwater Exposure Estimations

As previously stated, the Construction Worker (Adult) Population has been determined to have a potential for exposure to groundwater through ingestion, contact, and inhalation of volatiles. The Commercial/Indsutrial Worker (Adult) population in potential future structures has been determined to have a potential exposure to groundwater through inhalation of volaties only. Therefore, exposure estimations will only be calculated for these populations.

The construction worker's exposure to groundwater would be best represented by total inorganics groundwater data. Therefore, this HHRA will apply total (unfiltered) inorganics data for exposure of future construction workers.

Data from monitoring wells MW-1 through MW-3 and MW-5 through MW-11 have been used to calculate exposure concentrations. Furthermore, in keeping with USEPA Region III Guidance, COPCs in groundwater were selected based on detections greater than the EPA RBCs and/or MCLs for Tap/Drinking Water. The COPCs in groundwater greater than the screening criteria include tetrachloroethene, trichloroethene, bis(2-ethylhexyl) phthalate, total antimony, total arsenic, total iron and total manganese. The estimated exposure concentrations are summarized below:

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In addition, as potential residential exposures to groundwater would most likely occur through use of a groundwater well, water from the well would be filtered prior to use. Thus, the residential population would be exposed to inorganic concentrations akin to the dissolved samples obtained during the RI. However, a dissolved (filtered) inorganics data for exposure of future potential residential populations, and ... ... [13]
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SUMMARY OF GROUNDWATER EXPOSURE ESTIMATIONS		
COPC	95 Percentile UCL or Maximum	Estimated Exposure Concentration (mg/l)
Cis 1,2-DCE	UCL	0.0031
PCE	UCL	0.0029
TCE	UCL	0.0025
Bis(2-ethylhexyl) phthalate	UCL	0.0050
Total Antimony	UCL	0.0044
Total Arsenic	UCL	0.0052
Total Iron	UCL	2.63
Total Manganese	UCL	0.089
Total Vanadium	UCL	0.0035

6.4.6 Parameters and Assumptions in Assessing Exposures

Fort Story/Industrial Site Worker (Adults)

Soils

Tables 6-5, 6-6, and 6-7 present the parameters and assumptions used in assessing exposures for Fort Story site workers to chemicals in soil through ingestion, dermal contact, and inhalation of soil particulates. The following summarizes the assumptions made for exposure to chemicals in soil through ingestion, dermal contact, and inhalation of soil particulates:

Ingestion

- In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), an ingestion rate of 100 mg/day of soil per day for outdoor site workers (such as groundskeepers) has been assumed (EPA, 2001b).
- The "fraction ingested" (FI) is defined as the fraction ingested from a particular source. For this analysis, it is assumed that 100 percent of the incidental exposure is presumed to come from this scenario as per VDEQ Voluntary Remediation Program (VRP) exposure factors.
- The exposure frequency (EF) for site workers is assumed to be 250 days/year (VDEQ, 2003).

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Soils¶
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Tables 6-5 and 6-6 present the parameters and assumptions used in assessing potential exposures of adult Trespassers to chemicals in soil through ingestion and dermal contact. The following summarizes the assumptions made for exposure to chemicals in soil through ingestion and dermal contact:¶
¶
Ingestion¶
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<#>As a trespasser would be present on site for a short time, the ingestion rate would be low. VDEQ, 2003 recommends 100 mg/day to m ... [16]
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- For workers on the site, an exposure duration (ED) of 25 years is assumed (USEPA, 1995).
- The average body weight (BW) of an American adult is approximately 70 kg (USEPA, 1991).
- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:
  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.
  - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

Dermal Contact

The value recommended by VDEQ (2003) for available skin surface area is 800 cm^2/day.

- The value cited as the 50th percentile for skin surface area for males and females with exposed hands, forearms, feet, lower legs, and head exposed is 3,300 cm^2 (VDEQ, 2003).
- The soil to skin adherence factor (AF) used is 0.20 mg/cm^2 based on VDEQ (2003) recommendation.
- For the dermal contact with soil pathway, the absorption factor (ABS) is 13% for PAHs (USEPA, Region III, 1995).
- The exposure frequency, exposure duration, body weight, and averaging time values are the same as those used for the ingestion pathway.

Inhalation of Soil Particulates

- For the evaluation of inhalation of soil particulates, the constituent concentration in air is calculated using the methodology for the Particulate Emission Factor as provided in *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (EPA, 2001c), using default parameters. All calculations are provided in **Appendix E**.

- An inhalation rate (IR) of 1.6 m^3/hour for site workers is assumed in evaluating the inhalation of chemicals in air due to soil particulate suspension (USEPA, 1997).

- Exposure time (ET) for the inhalation pathway is estimated as 8 hours/day for adults based upon a standard work day.

- The exposure frequency, exposure duration, body weight and averaging time values are the same as those used for the ingestion pathway.

Construction Workers (Adults)

<u>Soils</u>

Tables 6-8, 6-9, and 6-10 present the parameters and assumptions used in assessing exposures for potential future construction workers to chemicals in soil through ingestion, dermal contact, and inhalation of particulates. The following summarizes the assumptions made for exposure to chemicals in soil through ingestion, dermal contact, and inhalation of soil particulates:

Ingestion

- In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), a conservative ingestion rate of 480 mg of soil/day is assumed, as per VDEQ, 2003.

- The "fraction ingested" (FI) is defined as the fraction ingested from a particular source. For this analysis, it is assumed that 50 percent of the incidental exposure is presumed to come from this scenario (VDEQ, 2003).

- The exposure frequency (EF) for construction workers is assumed to be 125 days/year (VDEQ VRP Exposure Factors).

- For workers on the site, an exposure duration (ED) of one year is assumed based upon professional judgment.

- The average body weight (BW) of an American adult is approximately 70 kg (USEPA, 1991).

- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

  - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

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Residential Populations (Adults and Children)¶
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<u>*Soils*</u>¶
¶
Tables 6-12, 6-13, and 6-14 present the parameters and assumptions used in assessing exposures for potential future residential populations to chemicals in soil through ingestion, dermal contact, and inhalation of particulates. The following summarizes the assumptions made for exposure to chemicals in soil through ingestion, dermal contact, and inhalation of soil particulates:¶
¶
Ingestion¶
¶
<#>In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), a conservative ingestion rate of 200 mg of soil/day is used as representative for children and 100 mg/day for adults (USEPA, 1991). ¶
¶
<#>The "fraction ingested" (FI) is defined as the fraction ingested from a particular source. For this analysis, it is assumed that 100 percent of the incidental exposure is presumed to come from this scenario.¶
¶
<#>The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1991).¶
¶
<#>An exposure duration (ED) of 24 years for adults and 6 years for children as recommended by VDEQ, 2003 and USEPA 1991.¶
¶
<#>The average body weight ... [17]

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Tables 6-15, 6-16, and 6-17 present the parameters and assumptions used in assessing potential exposures to chemicals in groundwater. In the evaluation of exposures resulting from ground water via ingestion and dermal contact, the following factors and assumptions are used.¶
¶
Ingestion¶ ... [18]

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- When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

Dermal Contact

- The value cited as the 50th percentile for skin surface area for males and females with exposed hands, forearms, feet, lower legs, and head is 3,300 cm^2 (VDEQ, 2003).
- The soil to skin adherence factor (AF) used is 0.90 mg/cm^2 based upon the 95th percentile for construction workers doing utilities-related work (VDEQ VRP Factors). This is a reasonable assumption as the individual workers mostly likely to be in intimate contact with soil for the most prolonged period would utilities workers.
- For the dermal contact with soil pathway, the absorption factor (ABS) is 13% for PAHs (USEPA, Region III, 1995).
- The exposure frequency, exposure duration, body weight and averaging time values are the same as those used for the ingestion pathway.

Inhalation of Soil Particulates

- For the evaluation of inhalation of soil particulates, the constituent concentration in air is calculated using the methodology for the Particulate Emission Factor (PEF) as provided in *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (EPA, 2001c). The PEF is calculated using default parameters and assumptions regarding vehicular traffic on the site during construction. Dust generated by vehicular traffic would be the greatest source of airborne constituents in this case, as most constituents are confirmed to the surface (or near surface) soils. In addition, site activities such as excavation, grading, bull dozing, and wind erosion of exposed soils may generate soil particulate emissions. All calculations are provided in **Appendix E**.
- An inhalation rate (IR) of 2.5 m^3/hour for construction workers is assumed in evaluating the inhalation of chemicals in air due to soil particulate suspension (VDEQ, 2003).
- Exposure time (ET) for the inhalation pathway is estimated as 4 hours/day for adults based

VDEQ, 2003.

The exposure frequency, exposure duration, body weight and averaging time values are the same as those used for the ingestion pathway.

Groundwater

Tables 6-11, 6-12, and 6-13 present the parameters and assumptions used in assessing exposures for potential future construction workers to chemicals in groundwater through ingestion, dermal contact, and inhalation of volatiles. The following summarizes the assumptions made for exposure to chemicals in groundwater through incidental ingestion, dermal contact, and inhalation of vapors from groundwater:

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Incidental Ingestion

- In evaluating inadvertent ingestion of groundwater, an ingestion rate of 0.02 liters/day based on VDEQ, 2003.
- The exposure frequency (EF) for construction workers is assumed to be 125 days/year (VDEQ VRP Exposure Factors).
- For workers on the site, an exposure duration (ED) of one year is assumed based upon professional judgment.
- The average body weight (BW) of an American adult is approximately 70 kg (USEPA, 1991).
- The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:
    - When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.
    - When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

Dermal Contact

- The value cited as the 50th percentile for skin surface area for males with exposed hands, forearms, feet, lower legs, and head is 3,300 cm^2 (VDEQ, 2003).

- It is assumed that the event frequency will be once per day based upon USEPA Guidance (1992b).

- Since the calculated exposure is designed to be the absorbed dose, not the amount of chemical that comes into contact with the skin, a permeability constant (PC) is necessary to access exposure through dermal contact. The PC reflects movement across the skin to the underlying skin layers and into the bloodstream. PCs for the COPC were obtained from USEPA, 2001 Appendix B, and are summarized above.

- The exposure frequency, exposure duration, body weight and averaging time values are the same as those used for the ingestion pathway.

Inhalation of Vapors Volatized from Groundwater

- For the evaluation of inhalation of airborne VOCs from the groundwater, the contaminant concentration in air is calculated using a model developed by VDEQ (VDEQ, 2002, Table 3.8) for the Voluntary Remediation Program. In order to estimate the air concentration, this approach applies a combination of a vadose zone model to estimate volatilization of gases from contaminated groundwater into a trench and a box model to estimate dispersion of the contaminants from the air inside the trench into the atmosphere. For this model, it is assumed that a trench three feet wide by eight feet long is excavated to a depth of 6 feet.

- The concentration in air for the chemicals of potential concern is presented below. All concentration-in-air calculations are provided in **Appendix E**.

COPC Concentrations in Air	
COPC	**Air Concentration (mg/m^3)**
Cis 1,2-DCE	3.90E-02
PCE	3.79E-02
TCE	2.90E-02
Bis(2-ethylhexyl)phthalate	6.09E-05

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- An inhalation rate (IR) of 2.5 m^3/hour for construction workers is assumed in evaluating the inhalation of chemicals in air due to soil particulate suspension (VDEQ, 2003).

- Exposure time (ET) for the inhalation pathway is estimated as 4 hours/day for adults based VDEQ, 2003.

The exposure frequency, exposure duration, body weight and averaging time values are the same as those used for the ingestion pathway.

Commercial/Industrial Workers (Adults)

Johnson and Ettinger (1991) Model for Subsurface Vapor Intrusion into Buildings was used to calculate the exposure to groundwater in indoor air. This model was used to account for inter-media transfer, specifically, from groundwater to indoor air. More information about the model can be found at the EPA web site:

http://www.epa.gov/superfund/programs/risk/airmodel/johnson_ettinger.htm

Input parameters used for the model are as follows:

- Chemical
- Initial chemical concentration in groundwater
- Depth below grade to water table – 4 ft bgs (495 cm)
- Soil type directly above water table – sand
- Average soil/groundwater temperature – 18 degrees Celsius
- Vadose zone soil type – sand

Input parameters were based on results from field investigations conducted at the site; an average temperature for shallow groundwater temperature was used (USEPA 1995). Default values were used for all other input parameters. Exposure medium concentrations are as follows for the three VOCs that exceeded screening criteria:

- TCE 8.55E-01 ug/m^3
- PCE 1.58E+00 ug/m^3
- Cis 1,2-DCE 4.13E-01 ug/m^3

Documentation of the model inputs for the VOC are provided in **Appendix G**. In addition, spreadsheets for the intermediate calculations and results have been included.

6.5 TOXICITY ASSESSMENT

The toxicity assessment, also termed the dose-response assessment, serves to characterize the relationship between the magnitude of exposure and the potential that an adverse effect will occur. It involves (1) determining whether exposure to a chemical can cause an increase in the incidence of a particular adverse health effect and (2) characterizing the nature and strength of the evidence of causation. The toxicity information is then quantitatively evaluated and the relationship between the dose of the constituent received and the incidence of adverse effects in the exposed population is evaluated. The USEPA and other regulatory agencies have performed toxicity assessments for numerous chemicals and the guidance they provide is used when available. These include verified reference doses (RfDs) for the evaluation of noncarcinogenic effects from chronic exposure and cancer potency slopes (CPSs) for the evaluation of cancer risk from lifetime exposure. Each of these are discussed below.

Sources of toxicological guidance information, in order of preference, include: (1) IRIS (Integrated Risk Information System) which is a USEPA database containing current health risk and regulatory information for many chemicals; (2) USEPA Health Effects Summary Tables (HEAST) which are tabular presentations of toxicity data; and (3) USEPA National Center for Environmental Assessment.

The inherent toxicity of the COPC for the HHRA is briefly summarized in **Appendix F**.

6.5.1 Non-Carcinogenic Effects

The potential for non-cancer health effects associated with chemical exposure is evaluated by comparing an estimated intake (such as chronic daily intake or CDI) over a specified time period with an RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, which are likely to be without an appreciable risk of deleterious effects during a lifetime. RfDs often have an uncertainty spanning perhaps an order of magnitude or greater. Chronic RfDs, used in this report, are specifically developed to be protective of long-term exposure to a chemical.

The RfDs for the COPC used for the characterization of chronic non-cancer risk via oral exposure routes are presented in **Table 6-14**, along with the confidence level of the chronic RfD, the critical effect, the basis and source of the RfD and any uncertainty of modifying factors used in the derivation of the RfD.

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The ratio of the estimate of the CDI to the health-protective criterion (CDI/RfD) is called the hazard quotient (USEPA, 1989a). The hazard quotient assumes that there is a level of exposure (i.e., the RfD) below which it is unlikely for even sensitive subpopulations to experience adverse health effects. If the hazard quotient exceeds 1.0, there may be concern for potential non-cancer effects. The greater the hazard quotient above 1.0, then the greater is the level of concern.

RfDs for oral exposure are available for most chemicals. For dermal exposure, however, RfDs are not available. In their absence, the oral RfDs are used and adjusted to reflect absorbed dose. This allows for comparison between exposure estimated as absorbed doses and toxicity values expressed as absorbed doses.

The GI absorption values (ABS_{GI}) identified for the COPCs were obtained from Exhibit 4-1 in the EPA RAGs Part E guidance document and are presented as follows:

- Antimony (metallic) – 15%
- Arsenic (arsenite) – 95%
- Benz[a]anthracene – 89%
- Benzo[a]pyrene – 89%
- Benzo[b]fluoranthene – 89%
- Bis(2-ethylhexyl)phthalate – 100%
- Dibenzo(a,h)anthracene – 89%
- Cis 1,2-DCE – 100%
- Iron – 100%
- Manganese – 4%
- Tetrachloroethylene – 100%
- Trichloroethylene – 100%
- Vanadium – 2.6%

The oral RfDs are multiplied by the ABS_{GI} to come up with the RfD_{ABS} values. The calculated RfD_{ABS} values are presented in **Table 6-14.** It should be noted that no adjustment was made for arsenic, all PAHs, bis(2-ethylhexyl)phthalate, all VOCs, and iron because Exhibit 4-1 in RAGS Part E suggests no adjustment is needed because of their high absorption factors.

Except for a few COPCs, reference doses for inhalation exposure, referred to as RfD_i, are typically not available. The RfD_is were available for the following constituents (in mg/kg/d):

- Manganese – 1.43 x 10^{-5}
- PCE – 8.0 x 10^{-2}
- TCE – 1.0 x 10^{-2}

6.5.2 Carcinogenic Effects

Regardless of the mechanism of effect, risk assessment methods generally derive from the hypothesis that thresholds for cancer induction by carcinogens do not exist and that the dose-response relationship is linear at low doses. Such risk assessment methods require extrapolation from high dose animal studies to evaluate low dose exposures to humans. In the absence of adequate information to the contrary, a linearized, multistage, non-threshold low dose extrapolation model is recommended by the USEPA as the most appropriate method for assessing chemical carcinogens. The USEPA emphasizes that this procedure leads to a plausible upper limit to the risk that is consistent with some proposed mechanisms of carcinogenesis.

Through application of this approach, the USEPA has derived estimates of incremental excess

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cancer risk from lifetime exposure to potential carcinogens. This is accomplished by establishing the carcinogenic potency of the chemical through critical evaluation of the various test data and the fitting of those dose-response data to a low dose extrapolation model. The CPS (which describes the dose-response relationship at low doses) is expressed as a function of intake [i.e., per (mg/kg-day)-1]. This expression incorporates standard pharmacological considerations such as body weight. CPSo data for the COPC are presented in **Table 6-15** and are used to estimate finite, upper limits of risk at low dose levels administered over a lifetime. The weight-of-evidence classification for carcinogenicity, the type of cancer associated with each COPC and the basis and source of the CPSo are also presented in **Table 6-15**.

To arrive at an estimate of incremental cancer risk, the following equation is used (USEPA, 1989a):

Risk = CDI x CPS
where:

Risk = a unitless probability (e.g., 2×10^{-5} or 2 in 100,000) of an individual developing cancer
CDI = chronic daily intake averaged over 70 years (mg/kg-day)
CPS = Cancer Potency Slope expressed in $(mg/kg\text{-}day)^{-1}$

This linear equation is valid only at low risk levels (i.e., below estimated risks of 0.01). This approach does not necessarily give a realistic prediction of risk. The true value of the risk at trace ambient concentrations is unknown, and may be as low as zero.

As with RfDs, there are no assigned CPS values for dermal exposure. In their absence, CPS factors for oral exposures (denoted as CPSo) are used and adjusted to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses. The same ABS_{GI} values used to adjust RfDs are applied in adjusting CPSo values. The CPSs are divided by the ABS_{GI} values previously stated to come up with the adjusted CPSs. The adjusted CPS values are presented in **Table 6-15**.

Except for a few COPCs, cancer potency slope factors for inhalation exposure, referred to as CPS_i, are typically not available. The CPS_is were available for the following constituents (in $[mg/kg/d]^{-1}$):

- Arsenic – $1.51 \times 10^{+1}$
- Benzo(a)pyrene - 3.1×10^{0}
- PCE – 2.0×10^{-2}
- TCE – 4.0×10^{-1}

6.5.3 Mixtures

The USEPA has also developed guidelines to evaluate the overall potential for noncancer and

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Aldrin – $1.7 \times 10^{+1}$
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cancer effects posed by multiple chemicals. This approach assumes that subthreshold exposures to several chemicals at the same time could result in an adverse health effect. It assumes that the magnitude of the adverse effect will be proportional to the sum of the ratios of the subthreshold exposures to acceptable exposures. The hazard index is equal to the sum of the hazard quotients. When the hazard index exceeds 1.0, there may be concern for potential health effects. Generally, hazard indices are only used in the evaluation of a mixture of chemicals that induce the same effect by the same mechanism of action. In this evaluation, the hazard quotients of a mixture of chemicals that can have different effects are used as a screening-level approach, as recommended by the USEPA (USEPA, 1989a). This approach is likely to overestimate the potential for effects.

For the assessment of carcinogenic risks, the individual risks associated with exposure to each constituent are summed. This represents an approximation of the precise equation for combining risks, which accounts for the joint probabilities of the same individual developing cancer as a consequence of exposure to two or more carcinogens. This additive approach assumes independence of action by the constituents involved (i.e., that there are no synergistic or antagonistic chemical interactions and all chemicals produce the same effect, i.e., cancer).

6.6 RISK CHARACTERIZATION

The final step in the human health evaluation is the characterization of risk. Here the toxicity and exposure assessments are summarized and combined into quantitative and qualitative expressions of risk. Potential noncarcinogenic effects are characterized by comparing intakes and toxicity values, while carcinogenic risks are characterized by estimating the probability that an individual will develop cancer over a lifetime of exposure.

6.6.1 Use of Surrogate Constituents

Typically, constituents that do not have risk screening criteria and no, or minimal, toxicity data are identified as COPCs and retained for qualitative assessment. However, in the case of this HHRA, the VDEQ permits the use of "surrogate constituents" (i.e., constituents that are closely related to the particular constituent in question, and thus expected to have similar health impacts) that allows constituents to be evaluated with respect to COPC status in the absence of chemical-specific screening data. Thus, use of surrogates decreases the need to evaluate potential COPCs in only the qualitative manner. As shown in **Tables 6-1 to 6-3**, the following provides the constituents for which a no chemical-specific screening data, as well as the surrogate substitution:

- *Constituent*: Acenaphthylene – *Surrogate*: Pyrene
- *Constituent*: Benzo(g,h,I)perylene – *Surrogate*: Pyrene
- *Constituent*: Phenanthrene – *Surrogate*: Pyrene
- *Constituent*: Endosulfan I – *Surrogate*: Endosulfan
- *Constituent*: Endosulfan II – *Surrogate*: Endosulfan

- *Constituent*: Endosulfan Sulfate – *Surrogate*: Endosulfan

6.6.2 Quantitative Risk Assessment

Potential non-cancer health effects are presented. Carcinogenic risks are similarly presented for the COPC, for each pathway of concern and for each potentially exposed population. The cumulative impact of exposure from the various pathways evaluated is estimated for each potentially exposed population.

The USEPA (1989a) recommends absorption efficiency adjustments to ensure that the site exposure estimate (CDI) and the toxicity criteria (RfD and CPS) are both expressed as absorbed doses or both expressed as intakes (administered doses). All CDI calculations are provided in **Appendix G**. As indicated in the following tables, the oral RfD's and CPS's have been adjusted for absorption to match the absorbed dose for dermal exposure.

Fort Story/Future Industrial Site Workers

Non-cancer Effects

Table 6-16 presents the chemical-specific hazard quotients for each pathway involving Fort Story and potential future industrial; site worker exposures to surface soils. In addition, the total pathway hazard, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway, is presented in **Table 6-16**. The total exposure hazard incorporates all the appropriate exposure pathways for the Fort Eustis/Industrial site workers.

To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which on-site exposure may occur.

As shown in **Table 6-16**, the four PAHs do not have identified non-cancer effects, and therefore, no hazard index was calculated.

Cancer Risks

Table 6-17 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion and inhalation of, and dermal contact with chemicals in surface soils. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for Fort Story/Future Industrial site workers.

The estimated cancer risk for ingestion of, dermal contact with, and inhalation of chemicals in soils is about 3.29 in one hundred thousand (3.29 x 10^{-5}). This value is at the mid range of the USEPA Superfund target risk level of 10^{-4} to 10^{-6}. Exposure to (ingestion, dermal contact, and inhalation) soil

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Non-cancer Effects¶
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Table 6-26 presents the chemical-specific hazard quotients for each pathway involving trespasser exposures to surface soils. In addition, the total pathway hazard, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway, is presented in **Table 6-26**. The total exposure hazard incorporates all the appropriate exposure pathways for the trespasser.¶
¶
To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which on-site exposure may occur.¶
¶
As shown in **Table 6-26**, the total exposure hazard index for ingestion of, and dermal contact with surface soils is 0.0036, which is less than the criterion of 1.0. Thus, adverse non-carcinogen health effects in this population are unlikely.¶
¶
Cancer Risks¶
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Table 6-27 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion of, and dermal contact with, chemicals in surface soils. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for potential site trespassers.¶
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with benzo(a)pyrene accounts for approximately 70% of the risk for site workers.

Construction Workers

Non-cancer Effects

Table 6-18 presents the chemical-specific hazard quotients for each pathway involving construction workers exposures to soils (surface/subsurface combined) and groundwater. In addition, the total pathway hazard, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway, is presented in **Table 6-18**. The total exposure hazard incorporates all the appropriate exposure pathways for the construction workers. To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which on-site exposure may occur.

As shown in **Table 6-18**, the total exposure hazard index for all exposures associated with soil and groundwater is 0.275, which is less than the criterion of 1.0. Thus, adverse non-carcinogen health effects in this population are unlikely.

Cancer Risks

Table 6-19 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion and inhalation of, and dermal contact with chemicals in soils (surface/subsurface combined) and groundwater. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for construction workers. The estimated cancer risk is about 1.02 in one hundred thousand (1.02×10^{-5}). This value is at the mid-range of the USEPA Superfund target risk level of 10^{-4} to 10^{-6}. The summary of risk is presented as follows:

- Approximately 15% of the risk is associated with soil exposure (Total Soil Exposure Risk $=1.49 \times 10^{-6}$).
  - Approximately 71% of the soil exposure risk is associated with exposure (ingestion, dermal, and inhalation) to benzo(a)pyrene.

- Approximately 85% of the risk is associated with groundwater exposure (Total Groundwater Exposure Risk = 8.76×10^{-6}).
  - Approximately 93% of the groundwater exposure risk is associated with inhalation of TCE vapors from groundwater.

Commercial/Industrial Workers

Non-cancer Effects

The total exposure hazard incorporates all the appropriate exposure pathways for the

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Residential Population (Adults and Children)¶
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Non-cancer Effects¶
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Table 6-32 presents the chemical-specific hazard quotients for each pathway involving residential population exposures to site soils (surface/subsurface combined) and groundwater. In addition, the total pathway hazard, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway, is presented in **Table 6-32**. The total exposure hazard incorporates all the appropriate exposure pathways for the residential population. To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which exposure may occur.¶
¶
Adults¶
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As shown in **Table 6-32**, for adults, the total exposure hazard index for all exposure scenarios associated with soil and groundwater is 1.19, which is only slightly greater than the criterion of 1.0. The exposure hazard index associated with soil is 0.043, and 1.15 for groundwater. Thus, adverse non-carcinogen health effects in this population are possible, however mostly through exposure to groundwater. With the respect to groundwater exposure, the hazard index is summarized as follow ... [27]

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commercial/industrial workers. To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for the inhalation pathway only through which on-site exposure may occur.

The total exposure hazard index for inhalation of VOCs in structures associated with groundwater is 0.02, which is much less than the criterion of 1.0. Thus, adverse non-carcinogen health effects in this population are unlikely.

Cancer Risks

The estimated cancer risk is about 3.1 in one hundred thousand (3.1×10^{-5}). Approximately 90 percent of the risk is associated with TCE concentrations in groundwater. This value is at the mid-range of the USEPA Superfund target risk level of 10^{-4} to 10^{-6}. It should be noted that the 95th UCL concentrations for these three VOCs are all less than their respective MCL.

6.6.3 Uncertainty

Some uncertainty is inherent in the process of conducting predictive, quantitative health risk assessments. Environmental sampling and analysis, fate and transport modeling and human exposure modeling are all prone to uncertainty, as are the available toxicity values used to characterize risk. Such uncertainty is generally related to the limitations of the sampling in terms of the number and distribution of samples and analytical information in terms of systematic or random errors used to characterize a site, the estimation procedures and the input variables and assumptions used in the assessment.

There are uncertainties in every step of the risk assessment process; uncertainties that relate to this human health evaluation may be noted. Selection of the COPCs provides uncertainty since the selection process relies heavily on professional judgment. If different COPCs were chosen or if some were excluded the estimates of risk would be affected.

Additional uncertainties are inherent in the exposure assessment for individual chemicals and exposure routes. There is also some uncertainty in the derivation of health effects criteria in the toxicity assessment. In most cases, the criteria are derived from the extrapolation from laboratory animal data to the human condition. This may have the effect of either overestimating or underestimating the risk.

For this site, the only identified uncertainty that may influence the results of the HHRA included that the site was generally small in size (estimated at less than 1 acre); therefore, the estimates of receptor exposure to site media is likely a significant overestimation.

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Residential Population Exposure Scenarios¶
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A summary of the uncertainties associated with the residential population exposure scenarios is provided as follows:¶
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Soil ¶
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<#>One of the three inorganic COPCs (arsenic) detected in surface/subsurface soils above its respective EPA RBC for residential soils was also detected at concentrations (95th percentile UCLsas presented in Section 3.1.4) less than background soils, and therefore, it should be removed from the quantitative risk assessment.¶
¶
Groundwater¶
¶
<#>Exposure to site groundwater is a significant contributor to non-carcinogenic and carcinogenic risk for adult and children. To further reduce the actual list of contaminants of concern, a comparison of groundwater data to USEPA MCLs is made in that these standards are the primary enforceable standards for potable water sources. One dissolved metals (arsenic) and two organic constituents (trichloroethene and bis(2-ethylhexyl)phthalate) were detected at concentrations below USEPA MCLs. Although these contaminants may have been detected above the EPA RBCs for tap water, because they were detected below drinking water standards, no future remedial action for thes ... [28]

6.6.4 Human Health Risk Assessment Summary

A summary of the non-carcinogenic and carcinogenic risk (adjusted as discussed in Section 6.6.3) is provided in the following table:

Human Health Risk Assessment Summary

Exposed Population	Exposure Pathway	Non-Cancer Effects		Cancer Effects	
		PHI	TEHI	TPR	TER
Fort Story/Future Industrial Site Workers	Ingestion of Soil	N/A	N/A	1.77×10^{-5}	3.29×10^{-5}
	Dermal Contact with Soil	N/A		1.52×10^{-5}	
	Inhalation of Soil Particulates	N/A		4.90×10^{-10}	
Commercial/Industrial Workers inside Structures	Inhalation of Vapors from GW	0.02	0.02	3.1×10^{-5}	3.1×10^{-5}
Construction Workers	Ingestion of Soil	N/A	0.275	5.70×10^{-7}	1.02×10^{-5}
	Dermal Contact with Soil	N/A		9.16×10^{-7}	
	Inhalation of Soil Particulates	N/A		1.59×10^{-9}	
	Ingestion of Groundwater	0.00512		1.60×10^{-8}	
	Dermal Contact with GW	0.104		9.45×10^{-8}	
	Inhalation of Vapors from GW	0.165		8.65×10^{-6}	

For Non-Carcinogens:
PHI – Pathway Hazard Index indicates non-carcinogenic risk for specific exposure pathways
TEHI – Total Exposure Hazard Index indicates non-carcinogenic risk for exposed population
Criterion of 1.0 is used to determine if adverse health effects are possible or unlikely.
N/A – Not applicable because non-cancer effects were not identified for this population.
For Carcinogens:
TPR – Total Pathway Risk indicates carcinogenic risk for specific exposure pathways
TER – Total Exposure Risk indicates carcinogenic risk for exposed population
USEPA Remediation goal of 10^{-4} to 10^{-6} used to assess carcinogenic risk.
Bolded and underlined text indicates value exceeds the non-cancer criterion of 1.0 or above the carcinogenic risk level of 10^{-4}.

Finally, the above summary of potentially exposed populations was based on a conservative approach rather than a more reasonable estimation of risk. Additional factors that affect the conclusions drawn from the risk characterization results include the following:

- The exceedences of the industrial soil RBCs for the PAHs is limited to a small portion of the site in the interior area near the former location of the storage tanks.

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- The majority of the risk associated with construction and potential future commercial/industrial worker exposure to contaminated groundwater is associated with TCE; however, the 95th UCL utilized in the risk calculations was only 2.5 µg/L which is lower than the USEPA drinking water MCL of 5 µg/L. The estimated cancer risk associated with the other groundwater COPCs combined was in the 10^{-7} range.

- The cancer risk established for the site workers (3.29×10^{-5}), commercial/industrial workers (3.1×10^{-5}) and construction workers (1.02×10^{-5}) is within the EPA Superfund target risk level range. As quoted in Section 300.430(e)(2)(i)(A)(2) of the National Contingency Plan (NCP), "for known or suspected carcinogens, acceptable exposure levels are generally concentrations that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6};" therefore, the concentrations in soil and groundwater fall within the acceptable range based on carcinogenic risk.

Based on the limited soil area impacted by the PAHs, the relatively low concentration of TCE (and other constituents) in groundwater, and the calculated cancer risks for site and construction workers which is within the acceptable range per NCP guidance, no additional action is warranted at the site based on the potentially exposed populations.

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Soil

In the event that the Site is redeveloped for either industrial, residential, or recreational uses, several potentially exposed populations on the site may exist.

During construction, both surface and subsurface soils would be disturbed exposing the construction worker to the constituents present in the soils. Once construction is complete at the site and the site is occupied the potential for industrial or residential exposure exists depending on the intended use for the property. However, if the site were left in its current state in the future (i.e., no construction activities), or converted for recreational use (e.g., a ball field), then trespassers or recreational users would be exposed to surface soils only.

If the Site were used for an Industrial purpose, the exposed population would include the industrial workers tasked with maintaining the grounds (mowing, landscaping, etc.).

If the Site were developed into a residential area the exposed population would include adults and children living on the site exposed to surface and subsurface soil as a result of playing, yard work, and/or gardening.

There is a potential for the Site to be developed in to a recreational park area. If the site were converted into a recreational park area, the exposed population would include recreational user (adults and children).

If the Site were to remain totally undeveloped (i.e., with no form of access control), then the exposed population would include the occasional trespasser.

To maintain the conservative approach of this risk assessment the construction worker, industrial, residential, trespasser, and recreational receptors to site soil will be retained for further evaluation.

Groundwater

The water table aquifer for the site is the Columbia aquifer. This aquifer is typically at shallow depths, thin, with low yield, and variable water quality. Use of this aquifer is generally restricted to individual domestic supply in rural areas. Additionally, based on the Site's low-land location and proximity to wetland areas, the groundwater at the Site is expected to be very poor in quality and aesthetics. Based on the poor water quality and low yield conditions, no development of the Columbia Aquifer at or near the site for drinking water purposes is expected. Although the water quality is expected to be poor, and the area is served by a pubic water supply, if the site were developed into a residential area, a minimal potential for domestic use of the groundwater at the site exists.

To maintain the conservative approach of this risk assessment the residential (drinking water) and construction worker (incidental contact) receptors will be retained for further evaluation.

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For the future situation, the following potentially exposed populations to the contaminated media at the site have been identified:

Trespasser exposure (adults only) to contaminated surface soils,
Recreational exposure (adults and children) to contaminated surface soils,
Site industrial workers (adults only) exposure to surface/subsurface soils,
Residential exposure (adults and children) to contaminated surface/subsurface soils,
Residential exposure (adults and children) to contaminated groundwater during groundwater use,

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Trespasser Populations (Adults)

Ingestion of chemicals in surface soil
Dermal contact with chemicals in surface soil

Recreational Populations (Adults and Children)

Ingestion of chemicals in surface soil
Dermal contact with chemicals in surface soil

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Residential Populations (Adults and Children)

Ingestion of chemicals in surface/subsurface soil
Dermal contact with chemicals in surface/subsurface soil
Inhalation of particulates from surface/subsurface soil
Ingestion of chemicals in groundwater
Dermal contact with chemicals in groundwater
Inhalation of volatile chemicals in groundwater during bathing

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Acenaphthene	UCL	0.74
Anthracene	UCL	1.97

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Indeno(1,2,3-cd)pyrene	Max	3.60
Aldrin	UCL	0.045
Aluminum	UCL	7349
Arsenic	UCL	0.75
Iron	UCL	9463

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Acenaphthene	UCL	0.36
Anthracene	UCL	0.83

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Indeno(1,2,3-cd)pyrene	UCL	1.31
Aldrin	UCL	0.014
Aluminum	UCL	2780

Arsenic	UCL	0.59
Iron	UCL	3755

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and Residential (adult and child)

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ve

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drinking water

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In addition, as potential residential exposures to groundwater would most likely occur through use of a groundwater well, water from the well would be filtered prior to use. Thus, the residential population would be exposed to inorganic concentrations akin to the dissolved samples obtained during the RI. However, a

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dissolved (filtered) inorganics data for exposure of future potential residential populations, and

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Dissolved Arsenic	UCL	0.004
Dissolved Iron	UCL	3.09
Dissolved Manganese	UCL	0.13

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Trespasser (Adults)

<u>*Soils*</u>

Tables 6-5 and 6-6 present the parameters and assumptions used in assessing potential exposures of adult Trespassers to chemicals in soil through ingestion and dermal contact. The following summarizes the assumptions made for exposure to chemicals in soil through ingestion and dermal contact:

Ingestion

As a trespasser would be present on site for a short time, the ingestion rate would be low. VDEQ, 2003 recommends 100 mg/day to maintain a conservative approach.

The "fraction ingested" (FI) is defined as the fraction ingested from a particular source. For this analysis, it is assumed that 12.5 percent of the incidental exposure is presumed to come from this scenario (VDEQ, 2003). This represents 2 hours per day contact with contaminated soil.

The exposure frequency (EF) for trespassers is assumed to be exposed for 24 days/year, based upon the assumption that a trespasser will spend approximately six days per month on the site during four months out of the year (VDEQ, 2003).

An exposure duration (ED) of 24 years as recommended by VDEQ, 2003.

The average body weight (BW) of an American adult is approximately 70 kg (USEPA, 1991).

The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

Dermal Contact

VDEQ, 2003 recommends an available skin surface area value of 5000 cm^2, which assumes 25% of skin surface is available for contact.

The soil to skin adherence factor (AF) used is 0.20 mg/cm^2 based on VDEQ, 2003 recommendation.

For the dermal contact with soil pathway, the absorption factor (ABS) is 13% for PAHs, 3% for arsenic (USEPA, 2001, Exhibit 3-4), 10% for aldrin, and 1% for other metals (USEPA, Region III, 1995).

The exposure frequency, exposure duration, body weight, and averaging time values are the same as those used for the ingestion pathway.

Recreational User (Adults and Children)

<u>Soils</u>

Tables 6-7 and 6-8 present the parameters and assumptions used in assessing potential exposures for adult and child recreational users to chemicals in soil through ingestion and dermal contact. The following summarizes the assumptions made for exposure to chemicals in soil through ingestion and dermal contact:

Ingestion

In evaluating inadvertent ingestion of soil during recreational activities, a conservative ingestion rate of 200 mg of soil/day is used as representative for children and 100 mg/day for adults (VDEQ, 2003).

The "fraction ingested" (FI) is defined as the fraction ingested from a particular source. For this analysis, it is assumed that 12.5 percent of the incidental exposure is presumed to come from this scenario (VDEQ, 2003). This represents 2 hours per day contact with contaminated soil.

The exposure frequency (EF) for recreational users of the site is assumed to be 195 days per year, which assumes exposure occurs five days/month for 39 weeks (VDEQ, 2003).

An exposure duration (ED) of 24 years for adults and 6 years for children as recommended by VDEQ, 2003 and USEPA 1991.

The average body weight (BW) of an American adult and child is approximately 70 kg and 15 kg, respectively (USEPA, 1991).

The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

Dermal Contact

VDEQ, 2003 recommends an available skin surface area value of 5,000 cm^2 for adults and 1,750 cm^2 for children, which assumes 25% of skin surface is available for contact.

The soil to skin adherence factor (AF) used is 0.20 mg/cm^2 based on VDEQ (2003) recommendation.

For the dermal contact with soil pathway, the absorption factor (ABS) is 13% for PAHs, 3% for arsenic (USEPA, 2001, Exhibit 3-4), 10% for aldrin, and 1% for other metals (USEPA, Region III, 1995).

The exposure frequency, exposure duration, body weight, and averaging time values are the same as those used for the ingestion pathway.

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Residential Populations (Adults and Children)

<u>*Soils*</u>

Tables 6-12, 6-13, and 6-14 present the parameters and assumptions used in assessing exposures for potential future residential populations to chemicals in soil through ingestion, dermal contact, and inhalation of particulates. The following summarizes the assumptions made for exposure to chemicals in soil through ingestion, dermal contact, and inhalation of soil particulates:

Ingestion

In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), a conservative ingestion rate of 200 mg of soil/day is used as representative for children and 100 mg/day for adults (USEPA, 1991).

The "fraction ingested" (FI) is defined as the fraction ingested from a particular source. For this analysis, it is assumed that 100 percent of the incidental exposure is presumed to come from this scenario.

The exposure frequency (EF) for residential populations (adult and children) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1991).

An exposure duration (ED) of 24 years for adults and 6 years for children as recommended by VDEQ, 2003 and USEPA 1991.

The average body weight (BW) of an American adult and child is approximately 70 kg and 15 kg, respectively (USEPA, 1991).

The averaging time (AT) selected depends upon the type of toxic effect being assessed as described as follows:

When evaluating exposures for potential long-term non-cancer health effects, intakes are calculated by averaging over the period of exposure. This, in effect, is equal to the exposure duration multiplied by 365 days/year.

When evaluating potential carcinogenic risks, intakes are calculated by prorating the total cumulative dose over a lifetime. For calculation purposes, this is equal to 70 years multiplied by 365 days/year.

This distinction is consistent with the hypothesis that the mechanism of action for each of these effects is different. The approach for carcinogens is based on the assumption that a high dose received over a short period of time is equivalent to a corresponding low dose spread over a lifetime.

Dermal Contact

For the residential dermal exposure to soil, it is assumed that the exposed skin surface area is 5,000 cm^2 for adults and 1,750 cm^2 for children (VDEQ, 2003).

The soil to skin adherence factor (AF) used is 0.20 mg/cm^2 based on VDEQ (2003) recommendation.

For the dermal contact with soil pathway, the absorption factor (ABS) is 13% for PAHs, 3% for arsenic (USEPA, 2001, Exhibit 3-4), 10% for aldrin, and 1% for other metals (USEPA, Region III, 1995).

The exposure frequency, exposure duration, body weight, and averaging time values are the same as those used for the ingestion pathway.

Inhalation of Soil Particulates

For the evaluation of inhalation of soil particulates, the constituent concentration in air is calculated using the methodology for the Particulate Emission Factor as provided in *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites*

(EPA, 2001c), using default parameters. All calculations are provided in **Appendix E**.

An inhalation rate (IR) of 0.83 m^3/hour for adults and 0.5 m^3/hour for children is assumed in evaluating the inhalation of chemicals in air due to soil particulate suspension (USEPA, 1991).

Exposure time (ET) for the inhalation pathway is estimated as 24 hours/day based on VDEQ, 2003.

The exposure frequency, exposure duration, body weight and averaging time values are the same as those used for the ingestion pathway.

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<u>*Groundwater*</u>

Tables 6-15, 6-16, and 6-17 present the parameters and assumptions used in assessing potential exposures to chemicals in groundwater. In the evaluation of exposures resulting from ground water via ingestion and dermal contact, the following factors and assumptions are used.

Ingestion

For the ingestion of ground water, an ingestion rate (IR) of 2 liters/day is assumed for residential adults and 1 liter/day is assumed for residential children (VDEQ, 2003).

Exposure frequency and duration, body weight and averaging time assumptions were previously discussed.

Dermal Contact

Adults

For the evaluation of dermal contact with chemicals in ground water, it is assumed that the greatest, but not the exclusive, opportunity for exposure is during showering. The entire surface area (SA) of the body is used to evaluate these exposures. For adults, this value is 20,000 cm^2, and for children, this value is 7,000 cm^2.

Since the calculated exposure is designed to be the absorbed dose, not the amount of chemical that comes into contact with the skin, a permeability constant (PC) is necessary to access exposure through dermal contact. The PC reflects movement across the skin to the underlying skin layers and into the bloodstream. Predicted PCs for each COPC were obtained from USEPA, 2001 Appendix B-2 (organics) and B-4 (inorganics), and summarized below.

SUMMARY OF PERMEABILITY CONSTANTS	
COPC	Permeability Constant (cm/hr)
Tetrachloroethene	3.3×10^{-2}
Trichloroethene	1.2×10^{-2}
Bis(2-EH)phthalate	2.5×10^{-2}
Antimony	1.0×10^{-3}
Arsenic	1.0×10^{-3}
Iron*	1.0×10^{-3}
Manganese	1.0×10^{-3}

* : Default value for metals applied.

For adults, an exposure time (ET) of 35 minutes/day (0.58 hours/day) is assumed for dermal contact with chemicals in groundwater during showering activities, based upon the Reasonable Maximum Exposure Scenario presented in Exhibit 3-2 of USEPA 2001. For children, an exposure time (ET) of 60 minutes/day (1 hour/day) is assumed for dermal contact with chemicals in groundwater during bathing activities (i.e., it is assumed that a child takes a bath rather than a shower), based upon the Reasonable Maximum Exposure Scenario presented in Exhibit 3-2 of USEPA 2001.

The exposure frequency (EF) for residential populations (adult) is assumed to be exposed for 350 days/year with 15 days per year expected to be away from the residence (USEPA, 1995a).

Inhalation

For the evaluation of inhalation of airborne VOCs from the groundwater, the contaminant concentration in air is calculated using a simplified approach that assumes that all VOCs of potential concern in the hot water are released during showering. For this calculation, it is assumed that a non-water-conserving showerhead is used with a flow rate of 12.9 liters per minute (3.4 gallons per minute, USEPA 1997, Table 17-17), and the VOCs mix within the volume of the shower area (assumed to be $30 m^3$ in volume) to achieve an equilibrium concentration of the chemicals in air. In practice, concentrations would probably build up and plateau during the showering event. However, this analysis assumes exposure to the total amount of VOCs present in the water, with uniform dispersion in the room volume, over the entire shower event, with no loss due to ventilation. The following equation is used to determine the chemical concentration in air based on the above assumptions:

Chemical concentration in air (mg/m^3) = CW x CF x WV x 1/RV, where:

CW = chemical concentration in water (ug/l)
CF = conversion factor (1E-03 mg/ug)
WV = volume of water (= flow rate x exposure time = 12.9 lpm x 35 min = 452 liters)
RV = room volume ($30 m^3$)

The concentration in air for the chemicals of potential concern is presented below. All concentration-in-air calculations are provided in **Appendix E**.

COPC Concentrations in Air	
COPC	**Air Concentration (mg/m^3)**
Tetrachloroethene	6.03E-02
Trichloroethene	4.52E-02
Bis(2-ethylhexyl)phthalate	7.53E-02

An inhalation rate (IR) of 0.83 m^3/hour for adults and 0.5 m^3/hour for children is assumed in evaluating the inhalation of chemicals in air due to soil particulate suspension (USEPA, 1991).

An exposure time (ET) of 35 minutes/day (0.58 hours/day), as assumed for dermal contact with chemicals in groundwater during showering activities, is based upon the Reasonable Maximum Exposure Scenario presented in Exhibit 3-2 of USEPA 2001. This value is also applied for children in this scenario, as a conservative approach, as the volume of water to fill a tub would be similar to that used during the 35-minute shower.

Exposure frequency and duration, body weight and averaging time assumptions were previously discussed.

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These rates were obtained from the Risk Assessment Information System (RAIS) database. The RAIS is a U.S. Department of Energy database of information developed from data from the USEPA Integrated Risk Information System (IRIS) and Health Effects Assessment Summary Tables (HEAST) and other literature sources. Absorption efficiencies are included in the Toxicity Profiles provided in **Appendix F**, and summarized below.

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Acenaphthene – 31%
Aldrin – 50%
Aluminum – 10%
Anthracene – 76%

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Indeno[1,2,3-cd]pyrene – 31%

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Aluminum – 1 x 10^{-3}

Trespasser

Non-cancer Effects

Table 6-26 presents the chemical-specific hazard quotients for each pathway involving trespasser exposures to surface soils. In addition, the total pathway hazard, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway, is presented in **Table 6-26**. The total exposure hazard incorporates all the appropriate exposure pathways for the trespasser.

To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which on-site exposure may occur.

As shown in **Table 6-26**, the total exposure hazard index for ingestion of, and dermal contact with surface soils is 0.0036, which is less than the criterion of 1.0. Thus, adverse non-carcinogen health effects in this population are unlikely.

Cancer Risks

Table 6-27 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion of, and dermal contact with, chemicals in surface soils. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for potential site trespassers.

The estimated cancer risk for ingestion of and dermal contact with chemicals in soils is about 6.1 in one million (6.1 x 10^{-6}). This value is at the lower end of the USEPA Superfund target risk level of 10^{-4} to 10^{-6}. Thus, significant carcinogenic health effects in this population are unlikely. Exposure to (ingestion and dermal contact) soil with benzo(a)pyrene accounts for approximately 78% of the risk to trespassers.

Recreational Populations (Adults and Children)

Non-cancer Effects

Table 6-28 presents the chemical-specific hazard quotients for each pathway involving recreational population exposures to site surface soils. In addition, the total pathway hazard, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway, is presented in **Table 6-28**. The total exposure hazard incorporates all the appropriate exposure pathways for the recreational population.

To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which on-site exposure may occur.

As shown in **Table 6-28**, the total exposure hazard index for ingestion of, and dermal contact with, contaminated soils is 0.08 for children and 0.03 for adults, which are both less than the criterion of 1.0. Thus, adverse non-carcinogen health effects in this population are unlikely.

Cancer Risks

Table 6-29 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion of, and dermal contact with, chemicals in site surface soils. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for potential recreational users of the site.

The estimated cancer risk for ingestion of and dermal contact with chemicals in soils is about 5.03 in one hundred thousand (5.03×10^{-5}) for adults and 2.31 in one hundred thousand (2.31×10^{-5}) for children. This value is at the upper-mid range of the EPA Superfund target risk level of 10^{-4} to 10^{-6}. Exposure to (ingestion and dermal contact) soil with benzo(a)pyrene accounts for approximately 78% of the risk to recreational users (children and adults).

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the total exposure hazard index for ingestion, dermal contact, and inhalation of/with site soils is 0.027, which is less than the criterion of 1.0. Thus, adverse non-carcinogen health effects in this population are unlikely.

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Residential Population (Adults and Children)

Non-cancer Effects

Table 6-32 presents the chemical-specific hazard quotients for each pathway involving residential population exposures to site soils (surface/subsurface combined) and groundwater. In addition, the total pathway hazard, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway, is presented in **Table 6-32**. The total exposure hazard incorporates all the appropriate exposure pathways for the residential population. To assess the overall potential for adverse non-cancer effects posed by the chemicals of potential concern, the hazard quotients for the chemicals are summed for each of the pathways through which exposure may occur.

Adults

As shown in **Table 6-32**, for adults, the total exposure hazard index for all exposure scenarios associated with soil and groundwater is 1.19, which is only slightly greater than the criterion of 1.0. The exposure hazard index associated with soil is 0.043, and 1.15 for groundwater. Thus, adverse non-carcinogen health effects in this population are possible, however mostly through exposure to groundwater. With the respect to groundwater exposure, the hazard index is summarized as follows:

Approximately 60% of the Groundwater Hazard Index is associated with exposure (ingestion and dermal) to dissolved arsenic, iron, and manganese in groundwater.

Approximately 37% of the Groundwater Hazard Index is associated with exposure (ingestion, dermal, and inhalation) to trichloroethene in groundwater.

Children

As shown in **Table 6-32** for children, the total exposure hazard index for all exposures associated with soil and groundwater is 3.04, which is greater than the criterion of 1.0. The total exposure hazard index for all exposure scenarios associated with soil is 0.26, and 2.78 for groundwater. Thus, adverse non-carcinogen health effects in this population are possible, however mostly through exposure to groundwater. With the respect to groundwater exposure, the hazard index is summarized as follows:

Approximately 58% of the Groundwater Hazard Index is associated with exposure (ingestion and dermal) to dissolved arsenic, iron, and manganese in groundwater.

Approximately 39% of the Groundwater Hazard Index is associated with exposure (ingestion, dermal, and inhalation) to trichloroethene in groundwater.

Cancer Risks

Table 6-33 presents estimated chemical-specific and total pathway cancer risks calculated for exposure to site soil (surface and subsurface) and groundwater. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for the residential population.

Adults

The estimated cancer risk for adults for all exposure scenarios associated with soil and groundwater exposure is about 2.6 in ten thousand (2.60×10^{-4}). This value exceeds the USEPA Superfund target risk level of 10^{-4} to 10^{-6}. A summary of risk is presented as follows:

Approximately 53% of the risk is associated with soil exposure (Total Soil Exposure Risk = 1.37×10^{-4}).

Approximately 84% of the soil exposure risk is associated with exposure (ingestion, dermal, and inhalation) to benzo(a)pyrene.

Greater than 47% of the risk is associated with groundwater exposure (Total Groundwater Exposure Risk = 1.23 x 10^{-4}).

Approximately 47% of the groundwater exposure risk is associated with exposure (ingestion, dermal, and inhalation) trichloroethene.

Approximately 46% of the groundwater exposure risk is associated with exposure (ingestion, dermal, and inhalation) to dissolved arsenic.

Children

The estimated cancer risk for children for all exposure scenarios associated with both soil and groundwater is about 6.40 in ten thousand (6.4 x 10^{-4}). This value exceeds the USEPA Superfund target risk level of 10^{-4} to 10^{-6}. A summary of risk is presented as follows:

Approximately 88% of the risk is associated with soil exposure (Total Soil Exposure Risk = 5.62 x 10^{-4}).

Approximately 83% of the soil exposure risk is associated with exposure (ingestion, dermal, and inhalation) to benzo(a)pyrene.

Greater than 22% of the risk is associated with groundwater exposure (Total Groundwater Exposure Risk = 7.82 x 10^{-5}).

Approximately 50% of the groundwater exposure risk is associated with exposure (ingestion, dermal, and inhalation) trichloroethene.

Approximately 43% of the groundwater exposure risk is associated with exposure (ingestion, dermal, and inhalation) to dissolved arsenic.

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Residential Population Exposure Scenarios

A summary of the uncertainties associated with the residential population exposure scenarios is provided as follows:

Soil

One of the three inorganic COPCs (arsenic) detected in surface/subsurface soils above its respective EPA RBC for residential soils was also detected at concentrations (95th percentile UCLsas presented in Section 3.1.4) less than background soils, and therefore, it should be removed from the quantitative risk assessment.

Groundwater

Exposure to site groundwater is a significant contributor to non-carcinogenic and carcinogenic risk for adult and children. To further reduce the actual list of contaminants of concern, a comparison of groundwater data to USEPA MCLs is made in that these standards are the primary enforceable standards for potable water sources. One dissolved metals (arsenic) and two organic constituents (trichloroethene and bis(2-ethylhexyl)phthalate) were detected at concentrations below USEPA MCLs. Although these contaminants may have been detected above the EPA RBCs for tap water, because they were detected below drinking water standards, no future remedial action for these compounds would be expected.

The concentrations of dissolved iron and manganese were detected above the EPA RBCs. However, SWCB, 1981 cites 24 groundwater samples obtained from the water table aquifer in the municipality of Virginia Beach and analyzed for iron. The concentrations of iron in these samples ranged from 60 ug/l to 14,000 ug/l with a median value of 2,100 ug/l and an average value of 3,870 ug/l. Additionally, SWBC, 1981 cites 22 groundwater samples obtained from the water table aquifer in the municipality of Virginia Beach and analyzed for manganese. The concentrations of manganese in these samples ranged from 20 ug/l to 440 ug/l with a median value of 150 ug/l and an average value of 148 ug/l. Thus, the concentrations of iron and manganese observed in groundwater samples from the 80th DRS are consistent with regional background values. Therefore, these two constituents (dissolved iron and manganese) should be removed from the quantitative risk assessment.

Adjusted Residential Scenario Summary

With the removal of COPCs below background levels and removal of groundwater COPCs below USEPA MCLs, the revised risk is provided in **Tables 6-36 and 6-37**. A summary of the exposure pathways, the primary COPCs associated with the risk for each pathway, and any mitigating factors are presented as follows:

<u>Non-cancer Effects</u>

Total Exposure Hazard Index: Adverse non-cancer health effects associated with potential residential exposure to the site are unlikely as the total exposure hazard index for adults (0.055) and children (0.27) is less than the criterion of 1.

Soil Exposure Hazard Index: Adverse non-cancer health effects associated with potential exposure to surface/subsurface soils are unlikely as the total soil exposure hazard index for adults (0.039) and children (0.23) is less than the criterion of 1.

Groundwater Exposure Hazard Index: Adverse non-cancer health effects associated with ingestion of, inhalation of, and dermal contact with groundwater are not likely as the groundwater exposure hazard index for adults (0.016) and children (0.04) is less than the criterion of 1.

<u>Cancer Risk</u>

Total Exposure Risk: Increased cancer risk associated with potential residential exposure to the site is possible as total exposure risk for adults (1.4×10^{-4}) and children (5.54×10^{-4}) is greater than the USEPA Superfund target risk level of 10^{-4} to 10^{-6}. However, the vast majority (96% for adults and 99% for children) of this increased cancer risk is attributable to soil exposures, as detailed below.

Soil Exposure Risk: Cancer risk estimates of 1.35 x 10^{-4} (adults) and 5.51 x 10^{-4} (children), which exceed the USEPA target risk level, were estimated for ingestion of, inhalation of, and dermal contact with site soils. Soil exposure risk is primarily associated with benzo(a)pyrene (representing 85% of the soil exposure risk for both adults and children).

Groundwater Exposure Risk: Cancer risk estimates of 5.05 x 10^{-6} (adults) and 3.32 x 10^{-6} (children), which are at the lower end of the USEPA target risk level, were estimated for potential exposure to site groundwater.

A summary of the nature and extent of contamination, fate and transport characteristics and the risk assessment for the 80th DRS is provided in the following sections.

8.1 NATURE AND EXTENT OF CONTAMINATION

8.1.1 Soil

A summary of the nature and extent of soil contamination is provided as follows:

VOCs

- Acetone, methylene chloride, and toluene were detected in more than 85 percent of the surface and subsurface soil samples collected at the site. Many other VOCs including carbon disulfide, 1,4-dichlorobenzene, trans 1,2-DCE, ethylbenzene, MIBK, PCE, trichlorofluoromethane, 1,1,2-trichloro-1,2,2-trifluoroethane, and xylenes were detected frequently (in greater than 20 percent of the samples) throughout the site. Concentrations of these compounds varied from surface to deeper depths with no apparent trends.

- The lateral extent of VOC contamination was not defined because VOCs were detected in all of the surface soil samples collected in this area. However, concentrations were several orders of magnitude lower than EPA screening criteria.

SVOCs

- SVOCs were detected in all soil samples collected from the site. The primary SVOCs detected were PAHs, which are constituents of petroleum hydrocarbons. Bis(2-ethylhexyl)phthalate was the only SVOC detected in two of the soil borings, while only bis(2-ethylhexyl)phthalate, fluorene, phenanthrene, and pyrene were detected one of the borings indicating minimal downgradient migration of SVOCs in soils since these 3 borings are located directly downgradient of the former UST and AST, asphalted, and drum storage areas of the site.

- Although PAHs were detected throughout the site, the areas with the highest concentrations were centered around the former UST/AST area and the former drum storage area with lower concentrations in areas generally upgradient of these areas.

Pesticides

- Endrin ketone, DDT, and endosulfan sulfate were detected in site soil samples. Aldrin was the only pesticide detected above an EPA RBC for residential soils (38 ug/kg) in one sample on-site at a concentration of 73 ug/kg. Pesticides were detected in all soil samples at the site with little variation in location (upgradient, on-site, or downgradient) or with depth.

- Due to past widespread application of these pesticides, their presence at these low concentrations are expected at the site.

PCBs

- Aroclor-1260 was the only PCB detected at the site and it was detected in only 2 of 30 soil samples and at concentrations lower than EPA RBCs. Due to infrequent detection, there is not pattern to its distribution at the site.

Inorganics

- Metals were detected in soil samples throughout the site as would be expected since the majority of them are naturally occurring in various concentrations. Only three metals (arsenic, iron, and vanadium) concentrations exceeded EPA RBCs for residential soils, none exceeded industrial RBCs. Arsenic exceeded the RBC in 8 of 30 samples and iron exceeded the RBC in 6 of 30 samples while vanadium exceeded the RBC in 3 of 30 samples

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- In general, concentrations of metals typically were similar for soil samples collected from the surface and subsurface depths.

8.1.2 Groundwater

A summary of the nature and extent of ground water contamination is provided as follows:

VOCs/SVOCs

- Several VOCs and bis(2-ethylhexyl)phthalate were detected at concentrations greater than the EPA RBCs at the site.

- Other than toluene, which was detected in all 10 wells at the site, no other organics were detected in wells that are upgradient/cross-gradient of the former AST/UST and drum storage areas.

- The highest concentrations of organics were detected in the central portions of the site near the former UST/AST (assumed source area) and drum area, with some organics detected in downgradient wells as well.

- The lateral distribution of PCE, TCE, and cis 1,2-DCE implies these compounds have migrated with groundwater from the former UST area downgradient to the north/northwest in that these compounds have been detected in downgradient wells MW-5, MW-6, and MW-9.

- Bis(2-ethylhexyl)phthalate was detected in only one well on-site and its apparent distribution is limited to the former UST area.

Inorganics

Although most metals were detected in total and dissolved phase throughout the site, the distribution pattern will focus on those metals that exceeded EPA RBCs and/or MCLs:

- Total antimony concentrations are consistent across the site with detections in 8 of 10 wells across the site. The concentrations in the upgradient wells are greater than the concentrations in the central-site and downgradient wells. This indicates that the antimony concentrations detected at the site are probably naturally occurring levels and not influenced by the past operations at the former UST/AST and drum storage areas.

- Total arsenic was detected in only 3 of 10 wells with concentrations greatest in one central-site well and in two downgradient wells. Based on the low concentrations and infrequent detection, no discernible pattern is present and it is unclear if these concentrations are solely related to natural levels or are influenced by former site activities.

- Total iron was detected in all 10 wells with concentrations greatest in one central-site well (MW-7) and in three downgradient wells (MW-9, MW-10, and MW-11). These concentrations were the only total iron detects above the EPA RBC. Dissolved iron was also detected in all 10 wells with concentrations greatest in the same wells as the total iron concentrations. The highest concentrations of total and dissolved iron were present in downgradient wells MW-10 and MW-11 which are the least-impacted wells in relation to identified contaminants of concern for the site (VOCs and SVOCs from the former UST and drum storage areas). Based location of the highest iron concentrations (downgradient wells), it is unclear if these concentrations are solely related to natural levels or are influenced by former site activities.

- Total and dissolved manganese were detected in all 10 wells with concentrations greatest in two downgradient wells. These concentrations were the only total or dissolved manganese detects above the EPA RBC. The highest concentrations of total and dissolved manganese were present in two downgradient wells, which are the least-impacted wells in relation to identified contaminants of concern for the site (VOCs and SVOCs from the former UST and drum storage areas). Based location of the highest manganese concentrations (downgradient wells), it is unclear if these concentrations are solely related to natural levels or are influenced by former site activities.

- Total vanadium concentrations are fairly consistent across the site with detections in 9 of 10 wells across the site. The concentrations (1.2 to 4.2 µg/L) in the upgradient wells (MW-1 and MW-2) are consistent with the concentrations (1.1 to 6.3 µg/L) in the central-site wells (MW-3,

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MW-7, and MW-8) and greater than the concentrations (0.65 to 2.3 µg/L) in the downgradient wells. This indicates that the vanadium concentrations detected at the site are probably naturally occurring levels and not influenced by the past operations at the former UST/AST and drum storage areas.

8.2 FATE AND TRANSPORT

A summary of the fate and transport for the site contaminants is provided in the following sections.

8.2.1 Transport Pathways

The possible transport pathways identified for the site that are considered to be minor pathways due to mitigating site conditions or contaminant properties include the following:

- Volatilization of VOCs from shallow groundwater to shallow soils. The VOCs in site groundwater are all in the low (7.5 or less) part-per-billion range, and therefore would not be a significant contributor of vapor when view with respect to COPC mass.
- Migration, enhanced by infiltrating rainwater, of SVOCs, pesticides, and metals through the vadose zone to groundwater. SVOCs, pesticides, and inorganics strongly adsorb to soil/sediments and are not readily leached to groundwater due to their low aqueous solubility.
- Migration of VOCs, pesticides, SVOCs and inorganics adsorbed to sediment/soil and transported along with windblown dust/sand. Ground cover at the site should limit the amount of transport by wind.
- Leaching of sediment/soil contaminants to surface water. Due to the low solubility of pesticides, SVOCS, and most inorganics, it is very unlikely that these compounds would be readily leached from soil.

The major transport pathways identified for the site include:

- Migration of SVOCs, pesticides, and inorganics adsorbed to soil/sediments by storm runoff into the wetlands and beach/coastal areas.
- Bulk transport, dispersion, or diffusion of VOCs from soil to groundwater.

8.2.2 Fate and Transport of Contaminants in Specific Media

Soils

Soil samples results for the site indicate that VOCs, SVOCs, pesticides and inorganics were present.

Most VOCs were infrequently detected, and all that were detected had concentration several orders of magnitude less than the associated EPA risk screening criteria. Because of the infrequent detection and low concentrations detected (several were estimated concentration), migration of VOCs is not a significant concern at the site.

Of the detected SVOCs, PAHs were detected most frequently. PAHs strongly adsorb to soil, especially the fine fraction (silt and clay), and remains in the soil column at the source area but they can slowly leach to groundwater or surface water. Sandy soils, such as those at the site can lack sufficient organics to hold PAHs in place. Leaching of PAHs from soil to groundwater is increased in environments with a high annual precipitation rate and high infiltration rate similar to the site conditions observed at the site. Biodegradation is an important fate process for PAHs under aerobic conditions but not anaerobic conditions. There were multiple detection throughout the soil column that were above the EPA risk screening criteria. Most of the detections above the EPA risk screening criteria were found in the surface soil (less than 6 inches). PAHs were found above the industrial and residential EPA criteria. These constituents are most likely bound to the surface soil, but remain available for transport.

Numerous metals were detected on-site and downgradient of the site. Some soil samples exceeded the residential EPA RBCs for arsenic, iron, and aluminum. None of the samples collected exceeded the EPA RBCs for industrial soils. Arsenic can be transported adsorbed to soils/sediment particles (especially silts and clays) that are windborne. Arsenic in soil typically occurs predominately as an insoluble form. Arsenic is relatively immobile and in the presence of iron, calcium, and aluminum, and tends to form insoluble complexes that remain in the soils. It is expected that arsenic would be adsorbed to silts and clays in an insoluble form that would be unavailable for leaching to groundwater.

In general, pesticides were detected in soil samples throughout the soil column. Pesticides are persistent and relatively immobile compounds. These compounds would not be expected to significantly leach to groundwater. The compounds can migrate adsorbed to soil/sediment particles when transported by storm water runoff or surface water. There was one detection of a pesticide (Aldrin) that was found to be above the EPA risk screening criteria. The sample was detected in the surface soil.

Groundwater

Overall, VOCs were detected infrequently, with two constituents detected above EPA criteria for tap water RBCs. Three detections for both tetrachloroethene (MW-7, MW-8, MW-9) and trichloroethene

(MW-5, MW-7, MW-8) exceeded screening criteria. However, only tetrachloroethene at MW-8 exceeded the EPA's MCL criteria. PCE and TCE resist adsorption to soil and are identified as compounds that can leach into, and migrate in, groundwater. PCE can be biodegraded in to TCE. Confining layers in the subsurface restrict vertical migration.

Bis(2-ethylhexyl) phthalate (BEHP) was the only SVOC detected at the site. It was detected at in the sample from MW-8 above the EPA risk screening criteria RBC. BEHP's long persistence in the subsurface and ability to migrate through the soil at low concentrations could indicate that BEHP could be transported in site groundwater. AS BEHP was detected in only one sample location of 10, indicates that BEHP contamination is not wildly spread.

Numerous metals were detected in groundwater; however, the constituents most frequently detected over the RBCs were arsenic, iron and manganese. Dissolved phase inorganics will be transported with flowing groundwater, but most likely will not migrate as rapidly as the organics. Precipitation of the metals onto soil particles in the saturated zone may occur and impact dissolved inorganic concentrations available for migration.

8.3 RISK ASSESSMENT

8.3.1 Human Health Risk Assessment

A summary of the non-carcinogenic and carcinogenic risk is provided in the following table:

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- **Deleted:** Inhalation of Soil Particulates ... [12]

Human Health Risk Assessment Summary					
Exposed Population	Exposure Pathway	Non-Cancer Effects		Cancer Effects	
		PHI	TEHI	TPR	TER
Fort Story/Future Industrial Site Workers	Ingestion of Soil	N/A	N/A	$1.77x10^{-5}$	$3.29x10^{-5}$
	Dermal Contact with Soil	N/A		$1.52x10^{-5}$	
	Inhalation of Soil Particulates	N/A		$4.90x10^{-10}$	
Commercial/Industrial Workers inside Structures	Inhalation of Vapors from GW	0.02	0.02	$3.1x10^{-5}$	$3.1x10^{-5}$

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Human Health Risk Assessment Summary					
Exposed Population	Exposure Pathway	Non-Cancer Effects		Cancer Effects	
		PHI	TEHI	TPR	TER
Construction Workers	Ingestion of Soil	N/A	0.275	$5.70x10^{-7}$	$1.02x10^{-5}$
	Dermal Contact with Soil	N/A		$9.16x10^{-7}$	
	Inhalation of Soil Particulates	N/A		$1.59x10^{-9}$	
	Ingestion of Groundwater	0.00512		$1.60x10^{-8}$	
	Dermal Contact with GW	0.104		$9.45x10^{-8}$	
	Inhalation of Vapors from GW	0.165		$8.65x10^{-6}$	

For Non-Carcinogens:
PHI – Pathway Hazard Index indicates non-carcinogenic risk for specific exposure pathways
TEHI – Total Exposure Hazard Index indicates non-carcinogenic risk for exposed population
Criterion of 1.0 is used to determine if adverse health effects are possible or unlikely.
N/A – Not applicable because non-cancer effects were not identified for this population.
For Carcinogens:
TPR – Total Pathway Risk indicates carcinogenic risk for specific exposure pathways
TER – Total Exposure Risk indicates carcinogenic risk for exposed population
USEPA Remediation goal of 10^{-4} to 10^{-6} used to assess carcinogenic risk.
Bolded and underlined text indicates value exceeds the non-cancer criterion of 1.0 or above the carcinogenic risk level of 10^{-4}.

Finally, the above summary of potentially exposed populations was based on a conservative approach rather than a more reasonable estimation of risk. Additional factors that affect the conclusions drawn from the risk characterization results include the following:

- The exceedences of the industrial soil RBCs for the PAHs is limited to a small portion of the site in the interior area near the former location of the storage tanks.

- The majority of the risk associated with construction worker and commercial/industrial worker exposure to contaminated groundwater is associated with TCE; however, the 95th UCL utilized in the risk calculations was only 2.5 µg/L which is lower than the USEPA drinking water MCL of 5 µg/L. The estimated cancer risk associated with the other groundwater COPCs combined was in the 10^{-7} range.

- The cancer risk established for the site workers ($3.29x10^{-5}$), commercial/industrial workers ($3.1x10^{-5}$) and construction workers ($1.02x10^{-5}$) is within the EPA Superfund target risk level range. As quoted in Section 300.430(e)(2)(i)(A)(2) of the National Contingency Plan (NCP), "for known or suspected carcinogens, acceptable exposure levels are generally concentrations that represent an excess upper bound lifetime cancer risk to an individual of

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between 10^{-4} and 10^{-6};" therefore, the concentrations in soil and groundwater fall within the acceptable range based on carcinogenic risk.

8.3.2 Ecological Risk Assessment

This screening level ecological risk assessment (SLERA) was completed in accordance with USEPA guidelines. The results of the SLERA and conclusions for chemicals of potential concern (COPCs) are summarized below.

VOCs

A total of 21 VOCs were detected, 12 of these compounds had screening values. Only one compound, Tetrachloroethylene, had an EEQ of greater than one based on BTAG criteria. Nine compounds were retained as COPCs due to lack of screening values. There were no TRVs available to assess direct contact with plants or invertebrates for these initial ten COPCs. Five TRVs were available for mammalian receptors: 2-Butanone, Acetone, Carbon disulfide, Tetrachloroethylene and Trichlorofluoromethane. There was no avian TRVs available for VOCs. No hazard quotients for VOCs indicate these compounds present a potential risk to ecological receptors at the 80^{th} DRS site.

SVOCs

All 24 SVOCs were initially retained as COPCs, either for exceeding the BTAG values or because they lacked TRV criteria. Seven of these SVOCs are polyaromatic hydrocarbons (PAH) and two are phthalates. Of the initial COPCs, 16 that had screening criteria available were retained. This included seven PAHs. No phthalates were retained. Of the initial COPCs, only fluorene had a non-BTAG TRV available. Though fluorene did not exceed the invertebrate TRV, it was retained as a COPC for exceeding the BTAG screening value.

Mammalian TRV data was available for 11 of the COPCs. Avian TRV data was only available for bis(2-Ethylhexyl)phthalate. After completing the initial exposure assessment, eight COPCs were determained to have a HQ above one for mammalian species: Benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, phenanthrene and pyrene. No COPCs were found to have an HQ greater than one for avian species. Using area use factors (AUFs) were used to refine the risk characterization. Only one COPC, pyrene, was identified for shrew populations. The HQ for pyrene in shrews was 3 using a NOAEL-based TRV. Due to the minimal NOAEL-based HQ for one indicator species, pyrene is not considered to pose a risk to ecological receptors at the 80^{th} DRS and has not been retained as a COPC in this SLERA

Metals

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- **Deleted:** The following table indicates those compounds that could pose a risk to the flora and fauna of the 80^{th} DRS site. It does not include those compounds that have been removed due to lack of standards. ¶ ¶ **Parameters** ... [43]
- **Deleted:** Aluminum, chromium, and lead were identified as being sources of possible risk to food chain receptors. As chromium and lead had maximum detection values less than the background values for the local region of Ft. Story, they were not retained for the final list of COPCs. Aluminum is the only metal that has been retained, and has been identified as being a possible risk to all receptors.¶ ... [44]
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Six metals were initially retained as COPCs. Three of these did not have screening values. Mammalian and avian TRV data was available for three COPC metals. After completing the initial exposure assessment, aluminum was found to have an HQ equal to or greater than one for all avian and mammalian species. Aluminum toxicity in a soil matrix is related to its solubility and, therefore, soil pH. For sites with soil pH above 5.5, USEPA guidelines do not recommend including aluminum as a COPC for ecological receptors. The soil conditions at the 80th DRS are consistent with elimination of aluminum as a COPC.

Conclusions

As stated in Section 7.1, the assessment endpoints at the 80th DRS site do not include vegation or soil invertebrates due to the small size of the impacted site, the lack of endangered species on the site, and the type of soil and vegetation on the site. The appropriate evaluation of risk posed by COPCs in soil at this site was to determine the risk posed to the overall ecosystem at Fort Story. The assessment endpoints for this SLERA, therefore, were to evaluate: 1) Uptake of COPCs into food chain, 2) survival and reproduction of upper-trophic avian species, and 3) survival and reproduction of upper-tophic mamalian species.

Based on the results of this SLERA, COPCs in soil at the 80th DRS site are not likely to accumulate in the food chain of the ecosystem surrounding the site and, therefore, do not pose a risk to upper-trophic avian or mammalian species. There is ample habitat at Fort Story surrounding the site to maintain a healthy, diverse ecosystem. As a result, the management goal for the 80th DRS site of protecting the ecosystem surrounding the site by evaluating uptake of COPCs from soil into the food chain can be achieved without establishing COPCs based on ecological endpoints.

Based on the combination of the low HQ value for pyrene, the elimination of aluminum as a COPC, and a conservative risk assessment approach, the conclusion of this risk characterization is that concentrations of COPCs in soils at the 80th DRS do not pose a risk to upper trophic receptors. There is no evidence that remediation decisions should be based on existing adverse effects to ecological receptors. No further ecological risk assessment is recommended for this site.

8.4 RECOMMENDATIONS

The recommendations for the site are based on the nature and extent of contamination, fate and transport characteristics and the results of the human health and ecological risk assessments.

A feasibility (FS) study is not recommended for the 80th DRS site based on the results of the risk assessment that indicated no or minimal potential risks for the identified potentially exposed human and ecological populations. Typically, the results of the risk assessment are the triggers for

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¶
<#>Limited soil area impacted by the PAHs.¶
<#>The relatively low concentration of TCE (and other constituents) in groundwater.¶
<#>The calculated cancer risks for site and construction workers which is within the acceptable range per NCP guidance ¶
<#>The low HQ value for pyrene.¶
<#>The elimination of aluminum as a COPC.¶
<#>A conservative risk assessment approach which concludes that concentrations of COPCs in s ... [45]

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performance of a FS and since no potential current or future risk was identified, the FS is not warranted.

However, although no current or future risk was identified for site groundwater, there are concentrations of several contaminants are above EPA MCLs for drinking water including several VOCs. Since the site cannot currently be considered as unrestricted land use (because of the MCL exceedences primarily), it is recommended that a Decision Document be prepared for the site which will include a requirement for long term monitoring (LTM) and land use controls at the site to assess any migration potential or increases in contaminant concentrations and to ensure that the anticipated land use (continued industrial usage) is continued.

Compliance with Virginia Antidegradation policy is the long range objective for the site. Because no current or planned potable use of the site groundwater is anticipated, state and federal groundwater protection standards and MCLs are not applicable at this time. Based on the previous removal action at the site which included the removal of petroleum- and PCE-contaminated soils (the source of the groundwater contamination) and the relatively low concentrations of VOCs currently in groundwater, it is reasonable to assume that continued decreases in contaminant concentrations through natural processes will occur with eventual reduction to levels that satisfy the requirements of the Virginia Antidegradation policy.

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Non-Cancer Effects

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Cancer Effects

Page 6: [2] Deleted	pace	1/19/2007 4:22:00 PM

Exposed Population

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Exposure Pathway

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PHI

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TEHI

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TPR

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TER

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Ingestion of Soil

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0.000504

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0.00313

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5.93×10^{-6}

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Ingestion of Soil

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0.0041

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0.025

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4.82×10^{-5}

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Ingestion of Soil

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0.038

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0.042

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1.97×10^{-5}

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Ingestion of Soil

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0.021

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0.0052

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1.03×10^{-5}

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Inhalation of Soil Particulates

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0.00068

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8.77×10^{-10}

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Human Health Risk Assessment Summary

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Non-Cancer Effects

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Cancer Effects

Page 6: [15] Deleted	pace	1/19/2007 4:22:00 PM

Exposed Population

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Exposure Pathway

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PHI

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TEHI

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TPR

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TER

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Ingestion of Soil

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0.022

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0.017

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$7.98x10^{-5}$

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Inhalation of Soil Particulates

Page 7: [19] Deleted	pace	1/19/2007 4:22:00 PM

0.00056

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$1.02x10^{-9}$

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Residential Populations
(Adults)

Page 7: [21] Deleted	pace	1/19/2007 4:22:00 PM

Ingestion of Groundwater

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0.011

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$1.95x10^{-6}$

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Dermal Contact with GW

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0.0021

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$3.74x10^{-7}$

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Inhalation of Vapors from GW

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0.0028

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$2.73x10^{-6}$

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Inhalation of Soil Particulates

Page 7: [24] Deleted	pace	1/19/2007 4:22:00 PM

0.0016

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$7.16x10^{-10}$

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Residential Populations
(Children)

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Ingestion of Groundwater

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0.026

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$1.14x10^{-6}$

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0.0059

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$2.63x10^{-7}$

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Inhalation of Vapors from GW

Page 7: [28] Deleted	pace	1/19/2007 4:22:00 PM

0.008

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$1.92x10^{-6}$

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Ingestion of Soil

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0.02

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Dermal Contact with Soil

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0.0063

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1.13×10^{-6}

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Inhalation of Soil Particulates

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0.029

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3.52×10^{-9}

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Ingestion of Groundwater

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0.0046

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1.20×10^{-8}

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0.092

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1.15×10^{-7}

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Inhalation of Vapors from GW

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0.15

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8.25×10^{-6}

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For Non-Carcinogens:

PHI – Pathway Hazard Index indicates non-carcinogenic risk for specific exposure pathways
TEHI – Total Exposure Hazard Index indicates non-carcinogenic risk for exposed population
Criterion of 1.0 is used to determine if adverse health effects are possible or unlikely.

For Carcinogens:

TPR – Total Pathway Risk indicates carcinogenic risk for specific exposure pathways
TER – Total Exposure Risk indicates carcinogenic risk for exposed population
USEPA Remediation goal of 10^{-4} to 10^{-6} used to assess carcinogenic risk.
Bolded and underlined text indicates value exceeds the non-cancer criterion of 1.0 or above the carcinogenic risk level of 10^{-4}.

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The above summary of potentially exposed populations was based on a conservative approach rather than a more reasonable estimation of risk. The only significant human health risks are confined mainly to residential receptors exposure to site soils. In this scenario, the majority of the risk is associated with exposure to PAHs, in particular benzo(a)pyrene. Based upon this estimation of risk, it appears that further action is required in the form of a Feasibility Study to support selection of viable remedial alternatives

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The following table indicates those compounds that could pose a risk to the flora and fauna of the 80th DRS site. It does not include those compounds that have been removed due to lack of standards.

Parameters	Plants (Flora)	Invertebrates (Fauna)	Robin	Red-tailed Hawk	Short-tailed Shrew	Rabbit	Gray Fox
TCL VOCs							
Tetrachloroethene	√	√					
TCL SVOCs							
Acenaphthene	√	√					

Acenaphthylene	√	√					
Benzo(a)pyrene	√	√			√		√
Benzo(a)anthracene	√	√					√
Benzo(b)fluoranthene	√	√			√		√
Benzo(k)fluoranthene	√	√			√		
Benzo(g,h,i)perylene	√	√					
Chrysene	√	√			√		√
Dibenzo(a,h)anthracene	√	√					
Dibenzofuran	√	√					
Fluoranthene	√	√			√		√
Fluorene	√	√					
Indeno(1,2,3-cd)pyrene	√	√			√		
Naphthalene	√	√					
Phenanthrene	√	√			√		√
Pyrene	√	√			√		√
TAL Metals							
Aluminum	√	√	√	√	√	√	√
TCL Pesticides							
None Retained							
PCBs							
None Retained							

Tetrachloroethlene (TCE) is the only VOC that poses a risk to the environment at the site, TCE has been found to be a COPC in regards to the plant and invertebrate population at the 80th DRS. No other VOCs have been identified as posing danger to environmental receptors.

SVOCs are the most prevalent compounds that have been retained. Many of these compounds were detected at levels one magnitude greater than EPA Soil BTAG levels, **Table 7-3** Most of these SVOCs are identified as direct exposure risks, to the flora and invertebrate fauna at the site. Food chain calculations have found that eight SVOCs, including five PAHs pose a possible risk to mammalian species.

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Aluminum, chromium, and lead were identified as being sources of possible risk to food chain receptors. As chromium and lead had maximum detection values less than the background values for the local region of Ft. Story, they were not retained for the final list of COPCs. Aluminum is the only metal that has been retained, and has been identified as being a possible risk to all receptors.

No pesticides or PCBs have been identified as final COPCs.

It is believed that the results from this portion of the report are highly conservative in identifying risks form both direct exposure and uptake by way of the food chain.

Based upon these results of the environmental risk assessment portion of his report, it is suggested that a Feasibility Study is performed to investigate remedial action options for best restoration of the 80th DRS.

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Although contaminants have been detected across the site and some in concentrations greater than human health and ecological screening levels, based on the findings presented below, no additional investigative action is warranted. The reasons for the recommendation include the following:

Limited soil area impacted by the PAHs.
The relatively low concentration of TCE (and other constituents) in groundwater.
The calculated cancer risks for site and construction workers which is within the acceptable range per NCP guidance
The low HQ value for pyrene.
The elimination of aluminum as a COPC.
A conservative risk assessment approach which concludes that concentrations of COPCs in soils at the 80th DRS do not pose a risk to upper trophic receptors.

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A feasibility (FS) study is recommended for the 80th DRS based on the results of the risk assessment that indicated potential risks for the following populations:

Potential future residential populations exposed to soils at the 80th DRS. The site is currently an industrial area. This exposure scenario assumes that housing would be developed in this area.

Various ecological risks were identified including flora and fauna exposure to VOCs, SVOCs and aluminum, avian species exposure to aluminum and mammalian species exposure to SVOCs and aluminum. These populations currently have access to the site and thus a chance for exposure to these compounds.

Thus, consideration of both human health and ecological potential exposures at the site indicate that the evaluation of potential remediation options of the 80th DRS and surrounding areas may be prudent.