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DRAFT REMEDIAL INVESTIGATION REPORT 80TH DIVISION RESERVE SITE WITH
RESPONSES TO VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY COMMENTS
FORT STORY VA
1/30/2007
MALCOLM PIRNIE

File: GC 16
6D.11

80th DRS

Revised R1

WorkCentre 7132
Banner Sheet

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Start Page

Responses to VDEQ Comments
Draft Remedial Investigation and Quality Control Summary/Analytical Results Reports
80th Division Reserve Site
Fort Story, VA

Remedial Project Manager Comments

1. The Department has no comments on the *Draft QCS/AR Report* at this time.

✓ *Response: None required.*

2. 4.2.2.1, page 4-11 – Please insert a section heading for “**Metals**” as was done for “**Organics**.”

✓ *Response: “Metals” header added.*

3. 4.3.2, last paragraph, 3rd sentence, page 4-15 – This refers to “the shallow part of the aquifer.” Please clarify the meaning of this phrase or the specific location to which this phrase is referring.

✓ *Response: Additional text has been added to this paragraph for clarification.*

4. 5.1.1, paragraph 2, page 5-3 – This states that infrequent detection is an indication that impact and risk is minimal. The Department recommends that, initially, all detected constituents exceeding screening criteria be evaluated. Discussions concerning the frequency of detection (and the criteria by which detections are determined to be “infrequent”) may be addressed in the “**Uncertainty**” section.

✓ *Response: This is the “Fate and Transport” section, not the risk assessment section. We agree that infrequent detection will not be utilized in Section 6 as a means of screening out a constituent. The purpose of this section was to discuss the migration characterizations of the primary constituents of concern and infrequent detection is a tool of limiting the list for discussion.*

5. 5.1.1, VOCs, page 5-5 – The constituents listed do not include all those specified in the tables on pages 4-5, 4-10, and 5-2 through 5-3. Please specify the purpose for listing some of the detected VOCs and not others.

✓ *Response: This list has been updated. Due to an oversight, all of the VOCs were discussed in the paragraphs that followed but not presented in this sentence.*

6. 5.1.1, VOCs, page 5-5 – Benzene is listed here but is not shown on Tables 4-3 and 4-7, nor is a discussion provided for it later in this section. Please clarify this discrepancy.

✓ *Response: Benzene should not have been on the list and it has been deleted.*

7. 5.1.1, VOCs, pages 5-5 through 5-11 – Please correct the spelling for 2-butanone here and throughout the *Draft RI*. Also, please correct the headings for and verify that the correct information is provided for cis-1,2-dichloroethene and trans-1,2-dichloroethene (as opposed to the alkanes).

Response: Changes made and the discussion was correct for cis and trans 1,2-DCE.

8. 6.1.2, last paragraph, last bullet, page 6-4 – This states that data may be evaluated based on the frequency of detection. Please see comment 4 above.

Response: Text revised to state that infrequent detection will be discussed in the Uncertainty section and not as a method to screen out constituents before the quantitative assessment.

9. 6.1.2, last paragraph, last bullet, page 6-4 – This states that data may be compared to background. Please provide all background data.

Response: Text revised to state background has been included in Appendix J.

10. 6.3.1, paragraph 1, 1st sentence, page 6-9 – This references surface sediment. However, neither Section 2 nor Table 2-2 mentions any sediment samples. Please clarify this discrepancy.

Response: Text revised because no sediment samples were collected.

11. 6.3.1, paragraph 1, 2nd sentence, page 6-9 – This references 16 surface soil samples. However, only 10 samples are shown in Tables 4-3 through 4-6. Please clarify this discrepancy.

Response: Text revised to state "10 surface soil samples" were collected.

12. 6.3.1, paragraph 1, last sentence, page 6-9 – Please revise this to correctly reference **Tables 4-3** (as opposed to Table 4-4) **through 4-6**.

Response: Text revised to state Tables 4-3 through 4-6.

13. 6.4.3, last paragraph, page 6-18 – Please specifically indicate which qualifiers are subject to this treatment. Also, see comments 12 and 21 of the **Risk Assessor Comments** below.

Response: Text revised to state that this includes organics with a "J" qualifier and metals with a "B" qualifier.

14. 6.6.3, **Residential Population Exposure Scenarios, Soil**, page 6-46 – Please provide all background soils data and supporting statistical evaluations.

Response: Additional text added to Sections 6.1.2 and 6.6.3 concerning background data.

15. 6.6.3, **Residential Population Exposure Scenarios, Groundwater**, 2nd bullet, page 6-46 – The Department has reviewed the document (Siudyla, E.A., May, A.E., Hawthorne, D.W., 1981; Ground Water Resources of the Four Cities Area, Virginia; Commonwealth of Virginia, State Water Control Board, Bureau of Water Control Management) referenced in this section. It is not possible to determine whether or not any of the wells used in the SWCB, 1981 study have been impacted by contamination. Therefore, the SWCB, 1981 study is not sufficient (by itself) to determine background levels for this site. The Department recommends also obtaining site-specific background data. The Groundwater Flexibilities statement and related information (previously provided to you) may provide some guidance for the development of additional lines of evidence.

Response: This bullet was deleted because the residential scenario was deleted.

Will this question come up again?

16. 7.4.1, Terrestrial Plants and Invertebrates, paragraph 1, last sentence, page 7-13 – Please correct this incomplete sentence.

Response: Entire section has been revised.

17. 7.6.3, paragraph 2, last sentence, page 7-16 – Please provide all background data and supporting statistical evaluations.

Response: Entire section revised.

18. 7.6.6, paragraph 1, page 7-16 – Please provide the table referenced here.

Response: Entire section revised.

19. Figure 5-1 – This figure refers to the DOL Storage Yard. Please provide the correct figure.

Response: Figure revised.

Risk Assessor Comments

Page 1-3, Section 1.2.2:

1. Was there any history of explosive manufacture, use or storage at this site? Dinitrotoluene was detected in the subsurface soil and could be indicative of explosives.

Response: There was no identified history at the site related to the use or storage of explosive materials. DNT is also present in polyurethane foams, dyes, and car air bags.

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.

Page 6-1, Section 6.1:

3. The list of Human Health Risk Assessment (HHRA) guidance documents should also include Risk Assessment Guidance for Superfund (RAGS) Part D. The HHRA should use the standard table format presented in RAGS Part D. Not having the standard format added considerably to the review time for this project.

Response: We will strive to use the standard table format for future HHRAs.

4. The final version of RAGS, Part E (EPA, 2004) should be cited rather than the interim version.

Response: Text revised.

5. Page 6-16, Section 6.4.1: The section on groundwater indicates that no development of the Columbia Aquifer at or near the site for drinking water purposes is expected. Section 3.1.5 on page 3-9 states that several housing communities located within 1 mile west of Fort Story are

developing shallow drinking water wells in the water table aquifer. Are these communities downgradient of the 80th DRS site?

Response: Additional text has been added to this section stating that these communities are not downgradient of the site.

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.

7. Page 6-19, Section 6.4.5: The ProUCL program also calculates upper confidence limits (UCLs) based on a gamma distribution. These should be used when recommended by ProUCL. In addition, ProUCL sometimes recommends a 97.5 or 99% UCL. These should be used when recommended by ProUCL.

Response: Revised ProUCL calculations have been made and included in the revised report. The text has been revised in Section 6.4.5 to reflect the ProUCL approach.

Section 6.4.5:

8. Note that the Virginia Department of Environmental Quality (VDEQ) risk assessment guidance is updated at least twice a year. Some of the exposure factors cited in this section have been updated.

Response: Exposure factors were revised based on a review of the risk assessment guidance provided on-line.

9. VDEQ uses total metals concentrations in risk calculations for drinking water. We don't assume that a drinking water well would always have a filter. What is the basis for that assumption?

Response: EPA Region III document Draft Guidance on Selecting Analytical Metal Results from Monitoring Well Samples for the Quantitative Assessment of Risk, dated August 10, 1992, states that if there is a noticeable disparity between the filtered and unfiltered results (which typically is the case except for maybe essential nutrients) then the results from the filtered samples should be utilized in the risk assessment.

10. See comments below on Appendix D for comments regarding the UCL calculations.

11. Page 6-36, Section 6.5.1: Oral-to-dermal toxicity factor adjustments should be done according to RAGS Part E.

Response: Toxicity factors have been adjusted according to RAGS Part E including the use of the GI absorption factors presented in Exhibit 4-1 of that document.

Table 6-1:

12. It is not clear why certain constituents (such as trans-1,2-dichloroethylene (DCE), methylene chloride, trichloroethylene (TCE), etc.) were included as detections on this table when all of their detections were B qualified. If the qualifiers were applied correctly (concentration less

Should this be spelled out?

RAGS

than 10 times the blank concentration), B qualified data should not be included in the risk assessment.

Response: Agreed; however, since none of these compounds were identified as COPCs for soil, their inclusion is inconsequential. — Were the tables updated?

13. The EPA Region III Residential risk-based concentration (RBC) for Acenaphthene should be 470,000 µg/kg. Acenaphthene does not need to be retained as a contaminant of potential concern (COPC). The RBC for anthracene should be 2,300,000 µg/kg. Anthracene does not need to be retained as a COPC.

correct spacing
✓ *Response: Table changed.*

14. The residential RBC for dibenzo(a,h)anthracene should be 87 µg/kg. Dibenzo(a,h)anthracene should be retained as a COPC.

✓ *Response: Table changed.*

15. The residential and industrial RBCs for chromium should be 23 and 310 mg/kg, respectively.

✓ *Response: Table changed.*

16. According to Table 4-6, the maximum concentration of mercury should be 0.035 mg/kg.

✓ *Response: Table changed.*

17. The residential and industrial RBCs for vanadium should be 7.8 and 100 mg/kg, respectively. Vanadium should be retained as a COPC.

✓ *Response: Table changed.*

Table 6-3:

18. It is not clear why the detection of 11 µg/L cis-1,2-DCE in MW-9 was not included as the maximum concentration in groundwater. Cis-1,2-DCE should be a COPC since the maximum concentration exceeds the RBC.

✓ *Response: Table changed.*

19. The RBC for tetrachloroethylene (PCE) should be 0.1 µg/L. The RBC table is updated twice a year. The most recent version of the RBC table should be used.

✓ *Response: Table changed.*

20. It is not clear why the detection of 7.5 µg/L TCE in MW-9 was not included as the maximum concentration in groundwater.

✓ *Response: Table changed.*

21. It is not clear why the detections of toluene and 1,2,4-trichlorobenzene were included on this table since all of the detections had B qualifiers. If the qualifiers were applied according to

the 10X rule (concentration less than 10 times the blank concentration) B qualified data should not be included in the risk assessment.

Response: Agreed; however, since none of these compounds were identified as COPCs for groundwater, their inclusion is inconsequential.

22. The EPA carcinogen class for mercury (mercuric chloride) should be C.

✓ *Response: Table changed.*

23. The EPA RBC for vanadium should be 3.7 µg/L.

✓ *Response: Table changed.*

24. Table 6-9: The fraction ingested (FI) for the industrial worker should be 1.

✓ *Response: Revision made.*

25. Table 6-10: The skin surface area (SA) for the industrial worker should be 3300 cm².

Response: Revision made.

26. Table 6-13: The SA for the child resident should be 2800 cm².

Response:
The risk assessment has been revised and does not include residential exposures.

27. Table 6-24 and 6-25: See RAGS E for current guidance on adjustment of toxicity factors for dermal exposure assessment. It appears that some adjustments have been made that weren't required.

Response: Revisions have been made to the adjustments based on Rags Part E.

28. Table 6-33: I was not able to verify the oral carcinogenic risk estimates for residents. I was not able to determine the source of the discrepancy.

Response:
The risk assessment has been revised and does not include residential exposures.

Appendix D, UCL Calculations

29. Note that UCLs only need to be calculated for contaminants that exceed screening values.

Response: Comment noted.

Groundwater

30. ProUCL recommends a UCL of 2.631 mg/L for iron based on a gamma distribution.

31. ProUCL recommends a UCL of 0.0034 mg/L for dissolved arsenic using the modified t method.

32. ProUCL recommends a UCL of 2.3 mg/L for dissolved iron based on a gamma distribution.

33. ProUCL recommends a UCL of 0.09 mg/L for dissolved manganese based on a gamma distribution.

Response: ProUCL revisions for the above have been made.

Soil

↓
Comments 30-33 above

34. The surface soil concentration of Benzo(b)fluoranthene in SB-1 should be 240 µg/kg rather than 140 µg/kg according to Table 4-4. The UCL should be 6.2 mg/kg based on a non parametric distribution.

Response: Revisions made.

35. The surface soil concentration of indeno(1,2,3-cd)pyrene in SB-1 should be 150 µg/kg rather than 75 µg/kg according to Table 4-4. The UCL should be 3.1 mg/kg based on a gamma distribution.

Response: With the removal of the residential scenarios, the UCL for indeno did not need to be calculated since its max concentrations did not exceed the industrial RBC value.

36. The surface soil concentration of aldrin in SB-3 should be 43 µg/kg rather than 0.43 µg/kg according to Table 4-5. The UCL should be 0.067 mg/kg based on a non parametric distribution.

Response: With the removal of the residential scenarios, the UCL for aldrin did not need to be calculated since its max concentrations did not exceed the industrial RBC value.

37. The surface soil UCL for aluminum should be 5632 mg/kg based on a gamma distribution.

Response: With the removal of the residential scenarios, the UCL for aluminum did not need to be calculated since its max concentrations did not exceed the industrial RBC value.

38. The surface soil UCL for iron should be 6670 mg/kg based on a gamma distribution.

Response: With the removal of the residential scenarios, the UCL for iron did not need to be calculated since its max concentrations did not exceed the industrial RBC value.

39. Results that were qualified JB were not treated consistently. For example in the combined soils data set for benzo(a)anthracene the full value (140 µg/kg) was used for MW-7 while ½ the detection (150 µg/kg) was used for MW-8. As noted above, B qualified data are generally not included in quantitative risk assessment. However, if they are used they should be treated consistently.

Response: The full value for B qualified COPCs has been used in the revised assessment.

40. For benzo(a)anthracene and benzo(a)pyrene the summary statistics indicate that the number of samples in the data set was 10. However 30 data points are shown. This discrepancy should be corrected or explained.

Response: This has been corrected.

41. For the benzo(b)fluoranthene combined soil data set the concentration in SB-1 should be 240 µg/kg rather than 120 µg/kg, the concentration in SB-4 should be 2000 µg/kg rather than 200 µg/kg and the concentration in SB-5 should be 3400 µg/kg rather than 2400 µg/kg. My calculations resulted in a UCL of 4.4 mg/kg based on a non parametric distribution.

Response: Correction made.

42. For the indeno(1,2,3-cd)pyrene combined soil data set the concentration in SB-1 should be 150 µg/kg rather than 75 µg/kg. My calculations resulted in a UCL of 2.3 mg/kg based on a non parametric distribution.

Response: Indeno has been removed from the analysis because it did not exceed the industrial RBC value and no residential scenario was assessed.

43. In some cases ProUCL recommends a 99% UCL rather than a 95% UCL. It appears that the 95% UCL was selected regardless of the ProUCL recommendation. For example, the 99% UCL for aldrin in the combined data set should be 0.036 mg/kg based on the ProUCL recommendation. The UCL for aluminum should be 4884 mg/kg based on the ProUCL recommendation.

Response: Revised ProUCL outputs included.

Malcolm Pirnie, Inc. was contracted by the U.S. Army Corps of Engineers (USACE), Baltimore District, to conduct a Remedial Investigation at the 80th Division Reserve Site at Fort Story, Virginia. An extensive field investigation program was conducted in December 2002/January 2003 and June 2004 to acquire sufficient data to assess the nature and extent of contamination and risk to human health and the environment. A summary of the objectives, site description, nature and extent of contamination, fate and transport mechanisms, risk assessment, and recommendations are provided in the following sections.

ES.1 BACKGROUND

All work was conducted in accordance with the Scopes of Services developed by the USACE with field investigation procedures further developed in the Final Work Plan, dated November 2002, and approved by the USACE and the Virginia Department of Environmental Quality (VDEQ). The specific objectives of the RI were:

- Delineation of the nature and extent of contamination
- Evaluation of potential migration of contaminants
- Assessment of risks to human health and the environment
- Development of recommendations for future action based on the findings

ES.2 SITE DESCRIPTION

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.

ES.3 NATURE AND EXTENT OF CONTAMINATION

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. Several other VOCs were detected frequently 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 a 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.
- In general, concentrations of metals typically were similar for soil samples collected from the

surface and subsurface depths.

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 on the 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. *on the*

- 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 on the 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. *on the*
- 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, 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.

ES.4 FATE AND TRANSPORT

Soils

PAHs, metals, and pesticides remain in the soil column because these compounds strongly adsorb to soil, especially the fine fraction (silt and clay). Thus, these compounds tend to remain at the source area with little migration. Biodegradation is expected to be an important fate process for PAHs and pesticides at the site. Due to the potential for transport of soil particles by storm water runoff or surface water, these compounds can migrate when adsorbed to soil or sediment particles. It is expected that transport from on-site to downgradient locations, is accomplished by these mechanisms.

Groundwater

Overall, VOCs were detected infrequently, with three constituents (cis 1,2-DCE, PCE, and TCE), detected above EPA criteria for tap water RBCs. 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 a concentration} 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, 105 sample locations.} indicates that BEHP contamination is not widely 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.

ES.5 RISK ASSESSMENT

Human Health Risk Assessment

A summary of the non-carcinogenic and carcinogenic risk 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	1.77x10 ⁻⁵	3.29x10 ⁻⁵
	Dermal Contact with Soil	N/A		1.52x10 ⁻⁵	
	Inhalation of Soil Particulates	N/A		4.90x10 ⁻¹⁰	
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 exposure to contaminated groundwater is associated with TCE; however, the 95th UCL utilized in the risk calculations was only 3 $\mu\text{g/L}$ which is lower than the USEPA drinking water MCL of 5 $\mu\text{g/L}$. 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}) 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.

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 80th 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

This is not the first reference...

bis(2-Ethylhexyl)phthalate. After completing the initial exposure assessment, eight COPCs were determined 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 80th DRS and has not been retained as a COPC in this SLERA

Metals

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 vegetation 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-trophic mammalian 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.

ES.6 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.

Revise (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 or remedial action is warranted. The reasons for the no further action recommendations 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.

A Decision Document will be prepared that presents the findings of this remedial investigation and any long term restrictions, if any, required for the site.

REVISED DRAFT RI Report **NATURE AND EXTENT OF CONTAMINATION**

This section provides a preliminary identification of the applicable or relevant and appropriate requirements (ARARs) and the environmental media analytical results and an assessment of the nature and extent of contamination for the 80th Division Reserve Site (80th DRS).

The quality of the analytical data is presented in the Quality Control Summary/Analytical Results Report (QCS/ARR) submitted separately. The results of the data validation as conducted by our subcontractor, URS Corporation, are provided in Appendix C of the QCS/ARR.

Based on the data validation results, the analytical data were generally considered acceptable and valid for use in determining the nature and extent of contamination and in performance of the baseline risk assessment provided in Sections 6.0 and 7.0 of this report. Qualifiers are provided for those results that are considered deficient based on the data validation.

The data reported in the summary tables in this section include the highest concentration detected for a contaminant whether in the original, dilution, re-extraction, or duplicate sample so that the maximum concentration is shown and evaluated especially in the subsequent risk assessment.

4.1 IDENTIFICATION OF ARARS

4.1.1 Definition of ARARs

The National Contingency Plan (NCP) and Section 121 of the Comprehensive Environmental Response, Compensation and Liabilities Act (CERCLA) require that CERCLA remedial actions attain Federal and State ARARs unless specific waivers are granted. State ARARs must be attained under Section 121(d) of CERCLA, if they are legally enforceable and consistently enforced statewide. ARARs may be classified as either applicable or relevant and appropriate. In addition to ARARs, other guidance and regulations may be classified as guidance "to be considered" (TBC). Potential ARARs and TBCs are identified in this section to aid in development of remedial actions and in establishment of required cleanup levels. Additionally, ARARs and TBCs are used to scope and formulate remedial action alternatives and to govern implementation and operation of the selected remedial alternatives.

Discussions of ARARs and TBC criteria are provided as follows:

- **Applicable Requirements.** Applicable requirements refer to those Federal or State requirements that would be legally enforceable. An example of an applicable requirement would be the Safe Drinking Water Act's Maximum Contaminant Levels (MCLs) for a site that contaminates a public drinking water supply.
- **Relevant and Appropriate Requirements.** Relevant and appropriate requirements are Federal or State standards, criteria or guidelines that are not legally enforceable at a site, but where application is appropriate because they address problems similar to those on-site. Relevant and appropriate requirements have the same weight and consideration as applicable requirements. An example of Relevant and Appropriate Requirements might be

state groundwater protection levels established for other regulatory programs such as UST or RCRA Subtitle D.

- **To Be Considered (TBC).** Other Federal and State recommended standards or criteria applicable to a specific site which are not generally enforceable but are advisory are categorized as TBC. For example, where no specific ARAR exists for a chemical or situation, or where such an ARAR is not sufficient to be protective of human health or the environment, Federal and/or State guidance or advisories may be considered in determining the necessary level of cleanup for protection of public health and the environment. An example of a TBC would be use of EPA risk screening criteria or EPA Health Advisories for specific chemicals in determining action or cleanup levels.

4.1.2 Development of ARARs and TBCs

The development of ARARs and TBCs is conducted on a site-specific basis. ARARs and TBCs are further categorized as either chemical-specific, location-specific or action-specific. CERCLA actions may have to comply with them as follows:

- **Chemical-Specific.** Chemical-specific requirements define acceptable exposure levels for specific hazardous substances and therefore may be used as a basis for establishing preliminary remediation goals and cleanup levels for chemicals of concern in the designated media. Chemical-specific ARARs and TBCs are also used to determine treatment and disposal requirements for remedial actions. In the event a chemical has more than one requirement, the more stringent of the two requirements will be used.
- **Location-Specific.** Location-specific requirements set restrictions on the types of remedial actions that can be performed based on site-specific characteristics or location. Alternative remedial actions may be restricted or precluded based on Federal and State laws for hazardous waste facilities, proximity to wetlands or floodplains, or to man-made features such as existing landfills, disposal areas and local historic landmarks or buildings.
- **Action-Specific.** Action-specific requirements set controls or restrictions on the design, implementation and performance of remedial actions. They are triggered by the particular types of treatment or remedial actions that are selected to accomplish the cleanup. After remedial alternatives are developed, action-specific ARARs and TBCs which specify remedial action performance levels as well as specific contaminant levels for discharge of media or residual chemical levels for media left in place, are used as a basis for assessing the feasibility and effectiveness of the remedial action.

4.1.3 Identification of ARARs and TBCs

Chemical-Specific ARARs and TBCs

As a basis for comparison of the contaminant concentrations discussed in this section, lists of

chemical-specific ARARs and TBC criteria has been developed for the 80th DRS. These chemical-specific ARARs and TBCs have been identified for soil and groundwater in **Tables 4-1 and 4-2**, respectively. Chemical-specific ARARs and TBCs that have been identified from the following regulations and standards:

ARARs

- Virginia Groundwater Quality Standards
- Safe Drinking Water Act EPA Maximum Contaminant Levels (40 CFR 141 and 143)

TBC Criteria

- EPA Region III Risk-based Concentration Tables (October 2006)
- EPA Region III BTAG Screening Levels (August 1995)
- Virginia Groundwater Quality Criteria

Location-Specific ARARs and TBC

Identification of potential location-specific ARARs and TBC include the following:

- Virginia Stormwater Management Regulations
- Virginia Pollution Abatement (VPA) Permits
- Virginia Water Protection Permit Regulations
- Virginia Hazardous Waste Management Regulations
- Virginia Solid Waste Management Regulations
- Virginia Regulations for Transportation of Hazardous Materials
- Resource Conservation and Recovery Act (RCRA) Regulations (40 CFR 261-270)
- DOT Transportation Regulations (49 CFR 107, 171)
- Virginia Regulations for the Control and Abatement of Air Pollution
- Clean Air Act Regulations
- Virginia Erosion and Sediment Control Regulations

Action-Specific ARARs and TBC

Identification of potential action-specific ARARs and TBC may include the following based on the required remedial action:

- National (40 CFR 122) and Virginia Pollutant Discharge Elimination System permits
- Virginia and Federal Endangered Species Act
- Virginia Wetlands Regulations
- Federal Water Pollution Control Act Regulations (Clean Water Act)(33 CFR 323)
- Federal Wetlands Executive Order 11990
- Chesapeake Bay Preservation Regulations

- Virginia Beach Coastal Management Plan
- Virginia Historic Resources Law and Antiquities Act
- Federal Floodplain Executive Order 11988
- Local Noise Statutes

The applicability and refinement of these chemical, location and action-specific ARARs and TBC to future remedial actions will be evaluated in detail on a more site-specific basis in the feasibility study process, if required.

4.2 ANALYTICAL RESULTS

Soil and groundwater samples were collected at the 80th DRS to define the nature and extent of contamination. Surface and subsurface soil samples were collected by split spoon method using a drill rig. In addition, groundwater samples were collected from newly installed and existing monitoring wells.

In this section analytical data for all media is compared against EPA risk screening criteria. Groundwater data is screened against EPA RBC for tap water and EPA MCLs while soils data are compared to EPA RBC for industrial and residential soils. This initial screening against these criteria is only used to assign significance to the analytical data and not as an analysis of risk or impacts. A detailed risk assessment, which screens the data against all ARARs such as MCLs, EPA RBC soil criteria, EPA Region III BTAG ecological risk levels, etc. is provided in Sections 6.0 (Human Health Risk Assessment) and 7.0 (Ecological Risk Assessment).

4.2.1 Soil

Soil samples were collected from 10 soil borings with samples collected from three depths to assess the lateral and vertical extent of contamination in the vadose zone. All soil samples were analyzed for target compound list (TCL) volatile organic compounds (VOCs), TCL semivolatile organic compounds (SVOCs), TCL pesticides and PCBs, and target analyte list (TAL) metals.

Tables 4-3 through 4-6 provide the analytical results for the soil samples collected at the site. As shown in these tables, only those contaminants detected are presented. The entire data set (including those compounds that were not detected) are presented in the Data Validation Report (Appendix C of the QCS/AR Report). Additionally, the EPA Region III Risk-based Concentration (RBC) Criteria for Industrial and Residential Soils are presented for comparison purposes. The EPA Region III RBCs for industrial and residential soils for non-carcinogenic compounds presented in the tables 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 soil, the RBCs have been adjusted.

The risk assessment provided in Section 6.0 of this report will provide a more detailed risk screening against all chemical-specific ARARs and TBC criteria.

VOCs

As presented in **Table 4-3**, numerous VOCs were detected in surface and subsurface soils. A summary of these detects including range of detection, frequency of detection, and comparison to EPA RBCs for industrial and residential soils are provided in the table below:

VOC RESULTS RANGE AND FREQUENCY OF DETECTION IN SOIL SAMPLES			
Compound	Range (µg/kg)	Frequency	EPA RBC (Ind/Res) (µg/kg)
Acetone	5 to 57	26 of 30	9.2 E+07 / 7 E+06
2-Butanone (MEK)	5	1 of 30	6.1E+07 / 4.7E+06
Carbon Disulfide	0.8 to 6	9 of 30	10E+07 / 7.8E+05
Chlorobenzene	0.5	5 of 30	2E+06 / 1.6E +05
1,2-Dichlorobenzene	0.3	1 of 30	9.2E+06 / 7E+05
1,3-Dichlorobenzene	0.5	1 of 30	3.1E+05 / 2.3E+04
1,4-Dichlorobenzene	0.3 to 0.5	6 of 30	1.2E+05 / 2.7E+04
Dichlorodifluoromethane	0.6	3 of 30	2E+07 / 1.6E+06
1,2-Dichloroethane (1,2-DCA)	3	1 of 30	3.1E+04 / 7E+03
trans 1,2-Dichloroethene (1,2-DCE)	0.7 to 1	7 of 30	2E+06 / 1.6E+05
Ethylbenzene	0.5 to 0.7	6 of 30	1E+07 / 7.8E+06
2-Hexanone	13 to 230	2 of 30	4.1E+06 / 3.1E+05
Methyl acetate	5 to 69	3 of 30	1E+08 / 7.8E+06
Methylene chloride	4 to 10	26 of 30	3.8E+05 / 8.5E+04
4-Methyl-2-pentanone (MIBK)	5 to 16	8 of 30	---
Tetrachloroethene (PCE)	2 to 120	14 of 30	5.3 E+03/ 1.6E+03
Toluene	0.7 to 5	28 of 30	8.2E+06 / 6.3E+06
Trichloroethene (TCE)	0.5 to 1	7 of 30	7.2E+03 / 1.6E+03
Trichlorofluoromethane	0.8 to 3	8 of 30	3.1E+07 / 2.3E+06
1,1,2-Trichloro-1,2,2-trifluoroethane	0.7 to 2	15 of 30	3.1E+09 / 2.3E+08
Xylenes (total)	1 to 7	11 of 30	2E+07 / 1.6E+06

All concentrations were at least three orders of magnitude less than the risk screening criteria for industrial and residential soils. As reported in the EPA Region III Modifications to the National Functional Guidelines for Organic Review, methylene chloride, MEK and acetone are typical laboratory artifacts.

SVOCs

As presented in **Table 4-4**, numerous SVOCs were detected in soils at the site. A summary of these detects including range of detection, frequency of detection, and comparison to EPA RBCs for industrial and residential soils are provided in the table below:

SVOC RESULTS RANGE AND FREQUENCY OF DETECTION IN SOIL SAMPLES			
Compound	Range (µg/kg)	Frequency	EPA RBC (Ind/Res) (µg/kg)
Acenaphthene	49 to 960	7 of 30	6.1E+06 / 4.7E+05
Acenaphthylene	21 to 2,200	18 of 30	--- / ---
Anthracene	32 to 2,500	15 of 30	3.1E+07 / 2.3E+06
Benzo(a)anthracene	45 to 5,600	18 of 30	3.9E+03 / 2.2E+02
Benzo(a)pyrene	28 to 5,500	19 of 30	3.9E+02 / 2.2E+01
Benzo(b)fluoranthene	69 to 6,800	18 of 30	3.9E+03 / 2.2E+02
Benzo(g,h,i)perylene	26 to 3,700	20 of 30	--- / ---
Benzo(k)fluoranthene	36 to 4,100	19 of 30	3.9E+04 / 2.2E+03
1,1'-Biphenyl	26 to 470	6 of 30	5.1E+06 / 3.9E+04
Bis(2-ethylhexyl)phthalate	40 to 880	27 of 30	2E+05 / 4.6E+04
Carbazole	48 to 490	5 of 30	1.4E+05 / 3.2E+04
Chrysene	34 to 6,000	19 of 30	3.9E+05 / 8.7E+04
Dibenzo(a,h)anthracene	30 to 1,500	14 of 30	3.9E+02 / 2.2E+01
Dibenzofuran	30 to 790	6 of 30	2E+05 / 1.6E+04
3,3'-Dichlorobenzidine	41 to 290	2 of 30	6.4E+03 / 1.4E+03
2,4-Dinitrotoluene	130	1 of 30	2E+05 / 1.6E+04
2,6-Dinitrotoluene	51	1 of 30	1E+05 / 7.8E+03
Di-n-octyl phthalate	24 to 280	6 of 30	--- / ---
Fluoranthene	28 to 9,800	21 of 30	4.1E+06 / 3.1E+05
Fluorene	28 to 1,600	12 of 30	4.1E+06 / 3.1E+05
Indeno(1,2,3-cd)pyrene	25 to 3,600	19 of 30	3.9E+03 / 2.2E+02
2-Methylnaphthalene	34 to 2,400	11 of 30	4.1E+05 / 3.1E+04
N-Nitrosodiphenylamine	150	1 of 30	5.8E+05 / 1.3E+05

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SVOC RESULTS RANGE AND FREQUENCY OF DETECTION IN SOIL SAMPLES			
Compound	Range (µg/kg)	Frequency	EPA RBC (Ind/Res) (µg/kg)
Naphthalene	31 to 1,200	6 of 30	2E+06 / 1.6E+05
Phenanthrene	29 to 12,000	20 of 30	--- / ---
Pyrene	43 to 16,000	20 of 30	3.1E+06 / 2.3E+05

Sometimes listed as polycyclic aromatic

The primary SVOCs detected in site soils were the polynuclear aromatic hydrocarbons (PAHs), which were detected in approximately two-thirds of the samples collected. PAHs are typical constituents of petroleum hydrocarbons such as diesel fuels, hydraulic fluids, and other oils such as lube oils and motor oils. Only five SVOCs (benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenzo(a,h)anthracene and indeno(1,2,3-cd)pyrene) exceeded EPA risk screening criteria for industrial or residential soils.

Pesticides

As presented in **Table 4-5**, numerous pesticides were detected in soils at the site. A summary of these detects including range of detection, frequency of detection, and comparison to EPA RBCs for industrial and residential soils are provided in the table below:

PESTICIDE RESULTS RANGE AND FREQUENCY OF DETECTION IN SOIL SAMPLES			
Compound	Range (µg/kg)	Frequency	EPA RBC (µg/kg)
Aldrin	0.98 to 73	5 of 30	170 / 38
alpha-BHC	0.53 to 1.7	3 of 30	450 / 100
beta-BHC	2.4 to 100	3 of 30	1,600 / 350
delta-BHC	0.66	1 of 30	450 / 100
gamma-BHC (Lindane)	0.37 to 0.39	2 of 30	2,200 / 490
Chlordane (gamma)	1.7	1 of 30	8,200 / 1,800
4,4'-DDD	0.42 to 6.4	5 of 30	12,000 / 2,700
4,4'-DDE	1.6 to 3.1	4 of 30	8,400 / 1,900
4,4'-DDT	0.91 to 8.8	8 of 30	8,400 / 1,900
Dieldrin	7.1 to 27	3 of 30	180 / 40
Endosulfan I	0.9	1 of 30	610,000 / 47,000

Label Tables as (Ind./Res)

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PESTICIDE RESULTS RANGE AND FREQUENCY OF DETECTION IN SOIL SAMPLES			
Compound	Range (µg/kg)	Frequency	EPA RBC (µg/kg)
Endosulfan II	18	1 of 30	610,000 / 47,000
Endosulfan sulfate	0.8 to 110	7 of 30	610,000 / 47,000
Endrin aldehyde	0.88 to 0.97	2 of 30	31,000 / 2,300
Endrin ketone	1.1 to 110	17 of 30	31,000 / 2,300
Heptachlor	1	1 of 30	640 / 140

Label Tables as (Ind./Res)

Aldrin was the only compound detected above the EPA RBC for residential soils and it was detected above the criteria in only one sample (surface sample at boring SB-5). Pesticide concentrations at this site are consistent with levels seen on military installations from the widespread pesticide application and not from waste disposal or spills.

PCBs

As presented in **Table 4-5**, Aroclor-1260 was the only PCB detected in soils at the site. A summary of these detects including range of detection, frequency of detection, and comparison to EPA RBCs for industrial and residential soils are provided in the table below:

PCB RESULTS RANGE AND FREQUENCY OF DETECTION IN SOIL SAMPLES			
Compound	Range (µg/kg)	Frequency	EPA RBC (µg/kg)
Aroclor-1016	---	0 of 30	41,000 / 550
Aroclor-1221	---	0 of 30	1,400 / 320
Aroclor-1232	---	0 of 30	1,400 / 320
Aroclor-1242	---	0 of 30	1,400 / 320
Aroclor-1248	---	0 of 30	1,400 / 320
Aroclor-1254	---	0 of 30	1,400 / 320
Aroclor-1260	21 to 67	2 of 30	1,400 / 320

Label Tables as (Ind./Res)

Aroclor-1260 was detected in only 2 of 30 samples and its concentrations (21 to 67 µg/kg) were well below the EPA RBCs (1,400 µg/kg for industrial soils and 320 µg/kg for residential soils).

Metals

As presented in **Table 4-6**, numerous metals were detected in soils at the site. A summary of these detects including range of detection, frequency of detection, and comparison to EPA RBCs for industrial and residential soils are provided in the table below:

METAL RESULTS			
RANGE AND FREQUENCY OF DETECTION IN SOIL SAMPLES			
Compound	Range (mg/kg)	Frequency	EPA RBC (mg/kg)
Aluminum	135 to 8,530	30 of 30	--- / ---
Antimony	0.35 to 2.1	20 of 30	41 / 3.1
✓ Arsenic	0.35 to 1.2	13 of 30	1.9 / 0.43
Barium	0.98 to 15.8	30 of 30	20,000 / 1,600
Beryllium	0.01 to 0.12	21 of 30	200 / 16
Cadmium	0.11	1 of 30	100 / 7.8
Calcium	18.2 to 3,060	30 of 30	--- / ---
Chromium	1 to 10	30 of 30	310 / 23
Cobalt	0.07 to 0.93	27 of 30	--- / ---
Copper	0.28 to 6.3	15 of 30	4,100 / 310
✓ Iron	335 to 10,100	30 of 30	31,000 / 2,300
Lead	0.5 to 33.9	30 of 30	400 / 400
Magnesium	20.8 to 504	30 of 30	--- / ---
Manganese	1.9 to 69.1	30 of 30	2,000 / 160
Mercury	0.017 to 0.035	11 of 30	31 / 2.3
Nickel	0.13 to 3.7	26 of 30	2,000 / 160
Potassium	39.7 to 494	29 of 30	--- / ---
Selenium	0.37 to 0.74	5 of 30	510 / 39
Silver	0.09	1 of 30	510 / 39
Sodium	44.5 to 133	30 of 30	--- / ---
Thallium	---	0 of 30	7.2 / 0.55
✓ Vanadium	0.76 to 19.4	30 of 30	100 / 7.8
Zinc	1.1 to 81.8	30 of 30	31,000 / 2,300

The majority of the TAL metals were detected in soil at the site. However, only three compounds (arsenic, iron, and vanadium) exceeded EPA RBCs for residential soils. Arsenic exceeded the EPA RBC of 0.43 mg/kg in 8 of 30 samples while iron exceeded the EPA RBC of 2,300 mg/kg in 6 of 30

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samples. Vanadium exceeded the residential RBC of 7.8 mg/kg in 3 of 30 samples. None of these metals exceeded the EPA RBCs for industrial soils.

Soil detects above EPA RBCs are presented on **Figure 4-1**.

4.2.2 Groundwater

4.2.2.1 January 2003 Groundwater Sampling Event

Groundwater samples were collected from 10 monitoring wells to assess the lateral and vertical extent of contamination in the Columbia Aquifer (water table aquifer). All groundwater samples were analyzed for VOCs, SVOCs, pesticides, PCBs, and total and dissolved metals. **Table 4-7** provides a summary of the analytical parameters and results for the monitoring well samples collected at the site. In **Table 4-7**, only those compounds detected are presented. The entire data set (including those compounds that were not detected) are presented in the Data Validation Report (Appendix C of the QCS/AR Report). In addition, the EPA Region III RBC Criteria for Tap Water and EPA MCLs are presented for comparison purposes. The EPA Region III RBCs for tap water for non-carcinogenic compounds presented in **Table 4-7** 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 groundwater, the RBCs have been adjusted.

A more detailed risk evaluation which provides a comparative analysis of sample results and ARARs and TBC criteria is provided in the baseline risk assessment in Section 6.0.

Organics

For the organic analyses, the following table provides a summary of the range of concentrations detected by analytical parameter and frequency of detection:

ORGANIC RESULTS			
RANGE AND FREQUENCY OF DETECTION IN GROUNDWATER SAMPLES			
Compound	Range (µg/L)	Frequency of Detection	EPA RBC/MCL ⁽¹⁾
VOCs			
cis 1, 2-DCE	0.70	1 of 10	6.1 / 70
PCE	0.30 to 6.0	4 of 10	0.10 / 5
Toluene	0.2 to 1.0	10 of 10	230 / 1,000
TCE	0.8 to 3.0	3 of 10	0.026 / 5
1,2,4-Trichlorobenzene	0.20	1 of 10	6.1 / 70

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ORGANIC RESULTS RANGE AND FREQUENCY OF DETECTION IN GROUNDWATER SAMPLES			
Compound	Range (µg/L)	Frequency of Detection	EPA RBC/ MCL ⁽¹⁾
SVOCs			
Bis(2-ethylhexyl)phthalate	5.0	1 of 10	4.8 / 6
Notes: 1. EPA Region III Risk-based Concentration Criteria for Tap Water and EPA MCLs			

Analysis of monitoring well groundwater samples detected only six organic compounds including cis 1,2-DCE, PCE, toluene, TCE, 1,2,4-trichlorobenzene (1,2,4-TCB), and bis(2-ethylhexyl)phthalate. Concentrations of PCE, TCE, and bis(2-ethylhexyl)phthalate exceeded EPA RBCs while only one detect of PCE (6 µg/L in MW-8) exceeded the EPA MCL. No pesticides or PCBs were detected in any of the 10 monitoring wells sampled.

Metals

Numerous metals were detected in monitoring well samples. The following table provides a summary of the range of detected concentrations of metals and frequency of detection:

INORGANIC RESULTS RANGE AND FREQUENCY OF DETECTION IN GROUNDWATER SAMPLES					
Compound	Total Metals		Dissolved Metals		EPA RBCs/ MCLs ⁽¹⁾ (ug/l)
	Range (ug/l)	Frequency	Range (ug/l)	Frequency	
Aluminum	56.5 to 953	10 of 10	37.9 to 207	10 of 10	--- / ---
Antimony	2.5 to 6.4	8 of 10	---	0 of 10	1.5 / 6.0
Arsenic	4.8 to 6.0	3 of 10	5.0 to 5.4	2 of 10	0.045 / 10
Barium	5.2 to 30.8	10 of 10	4.9 to 28.2	10 of 10	730 / 2,000
Cadmium	0.41 to 1.1	3 of 10	0.98	1 of 10	1.8 / 5.0
Calcium	7,970 to 26,700	10 of 10	8,190 to 27,500	10 of 10	---
Chromium	1.0 to 6.6	10 of 10	0.78 to 1.2	4 of 10	11 / 100
Cobalt	0.53 to 0.59	2 of 10	0.53 to 1.1	3 of 10	73 / ---
Copper	1.9 to 4.2	2 of 10	2.1	2 of 10	150 / 1,300
Iron	292 to 5,130	10 of 10	81.6 to 4,650	10 of 10	1,100 / ---

INORGANIC RESULTS RANGE AND FREQUENCY OF DETECTION IN GROUNDWATER SAMPLES					
Compound	Total Metals		Dissolved Metals		EPA RBCs/ MCLs ⁽¹⁾ ($\mu\text{g/l}$)
	Range ($\mu\text{g/l}$)	Frequency	Range ($\mu\text{g/l}$)	Frequency	
Lead	1.2 to 4	4 of 10	1.2 to 1.3	2 of 10	15 ⁽²⁾
Magnesium	1,130 to 3,160	10 of 10	1,150 to 3,260	10 of 10	---
Manganese	10.6 to 165	10 of 10	9.7 to 167	10 of 10	73 / ---
Mercury	0.10 to 0.13	6 of 10	0.11 to 0.13	5 of 10	1.1 / 2.0
Nickel	2.5	1 of 10	1.5 to 2.2	3 of 10	73 / ---
Potassium	1,040 to 4,920	10 of 10	1,200 to 5,520	10 of 10	---
Selenium	2.6 to 3.5	2 of 10	3.0 to 10.3	6 of 10	18 / 50
Sodium	3,160 to 11,700	10 of 10	2,930 to 11,900	10 of 10	---
Vanadium	0.65 to 6.3	9 of 10	0.48 to 4.8	10 of 10	3.7 / ---
Zinc	6.8 to 309	10 of 10	3.6 to 299	10 of 10	1,100 / ---

Notes:
1. EPA Region III Risk-based Concentration Criteria for Tap Water and EPA MCLs.
2. USEPA Action Level for Lead in Drinking Water.

The detected concentrations of total arsenic, iron, manganese, and vanadium were over the EPA screening criteria in several wells (arsenic in MW-8, MW-10, and MW-11, iron in MW-7, MW-9, MW-10, and MW-11, manganese in MW-10 and MW-11, and vanadium in MW-2, MW-8, and MW-10). Total antimony was detected in concentrations above the EPA RBC of 1.5 $\mu\text{g/L}$ in 8 of 10 wells but above the EPA MCL of 6 $\mu\text{g/L}$ in only one well (MW-2). The dissolved metals detected above the EPA RBCs were as follows:

- Dissolved arsenic levels in MW-5 (5.4 $\mu\text{g/l}$) and MW-8 (5 $\mu\text{g/l}$) were above EPA RBCs for tap water of 1.5 $\mu\text{g/l}$ but were below the USEPA MCL for drinking water of 10 $\mu\text{g/l}$.
- Dissolved iron levels were above the EPA RBC of 1,100 $\mu\text{g/l}$ in three wells (MW-7, MW-10, and MW-11) at a concentration range of 1,170 to 4,650 $\mu\text{g/l}$.
- Dissolved manganese levels were above the EPA RBC of 73 $\mu\text{g/l}$ in two wells (MW-10 and MW-11) at a concentration range of 123 to 167 $\mu\text{g/l}$.
- Dissolved vanadium levels were above the EPA RBC of 3.7 $\mu\text{g/l}$ in only one well (MW-8) at a concentration of 4.8 $\mu\text{g/l}$.

Groundwater detects above EPA RBCs and/or MCLs are presented on **Figure 4-2**.

4.2.2.2 June 2004 Groundwater Sampling Event

In June of 2004 a second round of groundwater samples were collected from monitoring wells MW-1 through MW-13, and were analyzed for VOCs. Constituents detected in this round of sampling included cis-1,2-dichloroethene, TCE, and tetrachloroethene. Specifically, Cis1,2-DCE and TCE were detected in MW6- and MW-9. Tetrachloroethene was detected in MW-5, MW-6 and MW-9. **Table 4-8** contains the data collected in this round of sampling.

JUNE 2004 VOC RESULTS			
RANGE AND FREQUENCY OF DETECTION IN GROUNDWATER SAMPLES			
Compound	Range (µg/L)	Frequency of Detection	EPA RBC/ MCL ⁽¹⁾
VOCs			
cis 1, 2-DCE	1.9 to 11	2 of 12	6.1 / 70
PCE	1.2 to 6.3	3 of 12	0.10 / 5
TCE	1.5 to 7.5	2 of 12	0.026 / 5
Notes:			
1. EPA Region III Risk-based Concentration Criteria for Tap Water and EPA MCLs			

4.3 NATURE AND EXTENT OF CONTAMINATION

4.3.1 Nature and Extent of Soil Contamination

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 (i.e., concentrations decreasing/increasing with depth). 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, as discussed in Section 4.2.1, concentrations were several orders of magnitude lower than EPA screening criteria.

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 soil borings MW-9 and MW-11 while only bis(2-ethylhexyl)phthalate, fluorene, phenanthrene, and pyrene were detected at MW-10 indicating minimal downgradient migration of SVOCs in soils since these 3 borings are located directly downgradient of the industrialized areas

(e.g., 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 as the data shows for borings SB-1 and SB-2.

Endrin ketone was detected in over 50 percent of the soil samples while DDT and endosulfan sulfate were detected in over 20 percent of the soils samples. Aldrin was the only pesticide detected above an EPA screening criteria and it was detected above the 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. As previously discussed, due to past widespread application of these pesticides, their presence at these low concentrations are expected at the site.

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 a pattern to its distribution at the site. LNO

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 while iron exceeded the RBC in 6 of 30 samples and vanadium exceeded the RBC in 3 of 30 samples.

4.3.2 Nature and Extent of Groundwater Contamination

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 during the 2003 sampling event but not detected in 2004, no other organics were detected in wells that are upgradient (MW-1 and MW-2) or cross-gradient (MW-3) of the former AST/UST and drum storage areas. The highest concentrations of organics were detected in the central portions of the site (wells MW-7 and MW-8) near the former UST/AST and drum areas with some organics detected in downgradient wells (TCE in MW-5 and PCE in MW-9) as well.

The former UST was used to store waste oil and probably also contained PCE and other chlorinated solvents (degreasers from maintenance operations). Groundwater samples in the former UST area contained low concentrations of PCE and its degradation compounds (cis 1,2-DCE and TCE). If the former UST Area is assumed to be the source of the release of these compounds based on historical use of the former UST and the groundwater data which shows elevated levels of VOCs especially chlorinated hydrocarbons, then an apparent vertical and lateral distribution of PCE and degradation compounds can be discerned. Bis(2-ethylhexyl)phthalate was detected in only one well on-site and its apparent distribution is limited to the former UST area.

Based on the assumption that the former UST was the source of the release, 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 and MW-9. Although chlorinated organics were detected in MW-9, which is located approximately 60 feet downgradient of the former UST, no chlorinated organics have been detected in MW-6, which is located another 50 feet downgradient of MW-9. Although greater than the EPA RBCs in the downgradient wells (MW-5 and MW-9), concentrations of PCE and TCE are less than 1 µg/L in the downgradient wells. The downgradient lateral extent of contamination has been fully delineated. However, it should be noted that the westward cross-gradient extent of chlorinated organic contamination may not fully be delineated in that the PCE concentration in MW-8 is the highest on-site at 6 µg/L and no monitoring wells are located to the west of this well.

The June 2004 sampling results seem to confirm the lateral spread of chlorinated organics. As only three VOCs were detected (only VOCs were analyzed), cis 1,2-DCE, TCE and PCE, and all detection areas are indicative of gradual low concentration spread down gradient from the UST source location. As was noted in prior sampling results no detections of COCs were detected in monitoring wells up gradient from the UST site. Excepting the PCE detection in MW-5, the only wells to contain detectable levels of VOCs were MW-6 and MW-9. This presents a different snapshot of the site as prior sampling events found no detections in MW-6, where in June 2004 the sampling detected the same COCs in MW-9 and MW-6. As MW-6 is located approximately 50 feet in the down gradient direction from MW-9, it is reasonable that the concentrations of the detected COCs would be significantly less in MW-6, which follows a plume emanating from the UST sites up gradient of these wells. Additionally, samples from MW-12 and MW-13 (which lie to the west of MW-8) did not contain VOCs. Therefore, it appears that the area containing the VOCs has been bounded.

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, which were total antimony and total and dissolved arsenic, iron, manganese, and vanadium. A summary of the lateral distribution of the above-referenced metals is provided as follows:

- Total antimony concentrations are fairly consistent across the site with detections in 8 of 10 wells across the site. The concentrations (5.1 to 6.4 µg/L) in the upgradient wells (MW-1 and MW-2) are greater than the concentrations (3.1 to 4.0 µg/L) in the central-site wells (MW-3, MW-7, and MW-8) and the concentrations (2.5 to 4.6 µg/L) in the 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 (MW-8) and in two downgradient wells (MW-10 and MW-11). These concentrations were the only total arsenic detects above the EPA RBC (they were below the EPA MCL). Dissolved arsenic was detected in only 2 of 10 wells (MW-5 and MW-8). 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 on the 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. *on the*
- Total and dissolved manganese were detected in all 10 wells with concentrations greatest in two downgradient wells (MW-10 and MW-11). These concentrations were the only total or dissolved manganese detects above the EPA RBC. As for iron, the highest concentrations of total and dissolved manganese 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 on the 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. *on the*
- 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, 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.

At this time, no specific assessment was made related to the vertical delineation of contamination at the site. All wells were screened in the upper 10 feet of the shallow water table aquifer (Columbia Aquifer) at the site which in the Fort Story area is present to a depth of 40 to 60 feet below ground surface. In that the organic contamination in the shallow part of the aquifer is low (highest organic concentration was PCE at 6 µg/L), the vertical extent of contamination within this shallow aquifer is not anticipated to be significant.

This section provides a qualitative evaluation of contaminant fate and transport at the 80th DRS. Known and potential contaminant sources, site physical characteristics, physical and chemical properties of the contaminants, and the nature and extent of contamination are discussed.

A breakdown of the issues to be discussed in each subsection is provided as follows:

- Section 5.1 provides a general discussion of the mechanisms that influence the various contaminant transport pathways. Section 5.1 also identifies the physical and chemical properties of contaminants that control their environmental fate and transport.
- Section 5.2 discusses the contaminant transport pathways that are applicable to the site.
- Section 5.3 presents the conceptual fate and transport model developed for the site.
- Section 5.4 discusses the specific transport mechanisms, and pertinent physical and chemical properties of contaminants, where applicable, to support the site specific conceptual fate and transport model.

5.1 TRANSPORT MECHANISMS AND CONTAMINANT PROPERTIES

The fate and transport of contaminants in the environment is influenced by the following mechanisms:

- **Adsorption/Desorption.** The process by which contaminant transport is retarded due to adsorption of contaminants to soil particles. Desorption is the reverse process of adsorption.
- **Advection.** The physical process by which contaminants are transported in solution at the average linear velocity of groundwater in the direction of groundwater flow.
- **Complexation.** The chemical process by which dissolved species are formed from two or more simpler dissolved species, each of which can exist in an aqueous solution.
- **Diffusion.** The chemical process that results in the movement of contaminants in response to concentration gradients.
- **Dispersion.** The mechanical process of mixing that results from local variations in the average velocity of groundwater.
- **Dissolution/Precipitation.** The chemical process by which a material is dissolved in a liquid solvent such as water. Precipitation is the reverse process of dissolution.
- **Ion Exchange.** The chemical process involving the reversible exchange of ions between a liquid and a solid.

- **Reduction/Oxidation.** A chemical reaction (redox reaction) involving changes in the oxidation states of elements.
- **Transformation.** The loss or degradation of contaminants from the environment as a result of chemical reactions of microbial activity.
- **Volatilization.** The transfer of contaminants from the liquid phase to the vapor phase (i.e., soil gas in unsaturated environments or the atmosphere).

The following sections discuss the physical and chemical properties of organic and inorganic contaminants that influence these fate and transport mechanisms.

5.1.1 Organic Contaminants

Several VOCs, SVOCs, pesticides, and PCBs were detected at the site. The frequency of organic compounds detected in at least one media include the following (number of detects/number of samples):

Parameter	Surface / Subsurface Soil	Groundwater
Volatile Organics		
Acetone	26 of 30	----
2-Butanone (MEK)	1 of 30	----
Carbon Disulfide	9 of 30	----
Chlorobenzene	5 of 30	----
Dichlorobenzene (o, m, & p)	6 of 30	----
Dichlorodifluoromethane	3 of 30	----
1,2-Dichloroethane (1,2-DCA)	1 of 30	----
cis 1,2-Dichloroethene (1,2-DCE)	----	1 of 10
trans 1,2-Dichloroethene (1,2-DCE)	7 of 30	----
Ethylbenzene	6 of 30	----
2-Hexanone	2 of 30	----
Methyl acetate	3 of 30	----
Methylene chloride	26 of 30	----
4-Methyl-2-pentanone (MIBK)	8 of 30	----
Tetrachloroethene (PCE)	14 of 30	4 of 10
Toluene	28 of 30	10 of 10
1,2,4-Trchlorobenzene (1,2,4-TCB)	----	1 of 10
Trichloroethene (TCE)	7 of 30	3 of 10

Parameter	Surface / Subsurface Soil	Groundwater
Trichlorofluoromethane	8 of 30	----
1,1,2-Trichloro-1,2,2-trifluoroethane	15 of 30	----
Xylenes (total)	11 of 30	----
Semivolatile Organics		
PAHs ⁽¹⁾	21 of 30	----
Phthalates ⁽²⁾	27 of 30	1 of 10
1,1'-Biphenyl	6 of 30	----
3,3'-Dichlorobenzidine	2 of 30	----
2,4-Dinitrotoluene	1 of 30	----
2,6-Dinitrotoluene	1 of 30	----
N-Nitrosodiphenylamine	1 of 30	----
Pesticides/PCBs		
Aldrin	5 of 30	----
BHC (alpha, beta, delta, & gamma [Lindane])	3 of 30	----
Chlordane (gamma)	1 of 30	----
4,4'-DDD/4,4'-DDE/4,4'-DDT	8 of 30	----
Dieldrin	3 of 30	----
Endosulfan (I, II, and sulfate)	7 of 30	----
Endrin (aldehyde and ketone)	17 of 30	----
Heptachlor	1 of 30	----
Aroclor-1260	2 of 30	----

- (1) PAHs grouped together and considered as one detection
- (2) Phthalates grouped together and considered as one detection

As shown in the table above, several VOCs, SVOCs, and pesticides were detected infrequently (one detection in groundwater and three or less detections in soil) and they will not be discussed further because their impact on site conditions and risk is minimal.

The potential for a chemical to elicit an adverse human health or ecological effect depends upon the chemical's potential to migrate and persist in an environmental media. Factors that influence chemical mobility include: the physical and chemical properties of a chemical, the physical characteristics of the environmental media, and the site chemistry. This section presents a discussion of the various physical and chemical properties of the types of compounds detected at the 80th DRS. The section also discusses the fate and transport of the detected organics at the site.

Table 5-1 presents a summary of some physical and chemical properties associated with organic compounds detected at the 80th DRS. The potential for chemical mobility and fate is determined by

the chemical's properties and its interaction with the site's physical and chemical properties. Physical and chemical properties of organic compounds that affect mobility include:

- Vapor Pressure
- Water Solubility
- Octanol/Water Partition Coefficient
- Organic Carbon Adsorption Coefficient (Sediment partition)
- Specific Gravity
- Henry's Law Constant
- Mobility Index

Vapor pressure provides an indication of the rate at which a chemical volatilizes. Significant volatilization occurs at interfaces such as surface soil and air or surface water and air, and to a lesser extent, at the water table and overlying unsaturated shallow soils. Volatilization impacts selection of remedial technologies for groundwater and subsurface soils. Generally vapor pressure for monocyclic aromatics is higher than that of PAHs. Chemicals with high vapor pressure such as volatile organic compounds (VOCs) enter the atmosphere more rapidly than those with low vapor pressures such as semivolatile organic compounds (SVOCs).

Water solubility impacts the rate at which a compound leaches from soil via infiltrating precipitation. More soluble compounds (e.g., VOCs) leach more readily than less soluble compounds (e.g., SVOCs or inorganics). Water solubility data indicates that VOCs are several-orders-of-magnitude more soluble than PAHs; therefore, highly soluble compounds (e.g., VOCs) migrate more rapidly than less water-soluble compounds (e.g., SVOCs or inorganics).

The octanol/water partition coefficient (K_{ow}) is the ratio of a chemical's soluble concentration in octanol divided by the soluble concentration in water. This coefficient correlates well with bioconcentration factors in aquatic organisms and adsorption to soil or sediment. A linear relationship has been demonstrated between the K_{ow} and the uptake of chemicals by fatty tissues in animal and human receptors (the bioconcentration factor - BCF) (Lyman et al., 1982). This coefficient also assists with characterizing the sorption of compounds by organic soils where experimental data does not exist.

The organic carbon adsorption coefficient (K_{oc}) describes the tendency of a chemical to adhere to soil particles high in organic carbon. The solubility of a chemical in water is inversely proportional to the K_{oc} . Compounds with a high soil/sediment adsorption coefficient generally have low water solubilities. For example, PCBs, which are relatively immobile in the environment, tend to preferentially sorb to soil/sediments and are less likely to migrate via aqueous transport mechanisms. However, erosional properties of surface soils that sorb immobile compounds must be considered in determining the potential for migration.

Specific density is the ratio of the weight of a given volume of pure chemical to the weight of the same volume of water at a specified temperature. Specific density primarily assists in determining

the potential for a compound to form a non-aqueous phase (NAPL) on top or at the base of an aquifer, if the compound concentration exceeds 1 to 10 percent of its corresponding water solubility. Henry's law constant (K_h) uses vapor pressure and water solubility to determine volatilization rates from surface water and groundwater for a compound. This constant is an estimate of the concentration of a compound at equilibrium in the water phase and in the air directly above the water. A general method used for estimating the rate at which a compound volatilizes uses the henry's law constant as follows:

- $10^{-3} > K_h < 10^{-5}$ rapid volatilization
- $10^{-5} > K_h < 10^{-7}$ slow volatilization
- $K_h > 10^{-7}$ low volatilization

The Mobility Index (MI) assesses quantitatively the mobility of a compound based on its water solubility (S), vapor pressure (VP), and organic carbon coefficient (K_{oc}) as defined by:

$$MI = \log ((S*VP)/K_{oc})$$

Ford and Gurba (1984) presented a relative scale that assists in evaluating MI and Dragun presented a summary that related mobility to the K_{oc} as follows:

Relative MI ⁽¹⁾	Mobility Description	log K_{oc} ⁽²⁾
>5	extremely mobile (EM)	< 1.7
0 to 5	very mobile (VM)	1.7 to 2
-5 to 0	slightly mobile (SM)	2 to 2.7
-10 to -5	immobile (IM)	2.7 to 3.3
< -10	very immobile (VIM)	> 3.3
Notes:		
1. From Ford and Gurba (1984)		
2. From Dragun (1988)		

A general discussion of the fate and transport of the general category of organic contaminants detected at the 80th DRS is presented below. The information is included in this section but not included in the site-specific conceptual model discussion (Section 5.3) in order to provide a general understanding of the fate and transport processes that may be applicable to the site.

VOCs

VOCs detected in at least one media on site include chlorobenzene, dichlorobenzene, ethylbenzene, 1,2,4-TCB, carbon disulfide, methylene chloride, methyl acetate, dichlorofluoromethane, 1,1,2-

trichloro-1,2,2-trifluoroethane, trichlorofluoromethane, TCE, 1,2-DCA, cis and trans 1,2-DCE, MIBK, PCE, 2-butanone, 2-hexanone, acetone, xylene, and toluene. A discussion of the fate and transport of each of these VOCs is provided below.

Acetone

Acetone may be relatively mobile in the soil/groundwater system when present at low concentrations (dissolved in water and sorbed on soil) or as a separate organic phase resulting from a spill of significant quantities of the chemical. In the unsaturated zone, equilibrium models (Mackay's Equilibrium Partitioning Model) indicate that little acetone is expected to be sorbed onto soil particles. The bulk of the acetone is expected to partition to the soil-water phase, and is thus available to migrate by bulk transport (e.g., downward movement of infiltrating water), dispersion, and diffusion. In the saturated zone, almost all of the acetone is predicted to be present in the soil-water phase and available for transport with flowing groundwater.

The portion of acetone that has been released from the soil into the air will either return to the soil via atmospheric washout or eventually undergo photochemical oxidation. Under normal environmental conditions, hydrolysis is not expected to occur at a rate competitive with volatilization or biodegradation. Acetone is expected to be highly susceptible to microbial biodegradation. In typical subsurface environments, the concentration of microorganisms capable of biodegrading acetone may be low and is expected to drop off sharply with depth. However, persistence of acetone in environments with sufficient active microbial populations is not expected.

Toluene

Toluene may be relatively mobile in the soil/groundwater system when present at low concentrations (dissolved in water and sorbed on soil) or as a separate organic phase resulting from a spill of significant quantities of the chemical. In the unsaturated zone, equilibrium models (Mackay's Equilibrium Partitioning Model) indicate that the bulk of the toluene will sorb to the soil particles. However, the amount of toluene typically available in the soil-air phase is high enough for volatilization to be an important pathway. The amount in soil-water is fairly low but migration with infiltrating rainwater, dispersion, and diffusion will occur. In saturated soils, a much higher fraction of toluene is in the soil-water phase and this would be readily transported with flowing groundwater.

The persistence of toluene in the subsurface should be assumed to be from months to years. Toluene under normal environmental conditions is not expected to undergo hydrolysis. Further, toluene is not expected to be susceptible to oxidation or reduction reactions in the subsurface. Available data indicate that toluene is biodegradable in the subsurface. A number of species of microorganisms are capable of using toluene as the sole carbon source. However, in most subsurface environments, such aerobic degradation would be of minimal importance because of the low concentration of microorganisms (at depth) and the low dissolved oxygen conditions.

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Xylenes (Total)

Xylenes may be moderately mobile in the soil/groundwater system when present at low concentrations (dissolved in water and sorbed on soil) or as a separate organic phase resulting from a spill of significant quantities of the chemical. In the unsaturated zone, equilibrium models (Mackay's Equilibrium Partitioning Model) indicate that the bulk of the xylenes (99%) will sorb to the soil particles. However, the amount of xylenes typically available in the soil-air phase is high enough for volatilization to be an important pathway. The amount in soil-water is fairly low but migration with infiltrating rainwater, dispersion, and diffusion will occur. In saturated soils, a much higher fraction of xylenes (74%) is in the soil-water phase and this would be readily transported with flowing groundwater.

The persistence of xylenes in the subsurface should be assumed to be from months to years. Xylenes under normal environmental conditions are not expected to undergo hydrolysis. Further, xylenes are not expected to be susceptible to oxidation or reduction reactions in the subsurface. Available data indicate that xylenes are biodegradable in the subsurface. A number of species of microorganisms are capable of using xylenes as the sole carbon source. However, in most subsurface environments, such aerobic degradation would be of minimal importance because of the low concentration of microorganisms (at depth) and the low dissolved oxygen conditions.

2-Butanone (MEK)

2-Butanone, used as a solvent, is often discharged into the atmosphere or in wastewater. If 2-butanone is released into the soil, it will partially evaporate into the atmosphere from the surface soils, and it will not hydrolyze in soil. Based on its estimated K_{oc}, 2-butanone is expected to be very mobile and therefore, it may leach into the groundwater. According to biodegradability studies, 2-butanone in groundwater may slowly degrade in anaerobic conditions. If 2-butanone is released into surface water, it will be evaporate (half-life of 3-12 days) or slowly biodegrade. It will not photooxidize in surface waters, adsorb to sediment, or bioconcentrate in aquatic organisms; however, it may be subject to direct photolysis. 2-butanone in the atmosphere may be subject to photolysis and removal from rain. Fate and transport data for 2-butanone obtained from *Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volume III, Pesticides*, Philip H. Howard, 1991.

2-Hexanone

2-hexanone, used as a solvent, typically is released into the environment through volatilization during its manufacture and evaporation of materials in which it is contained. 2-hexanone is highly mobile and if released to soil, it may biodegrade rapidly. If released to water, it is also capable of undergoing rapid biodegradation; however, it will not undergo aqueous hydrolysis, adsorption to sediment, or bioconcentration in aquatic organisms. Volatilization from soil and water to the atmosphere is a significant fate process. In addition, the water solubility of 2-hexanone indicates

that physical removal from air through wet deposition is a significant fate process. Fate and transport data for 2-hexanone obtained from *Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volume III, Pesticides*, Philip H. Howard, 1991.

Chlorobenzene

The main routes for chlorobenzene released into the air is to be diluted and photooxidized. Chlorobenzene released into water or onto land will be lost to evaporation or slowly biodegrade. It does not adsorb to soil, sediment or non-organic suspended solids. Chlorobenzene has the potential to leach into the groundwater, especially if the soil has low organic carbon content. Little bioconcentration is expected in fish or food products.

Dichlorobenzene (o, p & m)

Dichlorobenzene released onto and into soil may tightly adsorb to the sediment though the presence of dichlorobenzene in groundwater indicates that leaching may occur. Volatilization from soil and water is an important transport mechanism. It is possible that dichlorobenzene will biodegrade under aerobic conditions but is unlikely under anaerobic conditions. Transformation in soil or water by hydrolysis, oxidation or direct photolysis is not expected to occur. When released to water strong adsorption to sediment is expected. When released to air it will predominantly remain in the vapor phase and will react with photochemically produced hydroxyl radicals with a half-life of about 14-31 days. Direct photolysis is not expected to occur to dichlorobenzene, though the detection of dichlorobenzene in rainwater has indicated that wet washout is possible.

Ethylbenzene

Ethylbenzene released into the atmosphere will exist in the vapor phase, and will photochemically degrade by reaction with hydroxyl radicals, with a half-life from a few hours to two days. It may undergo wet deposition, and is not expected to undergo direct photolysis. In water loss will be mainly to biodegradation and evaporation with half-lives between a few days to a few weeks. Ethylbenzene sorbs moderately to sediments, and is not expected to bioaccumulate in aquatic biota. Released into soil it will moderately adsorb to sediment and can leach into the groundwater, where some can undergo biodegradation.

1,2,4-Trichlorobenzene

1,2,4-Trichlorobenzene sorbs strongly to soil, though some sites have shown 1,2,4-Trichlorobenzene in the groundwater indicating that some leaching may occur. 1,2,4-Trichlorobenzene will not biodegrade or hydrolyze in groundwater, but may slowly biodegrade in soil. 1,2,4-Trichlorobenzene released into water will bioaccumulate or adsorb to sediments and suspended solids. It will not hydrolyze in surface water but may significantly biodegrade. Evaporation is expected to be a significant loss with a half-life measured in hours. It is expected to have a vapor

phase half-life of about 18.5 days due to reactions with photochemically produced hydroxyl radicals.

Extra spaces

Carbon Disulfide

Carbon disulfide released into the ground will primarily be lost through volatilization and will also readily leach into groundwater where it may biodegrade. In water carbon disulfide is lost to volatilization, with a half-life of approximately 2.6 hours, whereas bioaccumulation and sorption to sediment should not be significant. In the atmosphere carbon disulfide is degraded by reacting with elemental oxygen and photochemically generated hydroxyl radicals. Soil can become a natural sink for carbon disulfide as it can be adsorbed then biodegraded.

1,2-Dichloroethene

In the atmosphere 1,2-Dichloroethane can travel long distances and is primarily removed by photooxidation, with a half-life of approximately 1 month. Decomposition elements are CO₂ and HCl. Releases to water are mainly removed by evaporation, with half-lives of up to 10 days. Hydrolysis and sorption to sediment are unlikely in water or in soil. On soil it is likely to either volatilize or percolate through the subsurface to the groundwater where it will be very persistent. It is not likely to bioaccumulate.

cis-1,2-Dichloroethene

Cis-1,2-DCE that is released at the soil surface either evaporates or leaches into the groundwater. Cis-1,2-DCE that leaches into the subsurface undergoes very slow biodegradation. In water cis-1,2-DCE is lost mainly through volatilization (half-life about 3 hours). Losses that occur through biodegradation, adsorption to sediment and bioconcentration should not be significant. In the atmosphere cis-1,2-DCE is lost mainly by reaction with photochemically generated hydroxyl radicals, in the air Cis-1,2-DCE has a half-life of about 8 days.

trans-1,2-Dichloroethene

Trans-1,2-DCE that is released at the soil surface either evaporates or leaches into the groundwater. Trans-1,2-DCE that leaches into the subsurface undergoes very slow biodegradation. In water trans-1,2-DCE is lost mainly through volatilization (half-life about 3 hours). Losses that occur through biodegradation, adsorption to sediment and bioconcentration should not be significant. In the atmosphere trans-1,2-DCE is lost mainly by reaction with photochemically generated hydroxyl radicals, in the air trans-1,2-DCE has a half-life of about 3.6 days.

4-Methyl-2-pentanone (MIBK)

When released on to soil MIBK may be removed by direct photolysis, volatilization and aerobic biodegradation. MIBK is readily percolated through the soil. In water MIBK is primarily lost through volatilization (half-life of 15-33 hours) and direct photolysis, aerobic biodegradation maybe of minor importance. MIBK is not expected to undergo chemical oxidation, chemical hydrolysis,

bioaccumulate or adsorb significantly to sediment. In the atmosphere MIBK will react with photochemically generated hydroxyl radicals, undergo direct photolysis or react with nitrogen oxides. When degraded nitrogen oxides MIBK may produce acetone, peroxyacetylnitrate and methyl nitrate.

Tetrachloroethylene

When released to soil, PCE is subject to evaporation and to leaching into the groundwater. In anaerobic soil and groundwater with acclimated bacterial populations biodegradation may be an important process. When released to water PCE will undergo rapid volatilization. It is not expected to undergo significant biodegradation, bioaccumulation, or adsorb to sediment. PCE is not expected to hydrolyze in soil or water. In the atmosphere PCE will be subject mainly to photooxidation, with some washout expected with rain. The half-life of PCE is expected to be about 2 months.

Trichloroethylene

TCE released to atmosphere will react rapidly, with a half-life of about 5 days. The reactions TCE undergoes in air produce phosgene, dichloroacetyl chloride and formyl chloride. TCE is not subject to direct photolysis. When released to water TCE is removed primarily by volatilization (half-life of minutes to hours). Other losses from biodegradation, hydrolysis and photooxidation will be slow in comparison to volatilization. Releases on to soil will partially evaporate and some will leach into the groundwater, where it will have a long residence time.

Trichlorofluoromethane

On the land surface or in water the main loss of trichlorofluoromethane will be through evaporation. In water trichlorofluoromethane bioaccumulation in fish or other aquatic biota is unlikely, nor will it sorb significantly to soils or sediments. On land it can leach into the subsurface, where it has a long persistence time. In the atmosphere it has a half-life of between 52 and 207 years, as it must diffuse from the troposphere to the stratosphere. Very slow interaction with ozone in the stratosphere will degrade trichlorofluoromethane. Trichlorofluoromethane can be transported over great distances and is found evenly spread through out the atmosphere.

1,1,2-Trichloro-1,2,2-trifluoroethane

When released to soil 1,1,2-Trichloro-1,2,2-trifluoroethane rapidly volatilizes, though a fraction will leach down to the groundwater. When released to surface water all 1,1,2-Trichloro-1,2,2-trifluoroethane is expected to be volatilized with a half-life of about 4 hours. In the atmosphere the dominate removal mechanism s photolysis in the stratosphere with a half-life between 80 and 140 years after diffusion out of the troposphere. The persistence of 1,1,2-Trichloro-1,2,2-trifluoroethane is indicated with its distribution around the globe.

Dichlorodifluoromethane

Dichlorodifluoromethane, when released onto land, either volatilizes or leaches into the subsurface, there are no known processes that degrade dichlorodifluoromethane. Dichlorodifluoromethane is also stable in water and the only loss is volatilization into the atmosphere. The water surfaces (oceans/lake) will come to an equilibrium with dichlorodifluoromethane and can transport it long distances. Dichlorodifluoromethane is very stable in the troposphere and slowly diffuses into the stratosphere where it is lost to photolysis. The degradation of dichlorodifluoromethane in the atmosphere produces chlorine atoms that attack ozone.

Methyl Acetate

When released onto soil methyl acetate is very mobile and has the potential to leach into groundwater. Rapid volatilization is expected to occur from both wet and dry soils. Hydrolysis is not expected to account for a significant loss from soil except under very basic conditions (pH>9). If released into water methyl acetate is expected to rapidly volatilize into the atmosphere. Some data indicates that methyl acetate will biodegrade in water under both aerobic and anaerobic conditions. Methyl acetate will not significantly adsorb to sediment or suspended solids, nor should it bioaccumulate in fish. Hydrolysis in water should only occur at significant rates at a pH of greater than nine. In the atmosphere methyl acetate is expected to undergo a slow reaction with photochemically generated hydroxyl radicals with half-lives in the range of 50 to 100 days. Some research has shown that the photooxidation of methyl acetate will be much faster.

Methylene Chloride

When released to the atmosphere methylene chloride will react with photochemically generated hydroxyl radicals and degrade over a few months, it will not undergo direct photolysis. Releases to surface water will primarily be losses to evaporation. Biodegradation is possible in surface water but would be a slow process. Methylene chloride is not expected to adsorb to sediment or organic suspended solids, nor is it expected to bioaccumulate in aquatic organisms. Releases to surface soil will evaporate rapidly, though a fraction of the mass is expected to percolate down toward the groundwater. The rate of biodegradation or final transport fate is still uncertain for methylene chloride in the subsurface. Hydrolysis is not an important process under normal environmental conditions.

Pesticides

Pesticides are persistent and immobile contaminants in environmental media. Typically, pesticides are insoluble in water so, whether they are sprayed, dusted, or applied directly to soil, pesticides ultimately accumulate in soil. Pesticides travel at various rates through soil, primarily due to their affinity for soil/sediment particles. The soil sorption coefficient (K_d) is the distribution of a pesticide between soil and water. In general, the K_d values are higher for high organic carbon soils (i.e.;

clays) than for nonorganic soils (i.e.; sands). Thus, soils (clays) with a high K_d adsorb more pesticides than nonorganic soils (sands).

A discussion of the pesticides detected is provided as below.

Chlordane

Technical chlordane, commonly used as an insecticide, is a complex mixture of many chlorinated components, having different persistence patterns in the environment. Chlordane is expected to be relatively immobile in the typical subsurface environment when present at low concentrations. Bulk quantities of the liquid chemical (e.g., from a spill, heavy spray application, or improper disposal) could be transported through the unsaturated zone. However, most studies have shown that proper application of chlordane to soil surfaces does not result in rapid transport through the soil. Estimates for the unsaturated zone using the Mackay's equilibrium model indicate that almost all of the chlordane is expected to be associated with the stationary phase with little available for transport, dispersion, and diffusion. In saturated deep soils, the percentage of the chlordane in the soil-water phase is expected to be small with little available for transport with flowing groundwater.

Due to chlordane's extensive use as an insecticide, numerous studies have indicated that chlordane is quite persistent in soils and transport through leaching is low. Chlordane has been reported to be susceptible to photolysis and biodegradation. Evidence of the microbial degradation has been presented in several studies with results indicating slow degradation in soils with the half-life for degradation of chlordane in natural soils to be on the order of 2 to 4 years.

4,4"-DDT/4,4"-DDE/4,4"-DDD

DDT and its metabolites are expected to be highly immobile in the subsurface environment when present at low dissolved concentrations. Bulk quantities of these pesticides dissolved in an organic solvent could be transported through the unsaturated zone as a result of a spill or improper disposal. However, the extremely low solubility of these pesticides and their strong tendency to sorb to soils results in a very slow transport rate in soils.

Based on Mackay's Equilibrium Model, due to their strong tendency to sorb to soils, virtually all of these pesticides partition to the soil particles in the unsaturated zone with negligible amount associated with the soil-water or soil-gas phases. Even in saturated environments, which is assumed to contain no soil-air and a smaller organic carbon fraction, almost all of the DDT, DDE, and DDD is retained on the soil.

The rate at which DDT and its metabolites degrade in the subsurface environment is dependent on the conditions under which they are present. The pH strongly affects the rate of aqueous hydrolysis. DDT has been found to undergo abiotic, reductive dehalogenation to DDD in the presence of porphyrin. Dehydrochlorination of DDT to DDE (removal of a hydrogen and chlorine atom to form a

double bond) has also been observed in model systems containing reduced porphyrins and in the natural environment. The half-life for the decomposition of DDT in aerobic soils has been reported to be in the range of 10 to 14 years compared to half-lives of 28 to 33 days in moist soils incubated under anaerobic conditions.

DDE is the major degradation product of DDT in aerobic soil and is quite resistant to further hydrolysis. The biological degradation of DDE in aquatic environments is believed to occur very slowly. Under anaerobic conditions, DDD is the major metabolite of DDT. As was the case for DDE, in aquatic systems, biodegradation is believed to be slow.

Endrin (Aldehyde and Ketone)

Endrin and other formulations such as endrin ketone and endrin aldehyde have been used as insecticides on cotton and grains, and as avicides and rodenticides. If endrin is released to the soil, it will be expected to persist for extremely long periods of time. Biodegradation may be enhanced somewhat in moist soils or under anaerobic conditions. Endrin aldehyde will be expected to strongly sorb to soil and be immobile in soil. If endrin aldehyde is released to water, it will not hydrolyze or biodegrade. It will be subject to photoisomerization to ketoendrin based upon experiments on solid endrin. Endrin will sorb to sediment and will significantly bioconcentrate in aquatic organisms. Fate and transport data for endrin aldehyde obtained from *Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volume III, Pesticides*, Philip H. Howard, 1991.

Dieldrin

Dieldrin has been used as an insecticide for corn and for termite control. If dieldrin is released to the soil, it will persist for long periods of time and is highly immobile. Due to its low water solubility and strong adsorption to soil, dieldrin is not expected to leach into groundwater. Dieldrin may adsorb onto dust particles and become suspended in the air or reach surface water through soil runoff. When released into water, it is subject to photorearrange to photodieldrin (water half-life of four months). It will also adsorb to sediments and bioconcentrate in aquatic organisms. Fate and transport data for dieldrin was obtained from *Handbook of Environmental Fate and Exposure Data for Organic Chemicals, Volume III, Pesticides*, Philip H. Howard, 1991.

Aldrin

Aldrin has been classified as moderately persistent with a half-life of 20-100 days. Biodegradation in soil is slow but Aldrin is not expected to leach into groundwater. In soil Aldrin decomposes to dieldrin. Aldrin residues in water will volatilize and photooxidation are expected to be significant. Photolysis has been observed in water and bioaccumulation will be significant as will be absorption to sediments. Vapor phase aldrin is expected to react with photochemically generated hydroxyl radicals with an estimated half-life of 36.46 minutes. Most aldrin in the atmosphere is expected to adsorb to particulates. Though aldrin can undergo direct photolysis in the atmosphere, the rate of

photolysis will be slow compared to reaction with hydroxyl radicals.

Endosulfan

Release of endosulfan to soils will most likely result in biodegradation and hydrolysis. Endosulfan on the surface may photolyze. Volatilization and leaching are not expected to be significant due to the high soil sorption coefficients. When released to water endosulfan isomers are expected to hydrolyze readily under alkaline conditions, and more slowly under neutral or acidic conditions, half-lives in water of between 35.4 and 37.5 for neutral conditions, and 150.6-187.3 days for acidic conditions. Volatilization, biodegradation and bioconcentration are expected to be significant as well. Photolysis and oxidation could also be important. Endosulfan released into the air will react which photochemically generated hydroxyl radicals with an estimated half life of 1.23 hours.

Heptachlor

Volatilization of heptachlor from surface soils, especially moist soil will be rapid, volatilization of heptachlor incorporated into soils will be slower. Hydrolysis in moist soils will be significant. Heptachlor degrades to 1-hydroxychlordehene, heptachlor epoxide and other unidentified metabolites. Biodegradation of heptachlor will also be significant. Heptachlor is expected to sorb strongly to soil sediments and therefore to resist leaching into groundwater. Release of heptachlor to water results in hydrolysis to 1-hydroxychlordehene with a half-life of approximately 1 day, as well as volatilization to the atmosphere. Hydrolysis will dominate over adsorption to sediments, biodegradation, photolysis and bioconcentration. In air the vapor phase will react with photochemically generated hydroxyl radicals and ozone with half-lives approximately 6 and 1.5 hours respectively. Direct photolysis may also occur.

BHC (alpha, beta, delta, and gamma (Lindane))

When released into water Lindane is not expected to volatilize significantly. Lindane may hydrolyze significantly in basic waters, but not in neutral or acidic waters. At a pH of 9.3 the half-life of lindane in water is approximately 4 days. Transport into sediment will be slow, primarily from diffusion rather than from settling. Lindane released to soil will either volatilize or leach slowly to the groundwater. Lindane reacts with photochemically produced hydroxyl radicals and has a half-life in the atmosphere of approximately 2.3 days. Lindane may slowly biodegrade under aerobic conditions and may rapidly degrade while under anaerobic conditions. Photolysis is considered the primary fate, though lindane is reported to photo-degrade in water. Lindane will bioconcentrate slightly in fish.

Polychlorinated Biphenyls (PCBs)

Aroclor-1260

Aroclor-1260 is expected to be highly immobile in the soil/groundwater system due to sorption.

Estimates from Mackay's equilibrium model indicate that approximately 99 percent of the Aroclor is expected to sorb to the soil in the unsaturated zone. Less than one percent is expected to partition to the soil-water phase and the remaining portion is available to migrate by bulk transport, dispersion, and diffusion. In saturated deep soils, sorption is expected to be the most significant fate process and Aroclor-1260 is not expected to leach into the groundwater. The tendency of PCBs to adsorb to sediment and suspended particles increases with the degree of chlorination and the organic content of the sediments.

SVOCs

Numerous SVOCs were detected at the site with PAHs being the primary contaminant detected above EPA RBCs. A discussion of each of the detected SVOCs is provided below.

Polynuclear Aromatic Hydrocarbons

Numerous PAHs including acenaphthene, acenaphthylene, anthracene, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(g,h,i)perylene, carbazole, chrysene, fluoranthene, fluorene, indeno(1,2,3-cd)pyrene, 2-methylnaphthalene, dibenzofuran, dibenzo(a,h)anthracene, phenanthrene, naphthalene and pyrene were detected in site soils, sediment, and groundwater samples. Fate and transport characteristics are similar for this class of compounds; therefore, PAHs will be discussed as a class of compounds rather than individually.

PAHs tend to strongly sorb to most soils, although lower molecular weight PAHs will leach in soils with low organic carbon content. Estimates from Mackay's equilibrium model indicate that 90 to 99 percent of PAHs are expected to sorb to the soil in the unsaturated zone. A small portion will be present in the soil-water phase and available for bulk transport, dispersion, and diffusion. In saturated soils, a higher percentage is expected to be present in the soil-water phase and transported with flowing groundwater.

Lower molecular weight PAHs may volatilize from shallow soils and surface water but higher molecular weight PAHs have limited volatility. Since PAHs have very low solubilities in water, these compounds will be readily sorbed and deposited onto sediment.

The major fate process for PAHs in soil and water is biodegradation; but PAHs in surface water may also photo degrade. PAHs under normal environmental conditions are not expected to undergo hydrolysis, and are not susceptible to oxidation or reduction reactions in the subsurface environment. Most PAHs are reported to be readily susceptible to aerobic biodegradation. However, the rate of biodegradation is dependent upon each PAH and the environmental conditions.

Phthalates

Phthalates detected at the site included bis(2-ethylhexyl)phthalate (DEHP), detected in 27 of 30

samples of soil, and di-n-octyl phthalate. Di-n-octylphthalate was only detected in 6 of 30 soil samples and not detected in groundwater samples, the discussion for phthalates will focus on DEHP.

DEHP may move through the subsurface environment when present at low concentrations (dissolved in water and sorbed on soil) or as a separate organic phase (from spills or improper waste disposal). In the unsaturated zone, equilibrium models (Mackay's Equilibrium Partitioning Model) indicate nearly all of DEHP would sorb onto the soil particles. A small portion will be in the soil-water phase and thus can migrate by bulk transport, dispersion, and diffusion. In saturated soils, a much higher fraction is likely to be present in the soil-water phase and transported with flowing groundwater. The extent of sorption is still very strong and groundwaters underlying DEHP-contaminated sites may not be affected unless the phthalates are mobilized by complexation with other chemical species.

The persistence of DEHP is not well documented. In most cases, it should be assumed that these compounds would persist for years. DEHP that has been released into the air, or that enters surface waters with significant sunlight exposure is not expected to be degraded by direct photolysis.

DEHP has been found to be biodegradable in several studies. The ease of degradability is however, less than that of most other phthalate esters. Therefore, biodegradation in typical subsurface environments should be assumed to be of minimal importance.

3-3'-Dichlorobenzidine

If 3-3'-dichlorobenzidine is released into water it will rapidly and strongly adsorb to sediment and particulate matter, some of the compound will be irreversibly adsorbed to the sediment. The compound will undergo very rapid photooxidation near the surface of water, with a half-life of about 90 seconds, forming 3-chlorobenzidine, benzidine and other water insoluble substances. Redox and free radical reactions could be important. When released onto soil 3-3'-dichlorobenzidine will adsorb strongly, and may under go slow mineralization. The compound may under go reactions with other soil components. If released into the air it will likely be adsorbed to particulates and rapidly photo-degrade.

2,4-Dinitrotoluene

When released to soil 2,4-Dinitrotoluene may biodegrade in both aerobic and anaerobic conditions. It will not bioconcentrate significantly in fish and shows a tendency to partition to suspended sediment and sediment organic matter. The volatilization from surface waters will not be significant, the most important removal process in water will be photolysis with listed half-lives between 2.7 and 9.3 hours. In the atmosphere 2,4-Dinitrotoluene is estimated to have a half-life of about 8 hours.

2,6-Dinitrotoluene

Information for 2,6-dinitrotoluene released into soil is unavailable; it is expected to be slightly mobile. 2,6-Dinitrotoluene will have a slight tendency to adsorb to sediments, suspended solids and biota when released into water. Volatilization from water is slow and hydrolysis is probably not significant. Photolysis is probably the most significant removal mechanism for 2,6-Dinitrotoluene in water. In the atmosphere the estimated half-life is 8 hours based upon reaction with photochemically generated hydroxyl radicals.

1-1'-Biphenyl

1-1'-Biphenyl released onto soil can volatilize, but a significant portion will adsorb to organics present in the soil. The main loss from soil is through biodegradation, in one study 9.1% of the biphenyl was biodegraded in 2 days. In the atmosphere 1-1'-Biphenyl reacted with hydroxyl radicals with an estimated half-life of 2.2 days. It is also subject to considerable photolysis with a half-life estimated at 2 hours. 1-1'-Biphenyl can react very slowly with ozone, but it is not expected to be a significant loss. In water 1-1'-Biphenyl can volatilize into the atmosphere, but also shows strong tendency to adsorb to organic suspended solids as well as sediment. The main losses from water are hydrolysis, with a half-life of about 40 hours and biodegradation with a half-life measured in hours. Biphenyl does bioaccumulate in aquatic animals.

Table 5-2 summarizes the potential transport pathways of organic and inorganic contaminants in soil, sediment, water, air, and biological systems, and identifies the applicable reactions and processes.

5.2 POTENTIAL PATHWAYS OF CONTAMINANT TRANSPORT

This section discusses the potential transport pathways by which groups of contaminants can migrate between and within environmental media (i.e., air, surface water, soil, sediment, and groundwater) at the 80th DRS.

5.2.1 On-site Deposition of Windblown Dust

Wind can act as a contaminant transport agent by eroding soil and exposed sediment and blowing it off-site. The net transport is influenced by: wind velocity, the grain size/density of the soil/sediment particles and the amount of vegetative cover over the site. The 80th DRS is covered partially (approximately 60%) by asphalt, which would limit the amount of windblown dust. However, the remainder of the site (northern portion) consists of vegetative cover and some bare sands, which would do little to inhibit windblown dust. Thus, there appears to be insufficient ground cover on the northern portion of the site where sampling was conducted to effectively limit this transportation mechanism.

5.2.2 Soil/Sediment Transport by Storm Water Runoff

Water can erode exposed soil/sediment particles during precipitation events. This is influenced by site topography, amount and rate of precipitation, soil/sediment particle size/density, cohesion of soil/sediment, and vegetative cover. Similar to windblown transport, asphalt cover at the site limits the surface area of soil/sediment subject to erosion by storm water runoff. Although the high permeability of the soil present in the unpaved portion of the site reduces the volume of storm water runoff, other factors (e.g., storm intensity, storm water conveyances, topography, etc.) make storm water runoff potentially a significant transport mechanism.

5.2.3 Soil/Surface Water to Air Transport

The primary mechanism of contaminant transport from soil and surface water to air is volatilization. Volatile soil contaminants can migrate up through soil pore spaces and diffuse into the atmosphere. Nonvolatile contaminants such as PCBs and metals can be transported to air only if adhered to airborne particulate matter.

5.2.4 Surface Water to Sediment Transport

Some important mechanisms that control contaminant migration from surface water to sediment are:

- **Seepage:** Contaminated storm water can flow through sediment under hydraulic head, potentially transporting dissolved contaminants to sediment.
- **Gravity Settling:** Gravity settling is a mechanism for separating particles with sorbed metals and organic chemicals from surface water.
- **Adsorption:** Depending on the chemistry of the surface water and sediment and the physical interactions between surface water and sediments, adsorption can be a mechanism for transporting contaminants in water to sediment.
- **Dissolution/Precipitation.** The chemical process by which a material is dissolved in a liquid solvent such as water. Precipitation is the reverse process of dissolution.

5.2.5 Sediment to Surface Water Transport

The primary mechanisms for transporting contaminants from sediment to surface water are desorption, dissolution, and ion exchange. This process is influenced by the physical and chemical properties of the contaminant, the sediment particle, the surface water and turbulence during transport. However, these mechanisms are considered minor for the compounds of concern relative to other transport mechanisms.

5.2.6 Soil/Vadose Zone to Groundwater Transport

space needed

The primary mechanism of contaminant transport from the soil/vadose zone to groundwater is through dissolution and transport of constituents via infiltration of rainwater. This mechanism can effectively transport soluble contaminants. Because of the high annual precipitation (44.68 in/yr) at Fort Story and the highly permeable soils present at the site, infiltration rates can be very high. Fort Story contains mostly sandy, coarse sandy, and sandy gravel soils allowing for fast infiltration, with little runoff. Some areas at Fort Story have significantly reduced the potential for infiltration due to localized impermeable features (i.e. pavement and buildings).

5.2.7 Groundwater to Soil/Vadose Zone Transport

There are several mechanisms of contaminant transport from groundwater to the vadose zone. VOCs in groundwater can volatilize into the unsaturated pore space in the vadose zone. At the capillary fringe, groundwater contaminants can be transported to unsaturated soil via precipitation, adsorption, and ion exchange.

5.2.8 Groundwater to Surface Water Transport

Organic contaminants associated with groundwater are either in a dissolved state or as an immiscible phase on top of or at the bottom of the aquifer. Subsurface transport of immiscible contaminants is governed by several processes: advection, dispersion, and retardation. Advection most strongly influences the transport of dissolved organic contaminants along the hydraulic gradient present as a result of the hydrogeologic framework of the site. Dispersion and spreading during transport results in dilution of contaminants hydraulically downgradient of the source area. Generally speaking, dispersion is greater along the direction of groundwater flow than it is transverse to the flow direction. Retardation of dissolved contaminants occurs as a result of adsorption, partitioning, ion exchange, and other processes that occur along the groundwater flow path. As a result of retardation, contaminants are distributed between the aqueous phase and aquifer sediments, contaminant concentrations in the aqueous phase decrease, and migration of the aqueous phase is reduced relative to groundwater flow.

5.3 FATE AND TRANSPORT CONCEPTUAL MODEL

The conceptual fate and transport model presented in this section provides a qualitative analysis of the environmental mechanisms, site characteristics, and physical/chemical properties of contaminants that have influenced, or currently influence, contaminant fate and transport at the 80th DRS. Evaluating the site conditions and contaminant properties resulted in identification of the potential contaminant pathways presented in **Table 5-3**.

Discharge of compounds from groundwater in the Columbia aquifer through the Yorktown confining unit to the underlying Yorktown-Eastover aquifer was considered to be unlikely based on the following considerations:

- The estimated vertical hydraulic gradient between the Columbia and Yorktown-Eastover

aquifers and groundwater flow simulations (Harsh and Lacznia, 1990) for these aquifers indicate that the potential for groundwater flow is from the Yorktown-Eastover aquifer upward through the Yorktown confining unit to the Columbia aquifer. Thus, contaminants are most likely to migrate along the horizontal groundwater gradient in the Columbia aquifer to discharge points such as creeks or streams.

- space*
- The Yorktown confining unit has a very low hydraulic conductivity that has been measured to be approximately 10^{-5} to 10^{-6} cm/sec by geotechnical studies.

Migration of the majority of the contaminants (primarily PAHs, pesticides, and metals) is more likely to occur by transport of soil/sediment by storm water or surface water rather than by vertical infiltration based on the physical and chemical properties of the identified compounds, the identified concentrations, and the established groundwater flow regime.

5.4 SITE FATE AND TRANSPORT

This section discusses the fate and transport for the 80th DRS. **Table 5-2** presents the transport mechanisms applicable to the individual transport pathways and the transport pathways identified for the site are presented in **Table 5-3**. Based on the fate and transport properties of the general type of chemical(s) present at the site and the site conditions, a conceptual model for the site is presented. A graphical presentation of the conceptual model for the site is presented on **Figure 5-1**.

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 (six or less) part-per-billion range, and therefore would not be a significant contributor of vapor when viewed 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.

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.

Of the remaining SVOCs that were detected in most surface and subsurface soil samples on-site and downgradient of the site, phthalates were also frequently detected. Typically, phthalates and other SVOCs strongly sorb to soil, are relatively immobile, and would biodegrade over time. As there is a lack of organics to help bind the phthalates and other SVOCs, they can potentially be available for transport offsite by leaching toward the groundwater or by surface runoff. The phthalates and other SVOCs were found throughout the soil column, both shallow (less than 6 inches) and deep soil. This indicates that they are available for both surface run off and possible further leaching into the subsurface. However, as none of the phthalates and SVOCs (excluding the PAHs discussed above) were detected above the RBC screening criteria, migration of SVOCs is not a significant concern at the site.

Numerous metals were detected on-site and downgradient of the site. Some soil samples exceeded the residential EPA RBCs for arsenic (8 of 30) and iron (6 of 30) and 1 sample exceeded the RBCs for 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, which is most likely in this case given the soil conditions of the site (sandy). Arsenic is relatively immobile and in the

presence of iron, calcium and aluminum 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. However, a change in pH in the soil column can make arsenic more soluble and increase the potential for leaching to groundwater and surface water.

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.

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, Interim Report*, USEPA, 2004.
- *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**.

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 80th 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**.

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**.

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.

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.

- 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.
- 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.

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.

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.

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.

- 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.

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.

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.

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.
- 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.

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.

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 continue to be identified as industrial usage; therefore, the future land use will be the same as the current land use. 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.

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

For the current and future situation, 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,
- Construction worker exposure (adults only) to contaminated surface/subsurface soils, and
- Construction worker exposure (adults only) to contaminated groundwater.

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

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

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, Jackknife, 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:

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. Therefore, exposure estimations will only be calculated for this population.

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:

SUMMARY OF GROUNDWATER EXPOSURE ESTIMATIONS		
COPC	95 Percentile UCL or Maximum	Estimated Exposure Concentration (mg/l)
Cis 1,2-DCE	UCL	0.0035
PCE	UCL	0.0044
TCE	UCL	0.0030
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).
- 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 cm²/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 cm² (VDEQ, 2003).
- The soil to skin adherence factor (AF) used is 0.20 mg/cm² 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 m³/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)

Soils

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.
 - 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 cm² (VDEQ, 2003).
- The soil to skin adherence factor (AF) used is 0.90 mg/cm² 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 m³/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:

Incidental Ingestion

- In evaluating inadvertent ingestion of groundwater, an ingestion rate of 0.02 liters/day based on VDEQ, 2003.

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- 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 cm² (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/m³)
Cis 1,2-DCE	3.90E-02
PCE	3.79E-02
TCE	2.90E-02
Bis(2-ethylhexyl)phthalate	6.09E-05

- An inhalation rate (IR) of 2.5 m³/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.

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.

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_i s were available for the following constituents (in mg/kg/d):

- Manganese – 1.43×10^{-5}
- PCE – 8.0×10^{-2}
- TCE – 1.0×10^{-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 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. CPS 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 CPS are also presented in **Table 6-15**.

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

$$\text{Risk} = \text{CDI} \times \text{CPS}$$

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-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 CPS_o) 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 CPS_o 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_s 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 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 (3.29×10^{-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 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 = 1.49×10^{-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.

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 a likely a significant overestimation.

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	1.77x10 ⁻⁵	3.29x10 ⁻⁵
	Dermal Contact with Soil	N/A		1.52x10 ⁻⁵	
	Inhalation of Soil Particulates	N/A		4.90x10 ⁻¹⁰	

HUMAN HEALTH RISK ASSESSMENT

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 exposure to contaminated groundwater is associated with TCE; however, the 95th UCL utilized in the risk calculations was only 3 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) 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 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.

The purpose of this Screening Level Ecological Risk Assessment (SLERA) is: 1) evaluate adverse effects or stressors on ecosystems and components of ecosystems at the 80th Division Reserve Site (DRS) and 2) identify which contaminants at the site, if any, could potentially pose a risk to the assessment endpoint(s) utilizing the limited data collected during the confirmation sampling phase of the project. This SLERA was conducted following the procedures contained in the *Ecological Risk Assessment Guidance for Superfund: Process for Design and Conducting Ecological Risk Assessments* (USEPA, 1997) and the *Guidelines for Ecological Risk Assessment* (USEPA, 1998).

According to current USEPA guidance, the following steps were completed for the risk assessment at the 80th DRS:

- Problem Formulation
 - Qualitative characterization of natural resources
 - Identification of chemicals of potential concern (COPC)
 - Identification of potential exposure pathways
 - Identification of assessment and measurement endpoints
 - Development of conceptual ecological site model
 - Define risk management goals
- Exposure assessment providing quantitative or qualitative exposure scenarios for selected ecological receptors
- Ecological effects assessment summarizing toxicity reference values for selected ecological receptors
- Characterization of risk
- Estimation of risk uncertainty

7.1 PROBLEM FORMULATION

Problem formulation is the first phase of ecological risk assessment and establishes the goals, breadth, and focus of the assessment (USEPA, 1997). The process involves a series of interrelated steps to identify potential stressors, pathways, and ecological effects. Ecological endpoints appropriate for the site is then derived, and an ecological conceptual site model is formulated. This model is a set of working hypotheses regarding the potential pathways and effects of site-related stressors on ecosystems of concern.

Problem formulation is based on information collected during the Remedial Investigation. This phase of the ecological risk assessment is presented in four parts: ecosystems of concern; potential stressors, exposure pathways, and ecological effects; ecological endpoints; and, the conceptual model.

7.1.1 Site Description

The 80th DRS is located north of DaNang Road and east of Hospital Road, on the Fort Story Army Base, Virginia Beach, Virginia. The site 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 80th 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 underground storage tank (UST), 250-gallon antifreeze aboveground storage tank (AST), and a former drum storage area were located west of the wash pad. The location of the 80th DRS is provided on **Figure 1-1**.

The 80th DRS area is at an elevation of approximately 10 feet above mean sea level (AMSL) and is generally devoid of topographic features. The asphalt area on the south half of the site is flat. The north half of the site is located in a sandy flat area with low sand ridges. This sandy area located north of the asphalt and concrete pads comprises an area of approximately 0.2 acres. The entire 80th DRS staging area is located within a relatively undisturbed portion of the Ft. Story Base providing habitat for local flora and fauna. As shown in **Figure 7-1**, the area of ecological concern for the site is the small area in the central portion of the site where the detections of organics and metals exceeded BTAG limits. This area is only approximately 120 feet wide and 60 feet long which equates to about 0.20 acres. Other areas with BTAG exceedences include the areas at SB-1 and SB-2 which are upgradient of the former source areas (UST and AST) at the site.

7.1.2 Flora and Fauna

A southeastern evergreen forest community covers most of Fort Story. This forest type is the northernmost extension of a vegetation type in which long-needled pines dominate. This forest type extends along the Gulf and Atlantic coastal plains from eastern Texas to the James River. The southeastern evergreen forest south of the James River is characterized by Loblolly Pine (*Pinus taeda*) interspersed with various oaks (*Quacus spp.*) and other hardwoods. This forest community is a mosaic of plant assemblages controlled largely by soils and drainage patterns. The indicator species of the southeastern evergreen forest was historically Longleaf Pine (*Pinus palustris*). Loblolly Pine now predominates in this area since it rapidly colonizes old fields, out competes Longleaf Pine and has been extensively planted.

Wildlife found at Fort Story is typical of that found in the Virginia Beach and Seashore State Park area. Common mammal species found at the installation include Muskrat (*Ondontra zibethicus*), Eastern Cottontail (*Sylvilagus floridanus*), Raccoon (*Procyon lotor*), Opossum (*Didelphis virginiana*), and Squirrel (*Scuirus spp.*). Some White-tailed Deer (*Odocoileus virginianus*) may take temporary residence in and around the cypress swamp.

Common species of birds include seagulls (*Larus spp.*), European Starling (*Sturnus vulgaris*), Robin (*Turdus migratorius*), American Crow (*Corvus brachyrhynchos*), and Bluejay (*Cyanocitta cristata*).

Typical species of amphibians and reptiles found within the installation include common species of frogs, turtles, and snakes, such as the Green Frog (*Hyla cinerea*), Eastern Box Turtle (*Terrapene carolina carolina*), and Copperhead Snake (*Agkistrodon contorix contorix*).

7.1.2.1 Threatened and Endangered Species

According to the Virginia Department of Conservation and Recreation, Division of Natural Heritage study conducted for Virginia Beach, several threatened and endangered species may occur in the vicinity of Fort Story where suitable habitat exists. These species are the Federal threatened Bald Eagle (*Haliaeetus leucocephalus*) the Federal threatened Dismal Swamp Shrew (*Sorex longirostris fisheri*), the State Endangered Chicken Turtle (*Deirochelys reticularia*), and the State threatened Eastern Glass Lizard (*Ophisaurus ventralis*). Terrestrial and semi-aquatic species are expected to utilize the habitats adjacent to the Reserve Site. The 80th DRS site is not located within designated critical habitat for any protected species.

An ongoing study by Old Dominion University on the Chicken Turtle at Seashore State Park and a portion of Fort Story has recorded no incidence of the turtle on the installation. No confirmed occurrences of the other species have ever been documented, (Horne Engineering and Environmental Services, 1995).

Given the habitat associated with the project area, it is unlikely that any threatened or endangered species will use the 80th DRS with any exclusivity or frequency.

7.1.3 Previous Investigations

A summary of previous investigations and studies conducted at this site is provided below.

Final Site Assessment Report, Montgomery-Watson, May 1994

Montgomery Watson conducted an investigation from February to May 1994 to evaluate the presence of possible soil contamination in the LARC staging area of the site and around the existing concrete pad. Elevated levels of total petroleum hydrocarbons (TPH), heavy oils and lead were detected in the shallow soils adjacent to the former drum storage area, tank area, and wash pad area. Based on the limited vertical extent of contaminated soil, excavation of soil and off-site treatment and disposal was feasible.

Site Characterization Report, Environmental Restoration Company (ERC), June 1994

ERC conducted a site characterization of the site in 1994. Based on the site characterization, two areas of soil contamination and one area of groundwater contamination were identified at the site. TPH and lead contamination was discovered in the shallow soil of the LARC staging area. These contaminants are most likely the result of discharging bilge water and sandblasting. TCE and PCE were detected in monitoring well MW-4.

Removal Action Final Report, IT Corporation, August 1995.

From April through July 1995, IT Corporation completed a removal action of contaminated soil from the LARC staging area and from the tank area. Approximately 3,500 tons of TPH-contaminated soils and 30 tons of PCE-contaminated soil were excavated from the site and transported off-site for thermal desorption. Significant quantities of contaminated soils remained in both areas. The areas were backfilled with clean fill.

7.1.4 Potential Stressors and Exposure Pathways

The second step in problem formulation involves the identification of the interrelationships between potential stressors, exposure pathways, and ecological effects for the identified ecosystems of concern. Chemical and/or physical stressors are identified, potential pathways for migration of contaminants in the on-site soils to the ecosystems of concern are discussed, and potential ecological effects are summarized.

Chemical analyses were performed on soils as outlined in Section 1 of this report. The conclusions derived from this study focus on identifying potential adverse impacts to species, habitats, and populations in the ecosystem surrounding the 80th DRS site, based only on these limited soils data. Sample results are provided in **Appendix K**. **Figure 2-1** shows the soil sample locations.

Potential Stressors

No physical stressors have been identified on the site. Potential chemical stressors, however, are present in the soils. Chemical stressors and affected media are screened to identify chemicals of potential concern (COPCs). All analytical data were compared to USEPA *Region III Biological Technical Assistance Group (BTAG) Fauna/Flora Screening Levels* (screening levels) (USEPA, 1995) and NOAA's *Screening Quick Reference Tables (SquiRT)* (NOAA, 1999). The SquiRT background geometric mean soils values were used, when applicable.

Chemicals were retained for consideration as a COPC if they met any of the following criteria:

- 1) The detected or estimated media concentration exceeded the selected screening level.
- 2) Undetected parameters ("U"-flagged) were retained as COPCs if ½ the method detection limit (MDL) was greater than the screening value. Consistent with laboratory protocol, the MDL was estimated as 10 percent of the PQL (practical quantification limit), which is the value in the laboratory reports and flagged with the "U".
- 3) Parameters that had no screening values were retained for consideration as final COPCs.

As noted in **Table 7-1**, an environmental effects quotient (EEQ) was calculated for each detected contaminant by dividing the maximum detected concentration by the lowest screening criteria. If the EEQ was equal to or greater than one, then the constituent was identified as a COPC.

Subsurface data was considered as the existence of burrowing animals and the possibility of other turbation of soil could lead to a potentially complete pathway for biota to be exposed to the subsurface soils. Groundwater sample results were not screened for COCPs as there are no pathways for groundwater interact with biota. The site contains no surface water areas that would allow a direct contact exposure to terrestrial receptors.

VOCs

A total of 10 volatile organic compounds (VOCs) were retained as COCPs. Of these compounds only Tetrachloroethylene had BTAG or SQuiRT screening values available. The remaining compounds were retained as COCPs in accordance to the above referenced protocol. These included: 1,1,2-trichloro-1,2,2-trifluoethane, 2-Hexanone, Carbon disulfide, Acetone, 1,3-Dichlorobenzene, 2-Butanone (MEK), Dichlorodifluoromethane, Trichlorofluoromethane and Methyl acetate.

SVOCs

A total of 24 semi-volatile compounds were retained as COCPs. Many of these COCPs had EPA BTAG or NOAA SQuiRT screening values including: Acenaphthene, Acenaphthylene, Benzo(a)anthracene, Benzo(a)pyrene, Benzo(b)fluoranthene, Benzo(g,h,i)perylene, Benzo(k)fluoranthene, Chrysene, Dibenzo(a,h)anthracene, Dibenzofuran, Fluoranthene, Fluorene, Indeno(1,2,3-cd)pyrene, Naphthalene, Phenanthrene and Pyrene. The remaining compounds were retained as COCPs in accordance with protocol, these COCPs were: 1,1'-Biphenyl, 2,4-trinitrotoluene, 2,6-Dinitrotoluene, 2-Methylnaphthalene, 3,3'-Dichlorobenzidine, bis(2-Ethylhexyl)phthalate, Carbazole, Di-n-octylphthalate

Metals

Six metals were retained as COCPs: Aluminum, Calcium, Chromium, Lead, Potassium and Sodium. Three of these did not have screening values but were retained according to the above-referenced protocol.

Pesticides

There were no pesticides with BTAG or SQuiRT screening values that were detected with EEQ values equal to or greater than one. Those pesticides that were detected that have no screening values were retained as per above. The pesticides that were retained as COCPs include: alpha-BHC, beta-BHC, delta-BHC, Endosulfan I, Endosulfan II, Endosulfan sulfate, Endrin aldehyde, Endrin ketone and Heptachlor.

PCBs

Aroclor-1260 was detected, but was not found to be above the BTAG screening level and thus was

not retained as a COPC.

Exposure Pathways

Several ecologically relevant migration pathways for contaminants exist at the 80th DRS. The media of concern on this site is the soil. Aquatic exposure or surface water exposure pathways for COPCs at the 80th DRS are not complete and, therefore, will not be assessed in this ERA. Types of receptors and the exposure routes are summarized below:

- root uptake from contaminated soil by plants;
- contact and absorption, incidental ingestion, and feeding on contaminated soils by invertebrates;
- incidental ingestion of contaminated soil by wildlife; and
- bioaccumulation from vegetation or animal prey at the base of the food chain by wildlife.

Based on these pathways, the following general classes of ecological receptors potentially might be exposed to contaminants at the 80th DRS.

- Uptake of COPCs by terrestrial plant and invertebrates from site soil;
- Birds that forage or nest on the Reserve Site;
- Small insectivorous mammals;
- Small herbivorous mammals that feed on the 80th DRS; and
- Other higher trophic level birds and mammals (e.g., carnivores) that feed within the vicinity of the 80th DRS.

These potential exposure pathways are shown in **Figure 7-1**.

7.1.5 Assessment and Measurement Endpoints

An assessment endpoint is a measurable character of a receptor or population of receptors that can be used to assess a COPCs impact on that receptor, i.e., reduced reduced growth or reproduction of receptor populations. Based on the COPCs, the affected media, and the potential routes of exposure the assessment endpoints include: 1) Uptake of COPCs into food chain, 2) survival and reproduction of upper-trophic avian species, and 3) survival and reproduction of upper-trophic mammalian species.

The 80th DRS comprises a small 0.2-acre site that is located within a much larger undisturbed portion of the Ft. Story Base. The site is comprised on sandy soil and minimal groundcover that does not provide a highly productive habitat for the surrounding ecosystem. Based on these site characteristics, the assessment endpoints for this SLERA will focus on risks to upper-trophic populations rather than individual receptors or local invertebrate and plant populations. The goal of this SLERA will be to determine whether COPCs in site soils pose a risk to the surrounding populations by uptake and concentration through the food chain.

A measurement endpoint is a quantifiable expression of observations that can be compared to a reference site or value to detect adverse responses to a site contaminant (USEPA, 1997). Measurement endpoints selected to measure the potential risk to the receptors or endpoint species are comprised of toxicity reference values (TRVs) obtained directly from the literature or calculated from published references. If the total exposure concentrations exceed these TRVs, there is a potential risk of adverse effects to individual receptors that could indicate a large risk to the overall ecosystem surrounding the site. The comparison of TRVs to estimated exposures is conducted in the Ecological Effects Assessment section of this report.

7.1.6 Ecological Conceptual Site Model

Following USEPA guidance (USEPA, 1997), a conceptual model was developed to evaluate how chemical stressors from the 80th Division Reserve Site may affect ecological components of the natural environment. This model illustrates the relationship between the ecosystem at risk, including the assessment endpoint species, and the chemical stressors. In addition, the contaminated media, exposure routes, and environmental transport are identified in the conceptual site model.

Following is a brief description of the endpoint species initially identified as potential species of concern for this assessment. The descriptions include the habitat and dietary requirements for each of these species. These receptors were identified based on the potential for exposure (i.e., potential site presence and food habitats) and susceptibility to adverse effects of the site contaminants. Also listed are the primary metabolic assumptions used for developing the exposure estimates (e.g., body weight and food consumption). A comparison of the typical home range for these species as compared to the 0.20 acre area of ecological concern for the site will be made to assess the acceptability of the initially identified species.

- **American Robin (*Turdus migratorius*).** The American robin occurs throughout most of the continental United States during the breeding season and winters in the southern half of the United States and in Mexico and Central America. Robins forage on the ground in open areas, along habitat edges, or the edges of streams. They forage by hopping along the ground in search of ground-dwelling invertebrates and by searching for fruit and foliage-dwelling insects in shrubs and low tree branches. Foraging home ranges of 0.4 to 2.0 acres have been measured.

The robin has been identified to represent the songbird community and avian omnivores at the 80th DRS. Although other small bird species are known to occur at the 80th DRS, the robin represents herbivorous and insectivorous small birds in the vicinity. Measurement endpoints for the robin are derived from avian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms. Select assumptions are listed below.

- Body Weight = 0.077 kg

- Food Consumption = 0.068 kg/d (dry weight)
 - Diet Consists of 68% fruit; 32% invertebrates
 - Contaminant concentration in invertebrates is equal to Exposure Point Concentrations
- **Red-tailed Hawk (*Buteo jamaciencis*)**. The Red-tailed Hawk is the most widespread and familiar member of the American buteos (large soaring hawks) and represents avian predators. It is a year round resident in Virginia. They nest in the month of March in tall trees. The red-tailed hawk is usually found in grasslands or marsh- shrub habitats, but is a very adaptable bird, being equally at home in deserts and forests, and at varying heights above sea level. The Red-tailed Hawk is an opportunistic hunter. As an avian predator, the red-tailed hawk has a large home range varying from approximately 148 acres to over 6,000 acres. Measurement endpoints for the red-tailed hawk are derived from avian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake effects on individual organisms. Select assumptions are listed below.
 - Body Weight= 1 kg
 - Food Consumption = 1.1 kg/d (dry weight)
 - Diet Consists of 100% small mammals and small rodents, with muskrats, snakes, lizards, and small raccoons included
 - **Short-tailed Shrew (*Blarina brevicauda*)**. The short-tailed shrew ranges throughout the north-central and eastern United States and into southern Canada. They occur in a wide variety of habitats, preferring those that are cool and moist and areas with abundant cover. The short-tailed shrew is primarily carnivorous, concentrating on insects, earthworms, slugs, and snails when available and represents mammalian omnivores. However, it will also eat plants, fungi, millipedes, and small mammals.

The home range for shrews varies significantly in different portions of the country and times of year. The home range can vary from 0.07 acre to over 5.4 acres. The *Wildlife Exposure Handbook* (USEPA, 1993) states that the shrew's home range can vary from 0.07 acres to 0.17 acres during non-breeding winter months in highly productive habitats. In lower productivity habitats, the shrew's home range in non-breeding winter months can vary between 0.25 and 0.54 acres. The year-round, average home range for shrews was reported to be approximately 1 acre. The small site size, sandy soil type, and minimal vegetative under story at the 80th DRS site would be consistent with a higher estimated year-round home range. Evaluations of area use factors in this risk assessment will assume approximately 0.5 acres for the shrew's year-round home range. The AUF associated with incidental soil ingestion was 1.0 assuming that a shrew could locate its burrow within the impacted 0.2 acres.

The short-tailed shrew is an important prey species for many raptors and carnivorous mammals (USEPA, 1993). As a carnivorous species, it represents the small mammals using

the 80th DRS. Measurement endpoints for the shrew are derived from mammalian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake effects on individual organisms. Select assumptions are listed below.

- Body Weight= 0.017 kg
 - Food Consumption = 0.0024 kg/d (dry weight)
 - Diet consists of 100% invertebrates
 - Contaminant concentration in food is equal to Exposure Point Concentrations
- **Eastern Cottontail (*Sylvilagus floridanus*).** The eastern cottontail is the most widely distributed of the medium-sized rabbits. The eastern cottontail measures 35 to 43 cm in length and weighs 0.7 to 1.8 kg. During the growing season, cottontails eat herbaceous plants (e.g., grasses, clover, timothy, alfalfa). During the winter in areas where herbaceous plants are not available, they consume woody vines, shrubs, and trees (e.g., birch, maple, apple). Measurement endpoints for the eastern cottontail are derived from mammalian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake effects on individual organisms. The typical home range for this species has been identified at 3 to 20 acres. Select assumptions are listed below.
 - Body Weight= 1.8 kg
 - Food Consumption = 0.31 kg/d (dry weight)
 - Diet consists of 100% herbs
 - Contaminant concentration in food is equal to Exposure Point Concentrations
- **Grey Fox (*Urocyon cinereoargenteus*).** Grey foxes are present throughout the United States, except in the northwest and northern prairies. Grey foxes prey on small mammals but will also eat insects, fruits, acorns, birds, and eggs. The home range of this species varies between 141 and 8,447 acres. This species is similar in size and habits of the red fox (*Vulpes vulpes*) (USEPA, 1993). Measurement endpoints for the fox are derived from mammalian toxicity data taken from published dose-response studies that relate contaminant exposure or uptake to effects on individual organisms. Select assumptions are listed below.
 - Body Weight= 4.5 kg
 - Food Consumption = 0.31 kg/d (dry weight)
 - Diet consists of 85% mammals and birds; 15% vegetable matter
 - Contaminant concentration in food is equal to Exposure Point Concentrations

7.1.7 Risk Management Goal

Following USEPA guidance (USEPA 1998), the risk management goal for the 80th DRS SLERA is to protect the ecosystem surrounding the site by evaluating uptake of COPCs from soil into the food chain. The management goals will be addressed by evaluation of the assessment endpoints

presented in Section 7.1.5.

7.2 EXPOSURE ASSESSMENT

This section includes site-specific information pertinent to the assessment of potential ecological exposures to contaminants at the 80th DRS. General discussions of ecosystems of concern, pathways and COPC are provided in the following sections.

7.2.1 Exposure Point Concentrations (EPCs)

Exposure media of ecological concern at the 80th DRS in this SLERA is focused on surface soils. The maximum exposure case is considered for invertebrates because they are either immobile or have limited mobility. In this case, the maximum value best represents the exposure received by the most exposed individual and therefore is a conservative estimate of the exposure experienced by the population.

Wildlife may be exposed to contaminants through ingestion of food, soil, and water. In this assessment, exposure through food and soil was estimated using exposure models. Because no surface water is present on the 80th DRS, exposure to contaminated drinking water was not considered in the exposure modeling. Exposure estimates were calculated using soils and soil-biota uptake factors for plant and invertebrates, i.e., earthworms, based on the maximum surface soil concentrations identified in the Problem Formulation effort of this SLERA (i.e., plant uptake factors-PUFs and earthworm uptake factors-EUFs).

PUFs and EUFs were derived from published sources, when available. Using these uptake factors, tissue levels in potential food items of the applicable receptor organisms were calculated. Where uptake factors were not available, invertebrate tissue concentrations were assumed to be equal to the soil concentration. Concentrations in the prey species of the gray fox and the red-tailed hawk were assumed to be equal to the maximum concentrations in soils of the respective COPCs. Earthworm and plant uptake factors are provided in **Table 7-2**.

In instances where uptake values were not available, the conservative estimate of 100 percent uptake was used (i.e., concentration of the contaminant in the organism equaled concentration in the environment).

7.2.2 Exposure Scenarios and Pathways

The wildlife scenarios are summarized previously in the conceptual model and include ingestion of contaminated surface soil by all of the wildlife, ingestion of contaminants by uptake of soil by terrestrial invertebrates, followed by predation by terrestrial predators. Plant uptake from contaminated soils was also another exposure route with consumption by birds, omnivores, and herbivores.

The exposure parameters were derived or obtained from published sources. The ingestion rate of food, normalized to body weight of the respective receptors was estimated according to the following equation provided in the *Wildlife Exposure Factors Handbook* (USEPA, 1993):

$$\mathbf{NIR_f = NFMR \text{ (kcal/g-day)}/ME_{avg} \text{ (kcal/g wet wt)}}$$

Where: NIR_f = Ingestion rate of food, normalized to body weight
 $NFMR$ = Field metabolic rate, normalized to body weight
 ME_{avg} = Average metabolizable energy

$$\mathbf{ME_{avg} \text{ (kcal/g wet wt)} = (P_k \times ME_k \text{ (kcal/g wet wt)})}$$

Where: P_k = Proportion of diet of food type k
 ME_k = Metabolizable energy of food type k

$$\mathbf{ME_k = GE_k \text{ (kcal/g wet wt)} \times AE \text{ (in percent)}}$$

Where: GE_k = Gross Energy of food type k
 AE = Assimilation Efficiency

Where soil ingestion rates were unknown, ingestion rates for species with similar foraging habits were utilized. The USEPA (1993) gives estimates of soil in diet for various invertebrate-consuming species. It was assumed that the use of the high end of this range would be appropriate for the short-tailed shrew, American robin, red-tailed hawk, and gray fox. Therefore, a conservative soil ingestion rate of 10 percent was used in the exposure calculations for these organisms.

7.2.3 Exposure Estimates

Dietary exposure and exposure from ingestion of soil for each wildlife receptor species were calculated using the following equations derived from the *Wildlife Exposure Factors Handbook* (USEPA, 1993).

The following equations were used to estimate exposure to contaminants in soils via ingestion:

$$\mathbf{EE_{soil/sediment} = (C \times FS \times IR_{total(dry\ weight)} \times FR) / BW}$$

- Where: $EE_{\text{soil/sediment}}$ = Estimated exposure through ingestion (mg/kg BW-day)
- C = Contaminant concentration in media in the area of concern (mg/kg dry wt)
- FS = Fraction of media in diet (as percentage of diet on a dry-weight basis divided by 100; unitless)
- IR_{total} = Food ingestion rate on a dry-weight basis (kg/day)
- FR = Fraction of total food intake from the area of concern (unitless)
- BW = Body weight (kg)

The food ingestion rate on a dry-weight basis was estimated based on body weight:

Birds: IR_{total} (kg/day) = 0.0582 $BW^{0.651}$ (kg)

Mammals: IR_{total} (kg/day) = 0.0687 $BW^{0.822}$ (kg)

Values for NIR_f , IR , soil ingestion, and body weights are provided in **Table 7-3**. Estimates of exposure to contaminants via dietary sources were made for the receptors using the following equations:

- Where: $EE_{\text{diet}} = \sum_{k=1}^M (C_k \times FR_k \times NIR_k)$
- Where: EE_{diet} = Estimated exposure through diet (e.g., in mg/kg BW-day)
- C_k = Contaminant concentration in the kth type of food (e.g., in mg/kg wet weight)
- FR_k = Fraction of intake of the kth food type that is contaminated (unitless).
- NIR = Normalized ingestion rate of the kth food type on a wet weight basis (e.g., in g/g-day).
- M = Number of contaminated food types

No estimates were calculated to account for contaminated water uptake because this is usually incidental and no samples were collected to represent these values.

The estimated maximum exposure (expressed as daily dosage) through ingestion of soil and food for each of the avian receptors is given in **Table 7-4** and mammalian receptors is given in **Table 7-5**. Full exposure calculations are provided in **Appendix H**.

For the initial analysis, all selected receptor species were assumed to feed in the contaminated

areas year-round 100 percent of the time and ingest incidental amounts of contaminated soils. This is especially conservative since the site is very small at 0.2 acres and relatively unattractive to ecological receptors due to location, surrounding habitat, and large portion of the site being capped by concrete and asphalt. The robin is migratory and actually only spends 75 percent of the year in this region. Exposure from ingestion and diet was calculated for COPCs in each media and for each receptor. These exposure estimates were summed together to obtain the total exposure. An additional analysis was performed to look at actual potential area use by receptor species as described in USEPA guidelines (USEPA 1997). Area use factors (AUFs) were derived for each species by taking the ratio of the species-specific home ranges and the impacted portion of the 80th DRS site (0.2 acres). Home ranges for individual species were based on lower-end estimates presented in the Wildlife Factors Handbook (USEPA 1993). Home ranges and AUFs for receptor species at the 80th DRS are summarized in **Table 7-3**.

7.3 ECOLOGICAL EFFECTS ASSESSMENT

7.3.1 Ecological Effects Summaries

Toxicity profiles summarizing the potential adverse ecological effects of each COPC were derived from the literature, and are included as **Appendix I**. The profiles provide discussions of the acute and chronic toxicity of the COPCs to plants and animals. Effects on growth, reproduction, and survival of aquatic and terrestrial species are given, where available. Also included are significant fate and transport characteristics of the chemicals. These summaries, in addition to established criteria, were used to identify the critical effects of COPCs.

7.3.2 Toxicity Reference Values

TRVs were obtained from literature or derived receptor organisms as described below.

Terrestrial Plants - Phytotoxicity screening values included USEPA Region III BTAG Screening Criteria (USEPA, 1995) for flora and other published phytotoxicity values are provided in **Table 7-1**. These values were used as TRVs to assess potential risks to terrestrial plants.

Terrestrial Invertebrates – Invertebrate toxicity screening values included USEPA Region III BTAG Draft Screening Criteria (USEPA, 1995) for faunas and other published invertebrate toxicity values are provided in **Table 7-1**. These values were used as TRVs to assess potential risks to terrestrial invertebrates.

Terrestrial Wildlife - TRVs for mammals and birds chosen as receptor species were derived based on methodology presented by Opresko et al. (1994) and (Sample et al., 1996), respectively. This general method is based on USEPA methodology for deriving human toxicity values from animal data. In this method, experimentally derived No Observed Adverse Effect Levels (NOAELs) are used to estimate NOAELs for wildlife by adjusting the dose according to differences in body size. NOAELs for laboratory species, obtained from the literature, were converted to mammalian receptor

species NOAELs as follows:

$$\text{NOAEL}_r = \text{NOAEL}_t (bw_t / bw_r)^{1/4}$$

Bird TRVs are represented as follows:

$$\text{NOAEL}_r = \text{NOAEL}_t (bw_t/bw_r)^0 = \text{NOAEL}_t (1) = \text{NOAEL}_t$$

Where: NOAEL_r = receptor species NOAEL
 NOAEL_t = test species NOAEL
 bw_r = receptor body weight
 bw_t = test species body weight

The test species and receptor species TRVs (NOAELs) are provided for each of the COPC in **Table 7-6**. As shown, NOAELs were not available for all receptors. Quantitative risk characterization cannot be performed in these cases.

7.4 RISK CHARACTERIZATION

In this section, the ecological risks posed by contaminants identified in various media at the 80th DRS are identified and summarized. As presented in the previous section, TRVs for COPCs in terrestrial habitats on the 80th DRS were obtained from the literature or calculated, where necessary. In addition, exposure estimates were calculated based on the food chain model developed for the 80th DRS and shown in **Figure 7-1**.

In this section, the exposure estimates are divided by the TRVs for each of the receptor species to calculate a hazard quotient (HQ) for each COPC. An HQ equal to or greater than one indicates that the COPC may have the potential to pose a risk to the species investigated. An HQ less than one indicates that the COPC is unlikely to pose a risk to the species investigated under the assumptions presented. The complete calculations are contained in **Appendix H**. A summary of the conservative risk characterization is provided in Section 7.4.1, and the effects of site- and species-specific area use factors are presented in Section 7.4.2.

7.4.1 Characterization

As outlined above in Section 7.3.2, quantitative assessment was performed for each selected receptor organism and each COPC that had a TRV (i.e., NOAEL). The complete exposure calculations are contained in **Appendix H**. Summaries of the HQs for avian and mammalian species are summarized in **Table 7-7** and **Table 7-8**, respectively. Based on the standard exposure assessment assumptions, aluminum was the only COPC with a hazard quotient above 1 for both

avian species, while a total of nine COPCs had HQ values above 1 in mammalian species. Eight SVOC compounds including benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, chrysene, fluoranthene, phenanthrene, and pyrene, had HQs ranging from 2 to 7 in shrews, foxes, and rabbits. Aluminum had HQ values ranging from 1,000 in foxes to 3,000 in rabbits. As previously stated, these HQ values were derived using the extremely conservative assumption that 100 percent of each receptor's life would be spent on the 0.2-acre 80th DRS site, which is highly unlikely to occur.

7.4.2 Area Use Based Risk Characterization

Species-specific AUF values derivations were presented in Section 7.2. These AUFs were applied to exposure equations as presented in Section 7.2 in the form of fraction intake (FR) in each of the exposure equations. A summary of the COPC intakes for avian and mammalian receptors are presented in **Table 7-9** and **7-10**, respectively. The calculations supporting these tables are presented in **Appendix H**. Each of the COPCs derived in the more conservative approach presented in the previous section are highlighted in bold print in **Table 7-9** through **Table 7-12** to draw attention to the impacts on calculation of HQ values by applying AUFs.

Table 7-11 and **Table 7-12** provide revised HQ values for avian and mammalian species, respectively, following the application of species specific AUFs. No COPCs were identified for the red-tailed hawk, while aluminum remained a COPC for the American robin. For mammalian species, aluminum also remained as a COPC for the short-tailed shrew, the gray fox, and the eastern cottontail; however, only pyrene remained as a COPC among the SVOCs in the shrew with an HQ value of 3. The risk of exposure to aluminum and pyrene in site soil to ecological receptors will be discussed in more detail in Section 7.5 – Uncertainty Analysis.

7.5 UNCERTAINTY ANALYSIS

Uncertainty in the risk estimates may arise during any stage in the SLERA process. Assumptions made regarding potential effects of stressors, ecosystems or the species residing within those ecosystems, and exposure parameters. These uncertainties could potentially lead to overestimating or underestimating the potential risks to ecological receptors. Generally, care was taken to fully assess and incorporate field observations into the decision process during problem formulation to minimize these uncertainties. Major areas of uncertainty are presented below along with analysis as to whether potential risk is likely to be overestimated or underestimated.

7.5.1 Exposure Assessment Uncertainty

Uncertainties associated with the exposure assessment include the use of the maximum concentration for individual COPCs as the source concentration term, the aerial extent of site soil impacted by COPCs, and routes of exposure. The use of the maximum concentration will lead to an overestimation of potential risk.

Uncertainties in exposure pathways are also inherent in the ERA process. Exposure of receptor species to COPCs in soil is limited to the ingestion route of exposure through ingestion of food web vectors and incidental ingestion of soil. Inhalation and dermal exposure to COPCs in site sediment are not accounted for in the SLERA exposure model. The limited exposure routes for COPCs in soil could result in an underestimation of potential risk.

The aerial extents of COPCs in soil at the 80th DRS site were based information developed for the remedial investigation. The certainty of delineating lateral and vertical extents of impacts could lead to overestimation or underestimation of potential risk.

7.5.2 Area Use Factors

Aerial extents of soil impacted by COPCs only extend over approximately 0.2 acres of the site. COPCs are not equally co-distributed and exposure to individual COPCs are likely to be in very localized areas within the impacted area. The assumption that all receptors will be simultaneously exposed to the maximum concentration of all COPCs is likely to lead to an overestimation of potential risk.

AUFs were used to develop alternative HQs for chemical exposure at the site based on conservative estimates of home ranges for indicator species with the exception of the shrew. These home range assumptions could lead to an overestimation of potential risk.

The home range for the shrew was not based on the minimum range published. The minimum reported home range, varying from 0.07 to 0.17 acres, was for non-breeding winter months in highly productive habitats with high prey densities (USEPA 1993). These conditions do not exist at the 80th DRS site. Text presented in the *Wildlife Exposure Handbook* (USEPA 1993) indicated that shrew home ranges in habitats with low prey densities could range from approximately 2.5 to 5.4 acres. The year-round average home range for the shrew is approximately 1 acre. The AUF used to evaluate potential exposures of COPCs represents a lower-end estimate for areas likely to have low prey densities such as the 80th DRS site. An AUF value of 1 was used for incidental soil ingestion since a shrew could locate its borough within the 0.2-acre site. The AUF selection for the shrew at this site is based on conservative assumptions and would likely lead to an overestimation of potential risk.

7.5.3 COPC Concentrations in Biota

Concentrations of COPCs in soil invertebrates and plants are estimated based on published life history and exposure factors rather than directly measured data. The literature values for invertebrate and plant uptake values were used rather than field data. The COPC concentrations in field collected tissue samples are typically lower than those modeled by published uptake factors. Similar trends may be likely for invertebrates and plants at the 80th DRS site; however, there are no data to draw any conclusion. COPC concentrations on invertebrates, therefore, could be overestimated or underestimated.

COPC concentrations in prey were assumed to be equal to the maximum reported concentrations in site soil samples. Limited uptake models are available to estimate concentrations of COPCs in upper-trophic species based on soil concentrations. A bioaccumulation model prepared by the Oak Ridge National Laboratories (Sample *et al.*, 1998) looked at uptake by small animals of trace metals and two organic compounds. These studies indicated that maximum uptake factor for aluminum in small animals is 0.093. The same study looked at uptake of two bioaccumulative organic compounds (tetrachlorodibenzo-p-dioxin; TCDD and tetrachlorodibenzo-furan; TCDF). The maximum uptake factor in small animals for TCDD was 2.2, while the maximum uptake factor for TCDF was 0.16. The organic COPCs at the 80th DRS site are not bioaccumulative as are the dioxin compounds. The assumption, therefore, that prey concentrations are equal to the maximum reported soil concentrations will likely overestimate risk to predator populations.

7.5.4 Exposure to COPCs in Surface Water

The exposure assessment model has all terrestrial receptors receiving COPC dose only in food, which is the dominant pathway. The dose of COPCs associated with the potential COPC migration to surface water such as ponded storm water and subsequent ingestion of such surface water, therefore, could be underestimated.

7.5.5 Toxicity Reference Values (TRVs)

The TRVs used in this risk assessment are based on NOAEL endpoints. The application of NOAEL TRVs ensures that concentrations of COPCs associated with HQs below unity are protective of ecological receptors. The approach, however, does not account for the uncertainty of whether an adverse effect is likely to occur at HQ values above unity. A risk assessment that focuses on HQ associated with NOAEL TRVs would lead to overestimation of risk.

Risk assessments that focus on the NOAEL TRVs provide a sound estimate of exposure levels that are not going to respond in an adverse impact to ecological receptors; however, the threshold for adverse impacts are not represented by the NOAEL TRVs. Estimates of potential risk can also be generated using TRVs based on the lowest observable adverse effect level (LOAEL) to determine at what exposure levels adverse impacts might be expected. The threshold exposure, therefore, would exist between the NOAEL-based HQ and the LOAEL-based HQ. Generally, LOAEL-based TRVs are approximately 10x the NOAEL TRVs. As a result, NOAEL-based HQs that are below 10 do not represent a threshold exposure above which an adverse impact might be expected. The HQ for pyrene in the short-tailed shrew is 3. This NOAEL-based HQ, therefore, indicates that soil concentrations of pyrene at the 80th DRS site are not likely to result in adverse impacts to shrew populations at Ft. Story.

7.5.6 Uncertainty in Hazard Quotient Analysis

The hazard quotient method is the approach stipulated by the USEPA Region III risk assessment guidelines for evaluating risk posed to ecological receptors from COPCs in environmental media.

The hazard quotient method has inherent limitations that influence the interpretation of potential ecological risks from potential COPC exposures from environmental media (Tannenbaum *et al.*, 2003). Limitations of the hazard quotient method include:

- Hazard quotients for ecological risk assessments are not a direct measure of risk as presented in human health-based risk assessments.
- Hazard quotients are not a population-based measure as assumed in the ERA process.
- Hazard quotients are not linearly scaled, so extrapolation of results is limited.
- Extremely low concentrations of COPCs in the environment can trigger a hazard quotient value greater than unity.

7.5.7 Uncertainty Associated with Exposure to Aluminum

The only HQ values significantly above unity are for aluminum for several species. The concentrations of aluminum in soil samples range up to 8,500 mg/kg. These concentrations are consistent naturally occurring concentrations in many soils types. Aluminum is the most commonly occurring metallic element, comprising eight percent of the earth's crust (Press and Siever, 1974). Typical range for aluminum in soils is from 1 percent to 30 percent (10,000 mg/kg to 300,000 mg/kg), with naturally occurring concentrations varying over several orders of magnitude.

The USEPA recognized that due to the ubiquitous nature of aluminum, the variability of aluminum concentrations in naturally occurring soil, and the availability of conservative screening benchmarks, aluminum is often identified as a COPC for ecological risk assessments (USEPA, 2003). In soil, aluminum toxicity is directly related to the soluble fraction. The USEPA states that comparisons of total aluminum concentrations to soluble-based screening values are inappropriate. Insoluble aluminum oxides are consistently less toxic than soluble forms. Potential ecological risks, therefore, are based on pH. The USEPA states that aluminum should only be identified as a COPC at sites where soil pH is less than 5.5 (USEPA, 2003). As a result, the site-specific risk from aluminum in soil at the 80th DRS site are significantly overestimated. In keeping with USEPA guidelines for ecological risk assessments for aluminum, aluminum is not considered a COPC at the 80th DRS site.

7.6 SUMMARY OF RISKS

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.

7.6.1 Volatile Organic Compounds (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 80th DRS site.

7.6.2 Semi-volatile Compounds (SVOC)

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 determined 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 80th DRS and has not been retained as a COPC in this SLERA

7.6.3 Metals

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.

7.6.4 Conclusions

As stated in Section 7.1, the assessment endpoints at the 80th DRS site do not include vegetation 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-trophic mammalian 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.

7.7 REFERENCES

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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
- 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.

CONCLUSIONS AND RECOMMENDATIONS

- 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, 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:

CONCLUSIONS AND RECOMMENDATIONS

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 exposure to contaminated groundwater is associated with TCE; however, the 95th UCL utilized in the risk calculations was only 3 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.

CONCLUSIONS AND RECOMMENDATIONS

- The cancer risk established for the site workers (3.29×10^{-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.

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 80th 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 determined 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 80th DRS and has not been retained as a COPC in this SLERA

Metals

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 vegetation 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-trophic mammalian 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.

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 or remedial action is warranted. The reasons for the no further action recommendations 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.

A Decision Document will be prepared that presents the findings of this remedial investigation and any long term restrictions, if any, required for the site.