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DRAFT HUMAN HEALTH RISK ASSESSMENT REPORT REMEDIAL INVESTIGATION FIREFIGHTER TRAINING AREA, LIGHTER AMPHIBIOUS RESUPPLY CARGO (LARC) 60 MAINTENANCE AREA, AND AUTO CRAFT AREA FORT STORY VA

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MALCOLM PIRNIE

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DRAFT REPORT
REMEDIAL INVESTIGATION

HUMAN HEALTH RISK ASSESSMENT

FIREFIGHTER TRAINING AREA
LARC 60 MAINTENANCE AREA
AUTO CRAFT BUILDING AREA

FORT STORY, VIRGINIA

PREPARED FOR:

U.S. ARMY CORPS OF ENGINEERS
BALTIMORE DISTRICT
BALTIMORE, MARYLAND

AND

U.S. ARMY TRANSPORTATION CENTER
FORT EUSTIS, VIRGINIA

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REVIEW COMMENTS

DOCUMENT:	*Draft Remedial Investigation, Human Health Risk Assessment, Fort Story, Virginia*		
PREPARED BY:	Malcolm Pirnie	DATE OF DOCUMENT:	September 1996
PROJECT:	Fire Training Area LARC 60 Maintenance Area Auto Craft Shop	1383 NUMBER:	STOS930001 STOS930004 STOS930006
REVIEWED BY:	Dan Musel, Fort Eustis	DATE OF REVIEW:	10 January 1997

NO.	SECTION	PAGE	PARA.	COMMENTS
1	6.2.5	6-25	1st arrow	<u>FTA Site HHRA Summary and Conclusions:</u> Recommend restating the bullet to say "A summary of the Non-Carcinogenic Risk for future residential land use is provided below:" This will further clarify it as future land use not current industrial use.
2	6.2.5	6-26	1st arrow	<u>FTA Site HHRA Summary and Conclusions:</u> Recommend restating the bullet to say "A summary of the Carcinogenic Risk for future residential land use is provided below:" This will further clarify it as future land use not current industrial use.
3	6.2.5	6-26	1st bullet	<u>FTA Site HHRA Summary and Conclusions, Carcinogenic Risk:</u> In the last sentence of the 1st bullet, recommend removing the words "the only adult exposure scenario".
4	6.2.5	6-26	2nd bullet	<u>FTA Site HHRA Summary and Conclusions, Carcinogenic Risk:</u> In the last sentence of the 2nd bullet, recommend rewriting the sentence to say "These child exposure scenarios are within the USEPA remediation goals."
5	6.2.5	6-26	2nd arrow	<u>FTA Site HHRA Summary and Conclusions:</u> Remove the words "above acceptable criteria." This makes it sounds like the risks for future residential development is acceptable.
6	6.2.5	6-26	last arrow	<u>FTA Site HHRA Summary and Conclusions:</u> Add the following sentence or other verbiage to further clarify the current risks. "However, under current land use, there are no risks from the metals in the groundwater."
7	6.3.2	6-35	3	<u>Future Land Use:</u> Rearrange the 1st sentence to read as follows: "Although …water, it is not expected the water would be consumed even if this drainage area was present after future residential development." This would make it read more clearly.
8	6.3.5	6-50	1st arrow	<u>LARC 60 Site HHRA Summary and Conclusions, Non-Carcinogenic Risk:</u> Recommend restating the bullet to say "A summary of the Non-Carcinogenic Risk for future residential land use is provided below:" This will further clarify it as future land use not current industrial use.
9	6.3.5	6-50	2nd arrow	<u>LARC 60 Site HHRA Summary and Conclusions, Carcinogenic Risk:</u> Recommend restating the bullet to say "A summary of the Carcinogenic Risk for future residential land use is provided below:" This will further clarify it as future land use not current industrial use.

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REVIEW COMMENTS

NO.	SECTION	PAGE	PARA.	COMMENTS
10	6.3.5	6-51	1st arrow	LARC 60 Site HHRA Summary and Conclusions: Remove the words "above acceptable criteria." This makes it sounds like the risks for future residential development is acceptable.
11	6.3.5	6-51	last arrow	LARC 60 Site HHRA Summary and Conclusions: Add the following sentence or other verbiage to further clarify the current risks. "However, under current land use, there are no risks from the metals in the groundwater."
12	6.4.5	6-72	1st arrow	Auto Craft Site HHRA Summary and Conclusions, Non-Carcinogenic Risk: Recommend restating the bullet to say "A summary of the Non-Carcinogenic Risk for future residential land use is provided below:" This will further clarify it as future land use not current industrial use.
13	6.4.5	6-73	1st arrow	Auto Craft Site HHRA Summary and Conclusions, Carcinogenic Risk: Recommend restating the bullet to say "A summary of the Carcinogenic Risk for future residential land use is provided below:" This will further clarify it as future land use not current industrial use.
14	6.4.5	6-73	1st bullet	Auto Craft Site HHRA Summary and Conclusions, Carcinogenic Risk: In the last sentence of the 1st bullet, recommend removing the words "the only exposure scenario."

6.1 INTRODUCTION

This risk assessment presents an assessment of potential human health risk associated with contaminants detected at the three RI sites at Fort Story, Virginia. The objectives of the human health risk assessment (HHRA) are to (1) provide an analysis of baseline risks, 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 and extent of 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 contaminants detected at or migrating from each of the three RI sites. The baseline risk assessment will follow 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
- *Risk-Based Concentration Table*, EPA Region III, January - June 1995, 1995a
- *Exposure Factors Handbook*, EPA, 1989c
- *Guidance for Data Useability in Risk Assessment, Part 2*, EPA, 1992a
- *Dermal Exposure Assessment: Principles and Applications*, Interim Report, EPA, 1992b

Objectives

The goal of the HHRA is to provide a framework for developing the risk information necessary to assist decision-making at the three RI sites. A site-by-site risk assessment will be conducted that includes the components of hazard identification, exposure assessment, toxicity assessment and risk characterization.

Preliminary screening may reduce the level of effort for this human health evaluation at some of the sites. Specific objectives of the process are to:

- Provide an analysis of baseline risks (human health) and help determine the need for remedial action at the three sites.
- Provide a basis for determining levels of chemicals that can remain at each of the sites 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 sites.
- Provide a consistent process for evaluating and documenting public health threats at the sites.

HHRA Components

The HHRA process is site-specific. Therefore it may vary in both detail and the extent to which qualitative and quantitative analyses are used, depending on the complexity and particular circumstances of the site, as well as the availability of ARARs and other criteria, advisories and guidance. There are four components to the HHRA: (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 each 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 contaminant 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.

6.2 FIREFIGHTER TRAINING AREA

6.2.1 Hazard Identification

Numerous groundwater, surface soil and sediment samples were collected from the Firefighter Training Area (FTA) and analyzed for various chemical contaminants. Figures 2-5 and 2-6 provide the sample locations. While the entire data set is presented in the *QCSR/ARR*, the data are summarized in Tables 6-1 through 6-6 to facilitate the hazard identification. Presented in the tables are the frequency of detection and the range of detected concentrations for each chemical, selected Applicable and Relevant and Appropriate Requirements (ARARs) [i.e., USEPA drinking water Maximum Contaminant Levels (MCLs)], "to be considered" (TBC) criteria and the USEPA weight-of-evidence classification for known or suspected human carcinogens.

The detection frequency, concentration range, ARARs and TBC criteria, and weight-of-evidence classification, along with information on the physical and chemical properties of the chemicals, the number of environmental media impacted and appraisal of the likelihood of human contact with the chemicals in each medium, are used to select COPCs for evaluation in the exposure assessment and risk characterization. Recognizing that the list of chemicals detected at the site is quite lengthy, the COPCs represent a manageable subset of chemicals at the site that are used to characterize exposure and risk. For the purposes of this assessment, a detection frequency of 5 percent will be used as a screening tool.

The EPA Region III RBC 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 (surface water, groundwater, soil and sediment), the RBCs have been adjusted.

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

Surface Soils

Surface soil sampling was conducted to evaluate the nature and extent of contamination in the surface soils at the site. Surface soil samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for soil cleanup, EPA Region III Risk-based Concentration (RBC) Criteria, EPA Region III Soil Screening Levels (SSL) - Transfers from Soil to Air, and Virginia Petroleum Program Criteria are included in Table 6-1 as TBC criteria for purposes of comparison. A total of 28 surface soil samples were collected during the field investigation.

<u>VOCs and SOCs</u>

All concentrations of VOCs and SOCs were less than EPA RBC criteria and SSLs, and therefore, are not selected as COPCs.

TABLE 6-1
HAZARD ASSESSMENT FOR SURFACE SOILS – FTA SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria				EPA Carcinogen Class(4)	Potential Concern?
			Virginia Petroleum Program(1)	EPA SSLs Transfers to Air(2)	EPA RBC Criteria Industrial Soils(3)	EPA RBC Criteria Residential Soils(3)		
VOCs (ug/kg)								
Acetone	3/28	134 – 290	–	62,000,000	20,000,000	780,000	D	
Methylene Chloride	2/28	5.0 – 6.4	–	7,000	760,000	85,000	B2	
Methyl ethyl ketone	1/28	28	–	–	100,000,000	4,700,000	D	
Styrene	1/28	3	–	1,400,000	41,000,000	1,600,000	D	
Toluene	24/28	8.3 – 140	–	520,000	41,000,000	1,600,000	D	
Xylenes	1/28	7	–	320,000	100,000,000	16,000,000	D	
SOCs (ug/kg)								
Benzo(b)fluoranthene	1/28	97	–	23,000	7,800	880	B2	
Benzo(k)fluoranthene	1/28	86	–	–	78,000	8,800	B2	
Bis(2-EH)phthalate	1/28	110	–	210,000	410,000	46,000	B2	
Chrysene	1/28	94	–	3,600	780,000	88,000	B2	
Di-n-butylphthalate	1/28	150	–	100,000	20,000,000	780,000	D	
Fluoranthene	1/28	650	–	68,000	8,200,000	310,000	D	
Pyrene	1/28	720	–	56,000	6,100,000	230,000	D	
TPH (mg/kg)								
Total TPH	3/28	48 – 5,300	100	–	–	–	–	
Total Metals (mg/kg)								
Aluminum	5/5	420 – 980	–	–	100,000	7,800	–	
Arsenic	4/5	1.2 – 1.6	–	380	61	2.3	–	
Arsenic (as carcinogen)	4/5	1.2 – 1.6	–	380	3.8	0.43	A	Yes
Barium	5/5	3.9 – 12	–	350,000	14,000	550	–	
Calcium	4/5	71 – 370	–	–	–	–	–	
Chromium	5/5	1.7 – 5.8	–	–	100,000	7,800	–	
Copper	5/5	3.2 – 13	–	–	7,600	290	D	
Iron	5/5	1,200 – 5,400	–	–	–	–	–	
Lead	5/5	7 – 33	–	–	400	–	B2	
Magnesium	5/5	62 – 190	–	–	–	–	–	
Manganese	5/5	10 – 34	–	–	1,000	39	D	
Mercury	2/5	0.011 – 0.013	–	–	61	2.3	D	
Potassium	1/5	160	–	–	–	–	–	
Vanadium	5/5	1.8 – 3.7	–	–	1,400	555	D	
Zinc	5/5	14 – 22	–	–	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III Soil Screening Levels for Transfers from Soil to Air/Groundwater (Jun – Dec 1995)
(3) EPA Region III RBC Criteria for Industrial/Residential Soils (Jun – Dec 1995)

(4) Weight of Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in only 1 of 28 surface soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, benzene, toluene, ethylbenzene and xylenes (BTEX) and polynuclear aromatic hydrocarbons (PAHs), which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA criteria.

Inorganics

Arsenic exceeded the carcinogenic RBC value for residential soils but did not exceed the industrial soils criteria. Arsenic concentrations in surface soils ranged from 1.2 to 1.6 mg/kg with a mean concentration of 1.3 mg/kg. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic levels detected in the surface soils are consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in Appendix H.

Although consistent with background levels, for the purposes of risk analysis, arsenic is selected as a COPC based on its exceedance of the residential soils criteria for carcinogens.

No other inorganics exceeded EPA RBC values.

Groundwater

Groundwater quality data are summarized in Table 6-2 along with EPA Maximum Contaminant Levels (MCLs) and Action Levels, Virginia Groundwater Standards, Criteria and Protection Levels, and EPA RBC criteria. Only the dissolved inorganic data is presented in Table 6-2. Total inorganic data are influenced by percentage of solids in the monitoring well or DPT sampling point and would not be indicative of groundwater quality if a drinking water well was installed at or near the site. The sediment typically is not available for transport with flowing groundwater and would also be filtered out before use if drinking water wells were installed in this area.

TABLE 6–2
HAZARD ASSESSMENT FOR GROUNDWATER
FIREFIGHTER TRAINING AREA

Parameters	Frequency of Detection	Range of Detection	ARARs: EPA MCLs(1)	ARARs: EPA Secondary MCLs(2)	ARARs: Virginia GW Stds(3)	ARARs: Va GW Protection Levels(4)	TBC Criteria: Virginia GW Criteria(5)	TBC Criteria: EPA RBC Criteria(6) Tap Water	EPA Carcinogen Class(7)	Potential Concern?
VOCs (ug/l)										
Acetone	2/27	27 – 28	–	–	–	–	–	370	D	
Benzene	1/34	10	5	–	–	5	–	0.36	A	
Carbon disulfide	3/27	5.0 – 8.3	–	–	–	1,000	–	100	–	
1,1–Dichloroethane	1/27	20	–	–	–	–	–	81	C	
Ethylbenzene	1/27	47	700	–	–	–	–	130	D	
Tetrachloroethene	2/34	6.4 – 78	5	–	–	7	–	1.1	B2	Yes
Toluene	1/27	20	1,000	–	–	1,000	–	75	D	
1,1,1–Trichloroethane	2/27	9.4 – 31	200	–	–	200	–	130	D	
Xylenes	3/27	25 – 200	10,000	–	–	–	–	1,200	D	
SOCs (ug/l)										
Bis(2–EH)phthalate	1/26	1	–	–	–	–	–	4.8	B2	
Fluorene	1/26	15	–	–	–	–	–	150	D	
2–Methylnaphthalene	1/26	120	–	–	–	–	–	–	–	
Naphthalene	2/26	11 – 60	–	–	–	–	–	150	D	
Phenanthrene	1/26	18	–	–	–	–	–	–	D	
TPH (mg/l)										
Total TPH	3/34	1.4 – 9.2	–	–	1	1	–	–	–	
Dissolved Metals (mg/l)										
Aluminum	2/3	0.12 – 0.25	–	0.05 – 0.2	–	–	–	3.7	–	
Barium	3/3	0.021 – 0.14	1	–	1	1	–	0.26	–	
Calcium	3/3	12 – 18	–	–	–	–	–	–	–	
Copper	1/3	0.025	1.3	–	1	1	–	0.14	D	
Iron	2/3	0.28 – 3.6	–	0.30	–	–	0.30	–	–	
Magnesium	3/3	1.7 – 5.8	–	–	–	–	–	–	–	
Manganese	2/3	0.011 – 0.081	–	0.05	–	–	0.05	0.018	D	Yes
Potassium	3/3	1.7 – 2.9	–	–	–	–	–	–	–	
Sodium	3/3	4.7 – 8.4	–	–	270	270	100	–	–	
Zinc	3/3	0.021 – 0.12	–	5	0.05	0.05	–	1.1	D	

Notes:
(1) U.S. EPA Maximum Contaminant Levels for Drinking Water (40 CFR 141)
(2) U.S. EPA Secondary Maximum Contaminant Levels for Drinking Water (40 CFR 143)
(3) Virginia Groundwater Quality Standards (VR680–21–04)
(4) Virginia Groundwater Protection Levels from Solid Waste Regulations (VR672–20–10)
(5) Virginia Water Quality Criteria for Groundwater (VR680–21–05)
(6) EPA Region III Risk–based Concentration Table for Tap Water (Jun – Dec 1995)
(7) Weight–of–Evidence Classifications
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B1 = Probable human carcinogen, sufficient data in animals
C = Possible human carcinogen
D = Not classified as to carcinogenicity

Thirty-four (34) groundwater samples (24 DPT and 10 monitoring well samples) were collected from the upper aquifer during the field investigation. The number of results for each chemical may vary due to the analysis of different compounds at different locations.

VOCs

Although numerous VOCs were detected during groundwater sampling, only tetrachloroethene (PCE) (6.4 and 78 ug/l) and benzene (10 ug/l) were detected in excess of the screening criteria. However, benzene was only detected in 1 of 34 samples (3 percent detection frequency), and therefore due to infrequent detection, it is not selected as a COPC. Although PCE was detected in only 2 of 34 samples, it is selected as a COPC.

SOCs

SOCs were not detected in any of the groundwater samples in excess of screening criteria, and therefore, are not selected as COPC.

TPH

Although TPH exceeded the Virginia Groundwater Standard of 1 mg/l in 3 of 34 groundwater samples, low concentrations of BTEX and PAHs were present and below their respective risk screening criteria.

Inorganics

Several dissolved inorganics (aluminum, iron, and zinc) were detected at concentrations greater than EPA Secondary MCLs and Virginia Groundwater Criteria. However, these standards were established for aesthetic qualities only for drinking water supplies. Because the concentrations of these dissolved inorganics were significantly lower than the EPA RBC criteria for human health risks, they are not selected as COPC. However, dissolved manganese exceeded the EPA RBC for tap water in one sample, and therefore, is selected as a COPC.

Sediment

Sediment sampling was conducted to evaluate the nature and extent of contamination in the sediment in the drainage area south of the site. Sediment samples were collected from depths of

0 to 12 inches. Because there are no federal or state standards for sediment cleanup, EPA Region III RBC Criteria and Virginia Petroleum Program Criteria are included in Table 6-3 as TBC criteria for purposes of comparison. A total of four sediment samples were collected during the field investigation.

VOCs and SOCs

All concentrations of VOCs and SOCs were less than EPA RBC criteria, and therefore, are not selected as COPC.

TPH

TPH exceeded the 100 mg/kg TBC criterion in three of four sediment samples. Because TPH is typically used as an indicator of contamination, it will not be used during this quantitative risk assessment. BTEX and PAH concentrations, as previously discussed, were lower than risk screening criteria.

Inorganics

Arsenic exceeded the non-carcinogenic and carcinogenic RBC values for residential soils but did not exceed the industrial soils criteria while, although only detected in one sample, thallium exceeded the RBC value for thallium compounds (e.g., thallium sulfate) for residential soils.

Arsenic was only detected in one sediment sample at a concentration of 2.5 mg/kg with a mean concentration of 1.1 mg/kg for all sediment values. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic levels detected in the sediment are consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in Appendix H. Sediment values for inorganics were compared against soils data because the samples were collected from lowlying area near the site and not from a stream. The sediment in that area of the site are more consistent with soils rather than typical sediments.

Although consistent with background levels, for the purposes of risk analysis, arsenic is selected as a COPC based on its exceedance of the residential soils criteria for carcinogens. Thallium is also selected as a COPC.

TABLE 6–3
HAZARD ASSESSMENT FOR SEDIMENT
FIREFIGHTER TRAINING AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: Virginia Petroleum Program(1)	TBC Criteria: EPA Region III Soil Screening Levels – Transfers to Air(2)	TBC Criteria: EPA Region III RBC Criteria – Industrial Soils(3)	TBC Criteria: EPA Region III RBC Criteria – Residential Soils(3)	EPA Carcinogen Class(4)	Potential Concern?
VOCs (ug/kg)								
Toluene	4/4	23 – 180	–	520,000	41,000,000	1,600,000	D	
SOCs (ug/kg)		BDL						
TPH (mg/kg)								
Total TPH	3/4	130 – 350	100	–	–	–	–	
Total Metals (mg/kg)								
Aluminum	4/4	160 – 7600	–	–	100,000	7,800	–	
Arsenic	1/4	2.5	–	380	61	2.3	–	Yes
Arsenic (as carcinogen)	1/4	2.5	–	380	3.8	0.43	A	Yes
Barium	4/4	2.4 – 110	–	350,000	14,000	550	–	
Calcium	4/4	64 – 120	–	–	–	–	–	
Chromium	1/4	21	–	–	100,000	7,800	–	
Cobalt	1/4	2.6	–	–	12,000	470	–	
Copper	1/4	26	–	–	7,600	290	D	
Iron	4/4	230 – 17,000	–	–	–	–	–	
Lead	4/4	4.3 – 210	–	–	400	–	B2	
Magnesium	1/4	960	–	–	–	–	–	
Manganese	3/4	1.7 – 42	–	–	1,000	39	D	
Mercury	2/4	0.017 – 0.051	–	7	61	2.3	D	
Nickel	1/4	9.4	–	6.900	41,000	1,600	–	
Potassium	1/4	260	–	–	–	–	–	
Sodium	2/4	87 – 180	–	–	–	–	–	
Thallium	1/4	1.4	–	–	16	0.63	–	Yes
Vanadium	2/4	2 – 18	–	–	1,400	55	D	
Zinc	2/4	6 – 76	–	–	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III Soil Screening Levels for Transfers to Air (Jan 1995)
(3) EPA Region III RBC Criteria for Industrial/Residential Soils (Jun – Dec 1995)

(4) Weight–of–Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

Subsurface Soils and Soil Leachability

To evaluate the potential exposures to subsurface soils (i.e., future excavation activities) and for the potential leaching of contaminants form soil to groundwater, as shown in Table 6-4, soil analytical data was compared against EPA Region III SSLs for Transfers from Soil to Groundwater and EPA RBC for industrial soils.

Soil sampling was conducted to evaluate the nature and extent of contamination in the surface and subsurface soils at the site. Soil samples were collected from varying depths. Because there are no federal or state standards for soil cleanup, EPA Region III RBC criteria and SSLs are included in Table 6-4 as TBC criteria for purposes of comparison. A total of 72 soil samples were collected during the field investigation.

<u>VOCs</u>

All concentrations of VOCs were less than EPA RBC criteria for industrial soils while acetone was the only VOC higher than the EPA SSLs. Acetone exceeded the SSL of 8,000 ug/kg in only 1 of 72 samples, and therefore, VOC contamination in site soils should not further degrade groundwater quality through potential leaching.

As discussed in Section 2.2.9, the high levels of acetone detected in several soil samples were the result of using isopropyl alcohol as a decontamination solution and not associated with site conditions. Acetone is a primary oxidation product of isopropyl alcohol.

<u>SOCs and Inorganics</u>

All concentrations SOCs and inorganics were less than EPA RBC criteria for industrial soils and the EPA SSLs, and therefore, are not selected as COPCs and should not further degrade groundwater quality through potential leaching.

<u>TPH</u>

TPH concentrations exceeded the 100 mg/kg TBC criterion in 7 of 72 soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, benzene, toluene, ethyl benzene and xylenes (BTEX) and polynuclear aromatic hydrocarbons

TABLE 6-4
HAZARD ASSESSMENT FOR SUBSURFACE SOILS & SOIL LEACHABILITY – FTA SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA SSLs Transfers to Groundwater(1)	TBC Criteria: EPA RBC Industrial Soils(2)	EPA Carcinogen Class(3)	Potential Concern?
VOCs (ug/kg)						
Acetone	34/72	27 – 18,000	8,000	20,000,000	D	
Methylene Chloride	4/72	3.1 – 6.4	10	760,000	B2	
Methyl ethyl ketone	9/72	28 – 110	–	100,000,000	D	
Styrene	2/72	2 – 3	2,000	41,000,000	D	
Toluene	59/72	6.4 – 140	5,000	41,000,000	D	
Xylenes	1/72	7	74,000	100,000,000	D	
SOCs (ug/kg)						
Benzo(b)fluoranthene	3/72	97	4,000	7,800	B2	
Benzo(k)fluoranthene	3/72	86	4,000	78,000	B2	
Bis(2-EH)phthalate	3/72	110	11,000	410,000	B2	
Chrysene	3/72	94	1,000	780,000	B2	
Di-n-butylphthalate	2/72	150 – 1,300	120,000	20,000,000	D	
Fluoranthene	3/72	600 – 1100	980,000	8,200,000	D	
Naphthalene	1/72	45	30,000	8,200,000	D	
Pyrene	3/72	440 – 720	1,400,000	6,100,000	D	
TPH (mg/kg)						
Total TPH	7/72	48 – 5,300	–		–	
Total Metals (mg/kg)						
Aluminum	14/14	250 – 980	–	100,000	–	
Arsenic	9/14	0.98 – 1.6	15	61	A	
Arsenic (as carcinogen)	9/14	0.98 – 1.6	15	3.8	A	
Barium	14/14	2.2 – 12	32	14,000	–	
Calcium	9/14	37 – 370	–	–	–	
Chromium	14/14	1.6 – 6.7	–	100,000	–	
Cobalt	1/14	0.44	–	12,000	–	
Copper	6/14	0.63 – 13	–	8,200	D	
Iron	14/14	740 – 5,400	–	–	–	
Lead	14/14	1.8 – 33	–	400	B2	
Magnesium	9/14	44 – 190	–	–	–	
Manganese	14/14	5.7 – 34	–	1,000	D	
Mercury	3/14	0.011 – 0.20	–	61	D	
Nickel	1/14	0.57	21	4,100	–	
Potassium	3/14	27 – 160	–	–	–	
Sodium	1/14	9.9	–	–	–	
Vanadium	14/14	1.1 – 3.7	–	1,400	D	
Zinc	14/14	2.3 – 22	42,000	61,000	D	

Notes:
(1) EPA Region III Soil Screening Levels for Transfers from Soil to Groundwater (Jun – Dec 1995)
(2) EPA Region III RBC for industrial soils (Jun – Dec 1995)
(3) Weight of Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

(PAHs), which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA criteria.

Chemicals of Potential Concern

Arsenic in surface soil and sediment, thallium in sediment and dissolved manganese and PCE in groundwater are the COPCs identified during the hazard identification of the FTA media. Potential risk associated with each COPC will be further evaluated in the exposure assessment section.

6.2.2 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to the surface soils, sediment and groundwater COPCs that are present at or migrating from the FTA.

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 site is currently used as a training area for heavy equipment operations and for unloading and loading of heavy equipment on the loading rack in the southeast corner of the site. Fort Story personnel are present at the site for approximately two days per week. However, because the only surface soils COPC identified was arsenic due to exceedance of the residential soils criteria and not the industrial soils criteria, no adverse exposures for Fort Story personnel are anticipated. Although the site is not in a restricted area and not fenced, potential exposures to the general public and/or trespassers would not be significant because their presence on the site would not be expected to be for only a short time and not routine. During the four weeks that the investigations were conducted at the site, a few public and/or off-duty personnel were observed at the site walking their dogs or jogging. However, their time spent on-site was limited to less than 30 minutes during their visit. Therefore, there are **no exposed populations to the surface soils at the FTA site under the current situation**.

Groundwater is not used in the vicinity of the site for drinking, process, or production purposes. The chief potable water supply in the region is the surface water reservoir system operated by the City of Norfolk. The system includes in-town lakes located near the Norfolk International Airport and other reservoirs (Lake Prince, Western Branch and Burnt Mills) located in Suffolk, Virginia. The in-town lakes are located over 5 miles from Fort Story while the Suffolk lakes are located over 20 miles from the facility. As previously stated in Section 3.1.5, several housing communities located within 1 mile of Fort Story are developing drinking water wells in the shallow aquifer, however, none of these communities are located downgradient of the site. Groundwater use at Fort Story is restricted to withdrawal from a single well located approximately 4,000 feet (cross groundwater flow gradient) from the site at the LARC 60 Maintenance Area; the water is obtained for nonpotable uses only. As discussed in Section 5.0, migration potential is minimal due to the very low vertical gradient present across the FTA site. There has been little or no migration of contaminants in the groundwater over the past 5 years based on a comparison of data from Montgomery-Watson's study in 1990 and data from Malcolm Pirnie's study in 1995. VOC concentrations have decreased substantially due to numerous subsurface mechanisms such as biodegradation, volatilization, and dispersion. Therefore, there are **no exposed populations to the groundwater at the FTA site under the current situation.**

In addition to the discussion for surface soils provided above, there are no expected exposures to the sediment located in the lowlying wooded area south of the site. Therefore, there are **no exposed populations to the sediment in the wooded area south of the FTA site under the current situation.**

__Future Land Use__

Although construction or excavation activities could be conducted in the future, neither surface nor subsurface soil contaminant concentrations exceeded industrial screening criteria. Therefore, no significant exposures during these activities would be expected because these activities are typically very short term and contaminant concentrations were below screening criteria.

Based on master planning issues for Fort Story, the facility is expected to remain government property. However, due to periodic base closure reviews by the federal government, there is the potential for Fort Story to be closed with subsequent development of the land as commercial or residential properties. Therefore, **as for future conditions, potentially exposed populations include residential exposures to the contaminated media at the FTA site**.

Exposure Pathways

The potential exposure pathways for future land use at the FTA site include:

- Residential exposure (adults and children) to **contaminated groundwater** through ingestion of drinking water, dermal contact with and inhalation of volatilized chemicals while bathing or showering.
- Residential exposure (adults and children) to **contaminated soil** through ingestion of chemicals.
- Residential exposure (adults and children) to **contaminated sediment** through ingestion of chemicals.

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 practical quantitation limit (PQL). The PQLs are chemical-specific values that laboratories should be able to routinely and reliably detect and quantitate, but which may vary depending on the medium analyzed and the amount expected to be present in the sample. Adjusting non-detects by assigning values at 1/2 the PQL assumes that a chemical may be present at a concentration just below the reported quantitation limit. One-half the PQL is used as a conservative "proxy" concentration consistent with USEPA guidance. This approach would tend to overestimate the risk.

In this evaluation, data which were qualified by indicating that the numerical value is an estimated quantity are treated in this evaluation the same as data without this qualifier.

Estimates of Contaminant 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 contaminant concentrations in the specific media of concern. Table 6-5 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.

The USEPA recommends that estimates of contaminant 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 contaminant 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. Alternatively, the lognormal distribution is a commonly used probability density model for environmental contamination data. The USEPA (USEPA 1989a) recommends that the upper confidence limit [i.e., the 95th percent upper confidence limit (UCL)] on the mean of all the data should be used for evaluating RMEs. Following this guidance, the equation used in this analysis (Gilbert, 1987) is:

$$UCL = e^{(x + 0.5s*s + Sh/\sqrt{(n-1)})}$$

where:

UCL = 95th percent upper confidence limit on the mean
e = constant (natural log)
x = the mean of the log transformed data
s = the standard deviation of the log transformed data
H = statistic for computing a one-sided upper 95% confidence limit on a lognormal mean
n = sample size

TABLE 6-5
GENERIC EQUATION FOR CALCULATING CHEMICAL INTAKES

I = [(C x CR X EFD)/BW] x 1/AT
Where: I = intake; the amount of chemical at the exchange boundary (mg/kg body weight-day) C = chemical concentration; the "average" concentration contacted over the exposure period (e.g., mg/liters water) CR = contact rate; the amount of contaminated medium contacted per unit time or event (e.g., liters/day) EFD = exposure frequency and duration; describes how long and how often exposure occurs; often calculated using two terms (EF and ED) EF = exposure frequency (day/year) ED = exposure durations (years) BW = body weight; the average body weight over the exposure period (kg) AT = averaging time; time period over which exposure is averaged (days)

As described previously, for all samples in which the COPC is not detected, a value of 1/2 the PQL for that chemical was assigned. Depending upon the number of non-detects and variability in measured concentrations, the UCL on the mean concentration may occasionally exceed the maximum detected value. Since exposure to chemicals having concentrations greater that 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 5 or greater.

Therefore, for the groundwater COPC of manganese, the maximum concentration will be used because only 3 dissolved groundwater samples were collected.

Because exposures to the soil and sediment (actually soils from a lowlying area adjacent to the site) would be similar, these data sets will be combined for the risk analysis.

The 95th percentile UCL concentrations were computed for arsenic and thallium in surface soils and sediment and PCE in groundwater to estimate the mean concentration. UCL calculations are provided in Appendix I. The results of the UCL calculations with comparison to the maximum concentration detected are provided in Table 6-6.

While the approach used in this evaluation assumes no transformation or loss due to environmental degradation from the current time to the future time when residential development may occur at the site, the environmental fate and transport of chemicals are important in determining the ultimate hazard to people. After a chemical is released to the environment, it may be transformed physically (e.g., by volatilization, precipitation, etc.), chemically (e.g., by photolysis, hydrolysis, oxidation, reduction, etc.), or biologically (e.g., by biodegradation); alternatively, it may be accumulated in one or more media (including biomass) or may be transported (e.g., convected downstream in water or on suspended sediment or through the atmosphere). In Appendix J, the environmental fate and transport mechanisms, as well as a brief toxicological profile, of each of the COPC (only those chemicals where a potential exposure pathway is present) for the HHRA are briefly discussed.

TABLE 6-6
COMPARISON OF EXPOSURE CONCENTRATIONS
FIREFIGHTER TRAINING AREA

POPULATIONS AND PATHWAYS	MAXIMUM CONCENTRATION	95th PERCENTILE UCL
ON-SITE RESIDENTIAL POPULATION - FUTURE LAND USE		
Surface Soils and Sediment		
Ingestion of Chemicals	mg/kg	mg/kg
Arsenic	2.5	**1.83**
Thallium	1.4	**0.80**
Groundwater		
Ingestion of and Dermal Contact with Chemicals	ug/l	ug/l
Manganese	**81**	NA
PCE	78	**4.41**
Inhalation of Chemicals Volatilized	mg/m^3	mg/m^3
PCE	5.20E-01	**2.94E-02**

Notes:
NA - Not applicable because insufficient number of samples to calculate 95th percentile UCL.

Surface Soil and Sediment

Table 6-7 presents the parameters and assumptions used in assessing potential exposures to chemicals in surface soil and sediment. Minimal exposures due to dermal contact and inhalation are typically present for metals, and therefore, these exposure pathways are not evaluated. In addition, arsenic did not exceed the EPA Transfer to Air screening criteria further indicating that the inhalation pathway is not significant. The following summarize the assumptions made for exposure to chemicals in soil through ingestion:

➢ In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), an average ingestion rate of 100 mg of soil/day is used as representative for age groups greater than 6 years old and 200 mg/day for children ages 1 through 6 (USEPA, 1995a).

➢ The "fraction ingested" (FI) is based on an estimate of the fraction of soil that is presumed to be contaminated. For this analysis, it is assumed that 50 percent (USEPA, 1995a) of the soil contacted is contaminated with concentrations equivalent to the appropriate representative exposure concentration.

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

➢ An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

➢ The average weight of an American adult is approximately 70 kg (USEPA, 1995a) and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

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

  o 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.

TABLE 6-7
RESIDENTIAL EXPOSURE:
INGESTION OF CHEMICALS IN SOIL

EQUATION:

Intake (mg/kg-day) = (CS x IR x CF x FI x EF x ED)/(BW x AT)

Where:

CS = Chemical concentration in soil (mg/kg)
IR = Ingestion rate (mg soil/day)
CF = Conversion factor (10^{-6} kg/mg)
FI = Fraction ingested from contaminated source (unitless)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CS = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

IR = 100 mg/day for adults estimated from all age groups greater than 6 years old
200 mg/day for children ages 1 through 6

CF = 10^{-6} kg/mg

FI = 0.5; assumes 50% of soil is contaminated

EF = 350 days per year with 15 days expected to be away from the residence

ED = 30 years based on the national upper-bound (90th percentile) at one residence for adults
6 years for children which assumes that the oldest child is under 6 and has lived at the residence since birth.

BW = 70 kg represents the average adult and 15 kg for children ages 1 through 6

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 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.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.2.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

Groundwater

Tables 6-8 through 6-10 present the parameters and assumptions used in assessing potential exposures to chemicals in ground water. In the evaluation of exposures resulting from ground water via ingestion of, dermal contact or inhalation, the following factors and assumptions are used.

Ingestion

- For the ingestion of ground water, an ingestion rate (IR) of 2 liters/day is assumed for residential adults. This represents the 90th percentile value for adult daily water consumption (USEPA, 1995a). For children, an IR of 1 liter/day is assumed (USEPA, 1995a).

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

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

TABLE 6-8
RESIDENTIAL EXPOSURE
INGESTION OF CHEMICALS IN GROUND WATER

EQUATION:

Intake (mg/kg-day) = (CW x IR x EF x ED)/(BW x AT)

Where:

CW = Chemical concentration in water (mg/l)
IR = Ingestion rate (liters/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CW = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

IR = 2 liters/day for an adult
1 liter/day for a child

EF = 350 days/year for adults and children

ED = 30 years for adults
6 years for children

BW = 70 kg represents the average adult and 15 kg for children ages 1 through 6.

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

TABLE 6-9
RESIDENTIAL EXPOSURE
DERMAL CONTACT WITH CHEMICALS IN GROUND WATER

EQUATION:

Absorbed Dose (mg/kg-day) = (CW x SA x PC x ET x EF x ED x CF)/(BW x AT)

Where:

CW = Chemical concentration in water (mg/l)
SA = Skin surface area available for contact (cm^2)
PC = Chemical-specific dermal permeability coefficient (cm/hr)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CS = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

SA = 19,400 cm^2; represents the 50th percentile total body surface area, adult male
7,310 cm^2; represents the 50th percentile total body surface area, male child

PC = Chemical-specific values estimated from the octanol/water coefficient

ET = 0.3 hours/day

EF = 350 days/year

ED = 30 years for adults and 6 years for children

CF = 0.001 (1 liter/1000 cm^3)

BW = 70 kg represents the average adult and 15 kg the average child ages 1 through 6.

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

TABLE 6-10
RESIDENTIAL EXPOSURE
INHALATION OF AIRBORNE CHEMICALS IN GROUND WATER

EQUATION:

Intake (mg/kg-day) = (CA x IR x ET x EF x ED)/(BW x AT)

Where:

CA = Chemical concentration in air (mg/m^3)
IR = Inhalation rate (m^3/hour)
ET = Exposure time (hours/day)
EF = Exposure frequency (days/year)
ED = Exposure duration (years)
BW = Body weight (kg)
AT = Averaging time (period over which exposure is averaged - days)

Variable values:

CA = 95th percentile UCL on the mean of the measured concentrations in site samples, except when it exceeds the maximum detected concentration

IR = 0.83 m^3/hour for adults
0.50 m^3/hour for children

ET = 0.2 hours/day

EF = 350 days/year

ED = 30 years; represents the national upper-bound at one residence for adults
6 years for children ages 1 through 6

BW = 70 kg represents the average adult and 15 kg for child ages 1 through 6.

AT = period of exposure for noncarcinogenic effects is equal to ED x 365 days/year; for carcinogenic effects - 70 x 365 days/year

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- 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.

Dermal Contact

- For the evaluation of dermal contact with chemicals in ground water, it is assumed that the greatest, but not the exclusive, opportunity for exposure is during showering. The entire surface area (SA) of the body is used to evaluate these exposures. For adults, this value is 19,400 cm^2 which represents the 50th percentile total body surface area for an adult male (USEPA, 1989d). The 50th percentile total body SA for a male child is 7,310 cm^2.

  Since the calculated exposure is designed to be the absorbed dose, not the amount of chemical that comes into contact with the skin, a permeability constant (PC) is necessary to access exposure through dermal contact. The PC reflects movement across the skin to the underlying skin layers and into the bloodstream. Chemical-specific PCs are estimated from the octanol/water partition coefficient for the chemical following USEPA guidance (1992b). PCs for the COPC are provided in Appendix I.

- An exposure time (ET) of 18 minutes/day (0.3 hours/day) is assumed for dermal contact with chemicals in groundwater. This is a composite of showering activities as well as household tasks. Twelve minutes per day (0.2 hours/day) represents the 90th percentile value for showering for all age groups (USEPA, 1989d). It is assumed that 6 minutes/day (0.1 hours/day) is spent on miscellaneous task which allow for dermal contact with groundwater.

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

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- 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.

Inhalation

- For the evaluation of inhalation of airborne VOCs from the ground water, the contaminant concentration in air is calculated using a simplified approach which assumes that all VOCs of potential concern in the hot water are released during showering. For this calculation, it is assumed that about 200 liters of water are used over the 12 minutes, and the VOCs mix within the volume of the shower area (assumed to be $30m^3$ in volume) to achieve an equilibrium concentration of the chemicals in air. In practice, concentrations would probably build up and plateau during the showering event. However, this analysis assumes exposure to the total amount of VOCs present in the water, with uniform dispersion in the room volume, over the entire shower event, with no loss due to ventilation. The following equation is used to determine the chemical concentration in air based on the above assumptions:

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

CW = chemical concentration in water (ug/l)
CF = conversion factor (1E-03 mg/ug)
WV = volume of water (200 liters)
RV = room volume (30 m^3)

The concentration in air for the chemicals of potential concern are presented in Table 6-6. All concentration-in-air calculations are provided in Appendix I.

- An inhalation rate (IR) of 0.83 m^3/hour for adults is assumed in evaluating the inhalation of vapor phase chemicals in ground water. For a child, ages 1 through 6, the IR is assumed to be 0.5 m^3/hour (USEPA, 1995a).

- Exposure time (ET) for the inhalation pathway is estimated as 12 minutes or 0.2 hours based on the 90th percentile for showering for all ages. There is no information available for differences in the time men, women and children spend showering. Since volatilization may occur from other indoor water uses (such as from the dishwasher, etc.), the 90th percentile for showering for all ages instead of the 50th percentile for all ages is used in estimating exposure time.

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

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- 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.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.2.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

6.2.3 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 contaminant 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 (USEPA, 1992a); (2) USEPA Health Effects Summary Tables (HEAST) which are tabular presentations of toxicity data (USEPA, 1991c); and (3) Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles which contain general toxicity information and levels of exposure associated with lethality, cancer, genotoxicity, neurotoxicity, development and reproductive toxicity, immunotoxicity and systemic toxicity.

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

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 a RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is 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 6-11, 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, the greater 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.

Reference doses for inhalation exposure, referred to as RfDi, are available for few contaminants at this time. However, a RfDi does not currently exist for PCE so no non-carcinogenic evaluation of the risks associated with inhalation of volatilized chemicals in groundwater will be made.

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-

TABLE 6-11
TOXICITY VALUES: NON-CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	Chronic RfD (mg/kg-day)	Confidence Level	Critical Effect	RfD Basis/ Source	Uncertainty Factor	Modifying Factors
ORAL ROUTE						
Arsenic	3.00E-04	Medium	Perpigmentation, keratosis and possible vascular complications	Oral/IRIS	3	1
Manganese	5.00E-03	Medium				
PCE	1.00E-02	Medium	Hepatotoxicity in mice, weight gain in rats	Gavage/IRIS	1,000 for HAS	1
Thallium	8.00E-05*					
INHALATION ROUTE						
Arsenic	---					
Manganese	1.43E-05			IRIS		
PCE	---					
Thallium	---					

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
H - Variation in human sensitivity
A - Animal to human extrapolation
S - Extrapolation from Lowest Observed Adverse Effect Level (LOAEL) to No Observed Adverse Effect Level (NOAEL)
* - RfD for thallium sulfate used for thallium.

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 $(mg/kg\text{-}day)^{-1}$]. This expression incorporates standard pharmacological considerations such as body weight. CPSo data for the COPC are presented in Table 6-12 and are used to estimate finite, upper limits of risk at low dose levels administered over a lifetime. The weight-of-evidence classification for carcinogenicity, the type of cancer associated with each COPC and the basis and source of the CPSo are also presented in Table 6-12.

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

Risk = CDI x CPS
where:

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

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

As with RfDs, there are no assigned CPS values for dermal exposure. In their absence, CPS factors for oral exposures (denoted as CPSo) are used and adjusted to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses. The same absorption factors used to adjust RfDs are applied in

TABLE 6-12
TOXICITY VALUES: CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	CPS (mg/kg-day)$^{-1}$	Weight of Evidence Classification	Type of Cancer	SF Basis	SF Source
ORAL ROUTE					
Arsenic	1.50E+00	A	Gross tumors	Oral	IRIS
Manganese	---				
PCE	5.20E-02	B2	Liver	Gavage	NCEA
Thallium	---				
INHALATION ROUTE					
Arsenic	1.51E+01	A			
Manganese	---				
PCE	2.03E-03	B2	Leukemia, liver	---	NCEA
Thallium	---				

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
NCEA - EPA Provisional Guidance

adjusting CPSo values.

CPS values for inhalation exposure, referred to as CPSi, are available for few contaminants at this time. However, there does exist a CPSi for PCE, and therefore, an evaluation of carcinogenic risk for the inhalation of volatilized chemicals will be made.

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 which 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 contaminant 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 contaminants involved (i.e., that there are no synergistic or antagonistic chemical interactions and all chemicals produce the same effect, i.e., cancer).

6.2.4 Risk Characterization

The final step in the HHRA 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.

Potential non-cancer health effects, those associated with long-term chronic exposure to surface soils and groundwater at the site for potential future residential populations are presented.

Carcinogenic risks are similarly presented for the COPC, for each pathway of concern and for each potential exposed population. The cumulative impact of exposure from the various pathways evaluated is estimated, for the residential populations (adults and children) including ingestion of chemicals in surface soils and ingestion of, dermal contact with and inhalation of volatilized chemicals in groundwater.

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 I. As indicated in the following tables, the oral RfDs and CPSs have been adjusted for absorption to match the absorbed dose for dermal exposure.

Non-cancer Risks

Table 6-13 presents the chemical-specific hazard quotients for each pathway involving surface soils and groundwater. In addition, the total pathway risk, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway are presented in Table 6-13. The total exposure risk incorporates all the appropriate exposure pathways for the residential populations.

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 6-13, the total exposure hazard index for ingestion of soils and ingestion of and dermal contact with chemicals in groundwater is less than the criterion of 1.0 for adults but greater than the criterion of 1.0 for children. Thus, adverse non-carcinogen health effects in this residential population (children) is likely. The majority of this risk is associated with ingestion of manganese in groundwater. In addition, exposure to manganese in groundwater is the only exposure scenario above the criterion.

Cancer Risks

Table 6-14 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater. The estimated total exposure cancer risks are also noted in this table, incorporating all the

TABLE 6-13
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg-day)	CDI Adjusted For Absorption	RfD (mg/kg-day)	Hazard Quotient	Pathway Hazard Index
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic Thallium	1.25E-06 5.48E-07	No No	3.00E-04 8.00E-05	4.17E-03 6.85E-03	1.10E-02
Ingestion of COPC in Groundwater	Manganese PCE	2.22E-03 1.21E-04	No No	5.00E-03 1.00E-02	4.44E-01 1.21E-02	4.56E-01
Dermal Contact with COPC in Groundwater	Manganese PCE	3.23E-06 8.44E-07	Yes Yes	5.00E-03 1.00E-02	6.46E-04 8.44E-05	7.30E-04
Inhalation of Volatilized COPC in Groundwater	PCE	6.69E-05	No	---		
					Total Exposure Hazard Index	**4.68E-01**
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic Thallium	1.17E-05 5.11E-06	No No	3.00E-04 8.00E-05	3.90E-02 6.39E-02	1.03E-01
Ingestion of COPC in Groundwater	Manganese PCE	5.18E-03 2.82E-04	No No	5.00E-03 1.00E-02	1.04E+00 2.82E-02	1.06E+00
Dermal Contact with COPC in Groundwater	Manganese PCE	5.68E-06 1.48E-06	Yes Yes	5.00E-03 1.00E-02	1.14E-03 1.48E-04	1.28E-03
Inhalation of Volatilized COPC in Groundwater	PCE	1.88E-04	No	---		
					Total Exposure Hazard Index	**1.17E+00**

Notes:
CDI = Chronic Daily Intake
RfD = Reference dose
Hazard Quotient = CDI/RfD

TABLE 6-14
CANCER RISK ESTIMATES
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg-day)	CDI Adjusted For Absorption	CPS $(mg/kg-day)^{-1}$	Chemical-Specific Risk	Total Pathway Risk
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic	5.37E-07	No	1.50E+00	8.06E-07	8.06E-07
Ingestion of COPC in Groundwater	PCE	5.18E-05	No	5.20E-02	2.69E-06	2.69E-06
Dermal Contact with COPC in Groundwater	PCE	3.62E-07	Yes	5.20E-02	1.88E-08	1.88E-08
Inhalation of Volatilized COPC in Groundwater	PCE	2.87E-05	No	2.03E-03	5.83E-08	5.83E-08
					Total Exposure Hazard Index	**3.58E-06**
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic	1.00E-06	No	1.50E+00	1.50E-06	1.50E-06
Ingestion of COPC in Groundwater	PCE	2.42E-05	No	5.20E-02	1.26E-06	1.26E-06
Dermal Contact with COPC in Groundwater	PCE	1.27E-07	Yes	5.20E-02	6.60E-09	6.60E-09
Inhalation of Volatilized COPC in Groundwater	PCE	1.61E-05	No	2.03E-03	3.27E-08	3.27E-08
					Total Exposure Hazard Index	**2.80E-06**

Notes:
CDI = Chronic Daily Intake
CPS – Cancer Potency Slope
Chemical specific Risk = CDI x CPS

appropriate exposure pathways for the residential populations.

The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 4 in 1 million for adults and 3 in 1 million for children. These values are within the USEPA Superfund remediation goal of 10^{-4} (1 in ten thousand) to 10^{-6} (1 in one million) which serves as the target for site cleanup. The greatest component (only component within the USEPA remediation goal) for adults exposures is ingestion of PCE in groundwater (3 in 1 million). The ingestion of arsenic in surface soils (1.5 in 1 million) and ingestion of PCE in groundwater (1.3 in 1 million) are the greatest exposure pathways for children. Risks associated with both of these child exposure scenarios are within the USEPA remediation goal.

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 chemicals of potential concern provides uncertainty since the selection process relies heavily on professional judgment. If different chemicals of concern were chosen or if some were excluded the estimates of risk would be affected.

Model input parameters and assumptions that tend to overestimate exposure were used in the exposure assessment. For example, the "representative" concentrations used in /some of the analyses were the maximum concentration detected. This may overestimate risk. Also, frequent exposure to contaminants is considered even though exposures may occur infrequently or not at all. 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 the FTA site, some important uncertainties that may influence the results of the HHRA include:

- Although a limited data set for arsenic in soils at the site was available, as previously stated in Section 6.2.1, arsenic concentrations in soils are consistent with Fort Story and USGS regional background soils data.

- Limited data set for dissolved manganese in groundwater. Only 3 dissolved groundwater samples were collected and analyzed for metals at the site. Therefore, the maximum concentration of 81 ug/l was used in the risk analysis which may bias the results high. Additional groundwater analysis for dissolved manganese would present a larger data set and provide for a more accurate analysis of risk.

- Dissolved data is a function of filtering efficiency in the field. Some of the monitoring well samples were very turbid and required extensive settling prior to filtering. As shown on the Groundwater Sampling Form in Appendix C of the RI report for monitoring well 4MW-2S where the 81 ug/l dissolved manganese result was detected, the sample collected was extremely turbid (310 NTUs) which may impact filter efficiency due to the passing of some turbid under the filter into the sample container. Dissolved results may be biased high based on the filtering limitations.

- PCE estimates for non-carcinogenic and cancer risk may be biased high because of the use of 2.5 ug/l (which is 1/2 the PQL) in the UCL calculations. PCE was not detected in 29 of the 31 groundwater sampling locations at the site. Analysis with a lower PCE PQL may more accurately estimate PCE concentrations and subsequent risk.

6.2.5 FTA Site HHRA Summary and Conclusions

The results of the HHRA for non-carcinogenic and carcinogenic risks and associated conclusions are summarized as follows:

- A summary of the **Non-Carcinogenic Risk** (for future residential land use.) is provided below:

  - The total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is less than the criterion of 1.0 for adults.

- The total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is greater than the criterion of 1.0 for children. However, ingestion of manganese from groundwater is the only child exposure scenario above the criterion.

➢ A summary of the **Carcinogenic Risk** for future residential land use is provided below:

- The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 4 in 1 million for adults. The greatest component for adults exposures is ingestion of PCE in groundwater (2.69 in 1 million - 75 percent of total risk) which ~~is the only adult exposure scenario~~ within the USEPA remediation goal. remove

- The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 3 in 1 million for children. The greatest components for child exposures are ingestion of arsenic (although detected at levels consistent with background) in surface soils (1.5 in 1 million - 54 percent of total risk) and ingestion of PCE in groundwater (1.26 in 1 million - 45 percent of total risk). These ~~are the only two~~ child exposure scenarios are within the USEPA remediation goal.

➢ Potential risk ~~above acceptable criteria~~ remove is only present for the future scenario of residential development at the site, and not for the current situation or future situations involving industrial activities.

➢ Concentrations of volatile organics decreased by about one order of magnitude from the 1991 PA/SI sampling event to the 1995 RI sampling event with natural attenuation expected to continue this trend. Because residential development would not be expected at the site for many years even if base closure were to occur in the future, the concentrations of PCE in groundwater due to natural attenuation would not be expected to be above USEPA MCLs at that time.

➢ Additional sampling as previously discussed in the Uncertainties Section may also present sufficient data for a more accurate analysis of risk for metals in groundwater, However, under current land use, there is no risk from the metals in groundwater.

6.3 LARC 60 MAINTENANCE AREA

6.3.1 Hazard Identification

Numerous groundwater, surface soil, surface water and sediment samples were collected from this site and analyzed for various chemical contaminants. Figures 2-7 and 2-8 provide the sample locations. While the entire data set is presented in the *QCSR/ARR*, the data are summarized in Tables 6-15 through 6-19 to facilitate the hazard identification. Presented in the tables are the frequency of detection and the range of detected concentrations for each chemical, selected Applicable and Relevant and Appropriate Requirements (ARARs) [i.e., USEPA drinking water Maximum Contaminant Levels (MCLs)], "to be considered" (TBC) criteria and the USEPA weight-of-evidence classification for known or suspected human carcinogens.

The detection frequency, concentration range, ARARs and TBC criteria, and weight-of-evidence classification, along with information on the physical and chemical properties of the chemicals, the number of environmental media impacted and appraisal of the likelihood of human contact with the chemicals in each medium, are used to select COPCs for evaluation in the exposure assessment and risk characterization. Recognizing that the list of chemicals detected at the site is quite lengthy, the COPCs represent a manageable subset of chemicals at the site that are used to characterize exposure and risk. For the purposes of this assessment, a detection frequency of 5 percent will be used as a screening tool.

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

Surface Soils

Surface soil sampling was conducted to evaluate the nature and extent of contamination in the surface soils at the site. Surface soil samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for soil cleanup, EPA Region III Risk-based Concentration (RBC) Criteria EPA Region III SSLs and Virginia Petroleum Program Criteria are included in Table 6-15 as TBC criteria for purposes of comparison. A total of 22 surface soil

TABLE 6-15
HAZARD ASSESSMENT FOR SURFACE SOILS
LARC 60 MAINTENANCE AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria				EPA Carcinogen Class[4]	Potential Concern?
			Virginia Petroleum Program[1]	EPA Region III Soil Screening Levels	EPA Region III RBC Criteria			
				Transfers to Air[2]	Industrial Soils[3]	Residential Soils[3]		
VOCs (ug/kg)								
Acetone	1/22	36	–	62,000,000	20,000,000	780,000	D	
Methylene Chloride	7/22	5.2 – 160	–	7,000	760,000	85,000	B2	
Toluene	3/22	5.1 – 12	–	520,000	41,000,000	1,600,000	D	
Trichloroethene	2/22	5.9 – 6.4	–	3,000	520,000	58,000	B2	
SOCs (ug/kg)	0/22	BDL						
TPH (mg/kg)								
Total TPH	19/22	42 – 1,500	100	–	–	–	–	
Total Metals (mg/kg)								
Aluminum	5/5	250 – 2,700	–	–	100,000	7,800	–	
Arsenic	1/5	1.1	–	380	61	2.3	–	
Arsenic (as carcinogen)	1/5	1.1	–	380	3.8	0.38	A	Yes
Barium	5/5	1.8 – 19	–	350,000	14,000	550	–	
Calcium	4/5	56 – 980	–	–	–	–	–	
Chromium	5/5	1.7 – 4.3	–	–	100,000	7,800	–	
Cobalt	1/5	2.3	–	–	12,000	470	–	
Copper	4/5	2.5 – 41	–	–	7,600	290	D	
Iron	5/5	400 – 1,100	–	–	–	–	–	
Lead	5/5	3.1 – 12	–	–	400	–	B2	
Magnesium	4/5	77 – 1,400	–	–	–	–	–	
Manganese	5/5	2.4 – 120	–	–	1,000	39	D	Yes
Potassium	1/5	1,200	–	–	–	–	–	
Vanadium	5/5	1.2 – 9.2	–	–	1,400	55	D	
Zinc	5/5	3.8 – 33	–	–	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III Soil Screening Levels for Transfers from Soil to Air (Jan 1995)
(3) EPA Region III RBC Criteria for Industrial/Residential Soils (Jan 1995)
(4) Weight-of-Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in amimals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

were collected during the field investigation.

VOCs and SOCs

All concentrations of VOCs and SOCs were less than EPA RBC criteria and SSLs, and therefore, they are not selected as COPC.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in 17 of 22 surface soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. BTEX and PAHs, which are hazardous constituents of petroleum products, will be the primary compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA criteria.

Inorganics

Arsenic and manganese exceeded the RBC values for residential soils but did not exceed the industrial soils criteria.

Arsenic was detected in only 1 of 5 surface soil samples at a concentration of 1.1 mg/kg with a mean concentration of 0.6 mg/kg for all surface soil samples. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic levels detected in the surface soils are consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in Appendix H.

Manganese concentrations in surface soils ranged from 2.4 to 120 mg/kg with a mean concentration of 29 mg/kg. Although no background 95th percentile UCL was established by Montgomery Watson during performance of the PA/SI, the USGS regional soils data indicates an observed range of less than 0.2 to 7,000 mg/kg with a mean of 290 mg/kg. Therefore, the manganese levels detected in the surface soils are consistent with regional background soils.

Although consistent with background levels, for the purposes of risk analysis, arsenic and manganese are selected as COPCs based on their exceedance of the residential soils criteria.

No other inorganics exceeded EPA RBC values.

Groundwater

Groundwater quality data are summarized in Table 6-16 along with EPA Maximum Contaminant Levels (MCLs) and Action Levels, Virginia Groundwater Standards, Criteria and Protection Levels, and EPA RBC Criteria. Only the dissolved inorganic data is presented in Table 6-16. Total inorganic data are influenced by percentage of solids in the monitoring well or DPT sampling point and would not be indicative of groundwater quality if a drinking water well was installed at or near the site. The sediment is not available for transport with flowing groundwater and would also be filtered out if drinking water wells were installed in this area.

Thirty-three (33) groundwater samples (25 DPT and 8 monitoring well samples) were collected from the upper aquifer during the field investigation. Groundwater samples were also collected from three temporary well points during a free-product investigation. However, because no QA/QC samples were collected and data validation was not conducted, these results will not be used during the risk assessment process. The number of results for each chemical may vary due to the analysis of different compounds at different locations.

<u>VOCs</u>

Acetone, carbon disulfide, methylene chloride, and vinyl acetate were detected in only 1 of 29 samples and in concentrations less than risk screening criteria, and therefore, they are not selected as COPC.

Chloroform was detected in only 1 of 29 samples but at a concentration greater than the EPA RBC of 0.15 ug/l. However, because of its infrequent detection (3 percent), it is not selected as a COPC.

MIBK was detected in two samples but in concentrations less than risk screening criteria, and therefore, it is not selected as a COPC.

p-Isopropyl toluene, 1,2,4-trimethylbenzene and 1,3,5-trimethylbenzene were detected in one QA split sample analyzed by the USACE NED lab but in concentrations less than risk screening criteria,

TABLE 6–16
HAZARD ASSESSMENT FOR GROUNDWATER – LARC 60 SITE

Parameters	Frequency of Detection	Range of Detection	ARARs: EPA MCLs(1)	ARARs: EPA Secondary MCLs(2)	ARARs: Virginia GW Stds(3)	ARARs: Va GW Protection Levels(4)	TBC Criteria: Virginia GW Criteria(5)	TBC Criteria: EPA RBC Criteria(6) Tap Water	EPA Carcinogen Class(7)	Potential Concern?
VOCs (ug/l)										
Acetone	1/29	30	–	–	–	–	–	370	D	
Carbon disulfide	1/29	10	–	–	–	1,000	–	100	–	
Chloroform	1/29	4.6	100	–	–	5	–	0.15	B2	
cis 1,2–Dichloroethene	4/33	3.5 – 150	70	–	–	–	–	6.1	–	Yes
Ethylbenzene	4/29	6.6 – 530	700	–	–	–	–	130	D	Yes
p–Isopropyl toluene	1/1	2.3	–	–	–	–	–	–	–	
Methylene chloride	1/29	2.7	5	–	–	600	–	4.1	B2	
MIBK	2/29	50 – 54	–	–	–	–	–	290	D	
Tetrachloroethene	3/33	8.5 – 170	5	–	–	7	–	1.1	B2	Yes
Toluene	3/29	6.4 – 2,200	1,000	–	–	1,000	–	75	D	Yes
Trichloroethene	4/33	18 – 260	5	–	–	5	–	1.6	B2	Yes
1,2,4–Trimethylbenzene	1/1	5.6	–	–	–	–	–	30	–	
1,3,5–Trimethylbenzene	1/1	4.3	–	–	–	–	–	30	–	
Vinyl acetate	1/29	220	–	–	–	–	–	3,700	–	
Xylenes	3/29	37 – 2,900	10,000	–	–	–	–	1,200	D	Yes
SOCs (ug/l)										
Acenaphthene	1/25	1	–	–	–	–	–	220	D	
Bis(2–EH)phthalate	1/25	2	–	–	–	–	–	4.8	B2	
m&p–cresol	1/25	12	–	–	–	700	–	–	–	
Di–n–butylphthalate	1/25	2	–	–	–	–	–	370	D	
Fluorene	1/25	1	–	–	–	–	–	150	D	
2–Methylnaphthalene	4/25	3 – 57	–	–	–	–	–	–	–	
Naphthalene	3/25	2.8 – 81	–	–	–	–	–	150	D	
Phenanthrene	1/25	2	–	–	–	–	–	–	–	
TPH (mg/l)										
Total TPH	6/32	0.18 – 33	–	–	1	1	–	–	–	
Dissolved Metals (mg/l)										
Arsenic	1/4	0.04	0.05	–	0.05	0.05	–	0.0011	–	Yes
Arsenic (as carcinogen)	1/4	0.04	0.05	–	0.05	0.05	–	0.000045	A	Yes
Barium	4/4	0.012 – 0.07	1	–	1	1	–	0.26	–	
Calcium	4/4	6.3 – 36	–	–	–	–	–	–	–	
Iron	3/4	5.8 – 9	–	0.30	–	–	0.30	–	–	
Magnesium	4/4	4.0 – 6.3	–	–	–	–	–	–	–	
Manganese	3/4	0.084 – 0.53	–	0.05	–	–	0.05	0.018	D	Yes
Potassium	4/4	1.7 – 11	–	–	–	–	–	–	–	
Sodium	4/4	9.8 – 33	–	–	270	270	100	–	–	
Zinc	1/4	0.026	–	5	0.05	0.05	–	1.1	D	

Notes:
(1) U.S. EPA Maximum Contaminant Levels for Drinking Water (40 CFR 141)
(2) U.S. EPA Secondary Maximum Contaminant Levels for Drinking Water (40 CFR 143)
(3) Virginia Groundwater Quality Standards (VR680–21–04)
(4) Virginia Groundwater Protection Levels from Solid Waste Regulations (VR672–20–10)
(5) Virginia Water Quality Criteria for Groundwater (VR680–21–05)
(6) EPA Region III Risk–based Concentration Table for Tap Water (Jun – Dec 1995)
(7) Weight–of–Evidence Classifications
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B1 = Probable human carcinogen, sufficient data in animals
C = Possible human carcinogen
D = Not classified as to carcinogenicity

and therefore, they are not selected as COPC.

Ethyl benzene, xylenes, toluene, PCE, cis 1,2-dichloroethene (cis 1,2-DCE), and TCE were detected in excess of screening criteria, and therefore, they are selected as COPC.

SOCs

SOCs were not detected in any of the groundwater samples in excess of screening criteria, and therefore, are not selected as COPC.

TPH

Although TPH exceeded the Virginia Groundwater Standard of 1 mg/l in 4 of 32 groundwater samples, only one of the petroleum product hazardous constituents, toluene, exceeds risk screening criteria. The risk associated with petroleum hydrocarbons will be further evaluated based on toluene as previously discussed.

Inorganics

Dissolved manganese was detected at a concentration greater than the risk screening criteria in 1 of 4 samples collected, and therefore, is selected as a COPC.

Although detected at concentrations less than the EPA MCL and Virginia Groundwater Quality Standards and Protection Levels, dissolved arsenic was detected in 1 of 4 samples in excess of the EPA RBC criteria as a non-carcinogen and carcinogen, and therefore, is selected as a COPC.

Dissolved iron was detected at concentrations greater than EPA Secondary MCLs and Virginia Groundwater Criteria. However, as these standards were established for aesthetic qualities only for drinking water supplies, iron is not selected as a COPC.

No other dissolved inorganics were detected in concentrations greater than risk screening criteria.

Sediment

Sediment sampling was conducted to evaluate the nature of contamination in the sediment in the drainage ditch north of the Sandbox. Sediment samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for sediment cleanup, EPA Region III RBC Criteria for industrial and residential soils and Virginia Petroleum Program Criteria are included in Table 6-17 as TBC criteria for purposes of comparison. A total of two sediment samples were collected during the field investigation.

VOCs and SOCs

No VOCs or SOCs were detected in sediment samples at the site, and therefore, they are not selected as COPC.

TPH

TPH exceeded the 100 mg/kg TBC criterion in both sediment samples. Because TPH is typically used as an indicator of contamination, it will not be used during this quantitative risk assessment. BTEX and PAH concentrations, as previously discussed, were not detected.

Inorganics

All concentrations of inorganics were less than EPA RBC criteria, and therefore, are not selected as COPC.

Surface Water

Surface water sampling was conducted to evaluate the nature of contamination in the surface water in the drainage ditch north of the Sandbox. Samples were collected from the surface of the standing water in the ditch. Virginia Surface Water Quality Standards and EPA Ambient Water Quality Criteria are included in Table 6-18 as ARARs for purposes of comparison. A total of two surface water samples were collected during the field investigation.

VOCs

Acetone was the only VOC detected in surface water samples. No surface water quality standards have been established for acetone, however, concentrations (30 and 35 ug/l) were less than EPA RBC criteria of 37,000 ug/l for tap water. Therefore, acetone is not selected as a COPC.

TABLE 6-17
HAZARD ASSESSMENT FOR SEDIMENT
LARC 60 MAINTENANCE AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: Virginia Petroleum Program(1)	TBC Criteria: RBC Criteria for Industrial Soils(2)	TBC Criteria: RBC Criteria for Residential Soils(2)	EPA Carcinogen Class(3)	Potential Concern?
VOCs (ug/kg)	0/2	BDL					
SOCs (ug/kg)	0/2	BDL					
TPH (mg/kg)							
Total TPH	2/2	530 – 2,700	100	–	–	–	
Total Metals (mg/kg)							
Aluminum	2/2	310 – 650	–	100,000	7,800	–	
Barium	2/2	1.4 – 2.7	–	14,000	550	–	
Calcium	2/2	53 – 210	–	–	–	–	
Chromium	2/2	1.6 – 2.5	–	100,000	7,800	–	
Copper	2/2	3.8 – 9.0	–	7,600	290	D	
Iron	2/2	310 – 940	–	–	–	–	
Lead	2/2	8.2 – 14	–	400	–	B2	
Magnesium	2/2	110 – 250	–	–	–	–	
Manganese	2/2	3.4 – 6.9	–	1,000	39	D	
Sodium	1/2	70	–	–	–	–	
Vanadium	2/2	1.3 – 2.7	–	1,400	55	D	
Zinc	2/2	11 – 30	–	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III RBC Criteria for Industrial/Residential Soils (Jan 1995)
(3) Weight-of-Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

TABLE 6-18
HAZARD ASSESSMENT FOR SURFACE WATER
LARC 60 MAINTENANCE AREA

Parameters	Frequency of Detection	Range of Detection	ARARs				EPA Carcinogen Class(4)	Potential Concern?
			Virginia SW (Freshwater) Quality Standards(1)		Federal AWQC (Freshwater)(2)			
			Water/Fish	Fish Cons.	Water/Fish	Fish Cons.		
VOCs (ug/l)								
Acetone	2/2	30 – 35	–	–	–	–	D	
SVOCs (ug/l)	0/2	BDL						
Total TPH (mg/l)	0/2	BDL						
Total Metals (mg/l)								
Aluminum	2/2	0.39 – 0.42	–	–	–	–	–	
Calcium	2/2	11 – 12	–	–	–	–	–	
Iron	2/2	0.84 – 1.4	0.30	–	–	–	–	Yes
Lead	2/2	0.0078 – 0.009	0.015	–	0.050	–	B2	
Magnesium	2/2	15 – 17	–	–	–	–	–	
Manganese	2/2	0.083 – 0.14	0.05	–	–	–	D	Yes
Potassium	2/2	9.1 – 9.4	–	–	–	–	–	
Sodium	1/2	120	–	–	–	–	–	
Zinc	2/2	0.04 – 0.062	5	–	–	–	D	

Notes:
(1) Virginia Surface Water Quality Standards (VR 680-21-01.14)
(2) Federal Ambient Water Quality Criteria (40 CFR 131)

SOCs and TPH

No TPH or SOCs were detected in surface water samples at the site, and therefore, they are not selected as COPC.

Inorganics

Iron and manganese concentrations were greater than Virginia surface water quality criteria for human health consumption of water and fish, and therefore, they are selected as COPC.

No other inorganics were detected at concentrations greater than water quality standards.

Subsurface Soils and Soil Leachability

To evaluate the potential exposures to subsurface soils (i.e., future excavation activities) and for the potential leaching of contaminants form soil to groundwater, as shown in Table 6-19, soil analytical data was compared against EPA Region III SSLs for Transfers from Soil to Groundwater and EPA RBC for industrial soils.

Soil sampling was conducted to evaluate the nature and extent of contamination in the surface and subsurface soils at the site. Soil samples were collected from varying depths. Because there are no federal or state standards for soil cleanup, EPA Region III RBC criteria and SSLs are included in Table 6-19 as TBC criteria for purposes of comparison. A total of 49 soil samples were collected during the field investigation.

VOCs

All concentrations of VOCs were less than EPA RBC criteria for industrial soils.

PCE concentrations exceeded the SSLs in only 1 of 49 soil samples collected and was detected in only 3 of 49 soil samples. Although PCE is a groundwater COPC, soil results indicate that the majority of the PCE has already volatilized and/or leached out due to a high percolation rate due to the presence of medium to fine grained sands present at the LARC 60 site. Two DPT groundwater points were sampled adjacent to SB-20 where the one PCE exceedance (71 ug/kg) occurred with no PCE detected in groundwater. The source of the PCE in the groundwater is the area near the former UST pit not the area near SB-20 which is located in the Sandbox. The one

TABLE 6-19
HAZARD ASSESSMENT FOR SUBSURFACE SOILS AND SOIL LEACHABILITY – LARC 60 SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA SSLs Transfers to Groundwater(1)	TBC Criteria: EPA RBC Industrial Soils(2)	EPA Carcinogen Class(3)	Potential Concern?
VOCs (ug/kg)						
Acetone	5/49	36 – 200	8,000	20,000,000	D	
sec–Butyl benzene	1/4	2.6	270	2,000,000	D	
Ethylbenzene	1/4	2.3	5,000	20,000,000	D	
Isopropyl benzene	1/4	1.7	65,000	8,200,000	D	
p–Isopropyl toluene	1/4	9.1	–	–	–	
Methylene Chloride	18/49	5.2 – 220	10	760	B2	
Methy ethyl ketone	4/49	31 – 44	–	100,000,000	D	
n–Propyl benzene	1/4	4.3	–	–	–	
Styrene	3/49	1.8 – 9.2	2,000	41,000,000	D	
Tetrachloroethene	3/49	8.8 – 71	40	110,000	B2	
Toluene	8/49	5.1 – 13	5,000	41,000,000	D	
1,2,3–Trichlorobenzene	1/4	2.7	–	–	–	
Trichloroethene	5/49	5.9 – 16	20	520,000	B2	
1,2,4–Trimethylbenzene	1/4	29	–	10,000,000	–	
1,3,5–Trimethylbenzene	1/4	26	260	10,000,000	–	
Xylenes	1/49	11	74,000	100,000,000	D	
SOCs (ug/kg)						
Benzo(a)anthracene	1/49	27	700	7,800	B2	
Benzo(b)fluoranthene	1/49	36	4,000	7,800	B2	
Benzo(k)fluoranthene	1/49	47	4,000	78,000	B2	
Benzo(g,h,i)perylene	1/49	24	–	–	–	
Benzo(a)pyrene	1/49	35	4,000	780	B2	
Bis(2–EH)phthalate	1/49	51	11,000	410,000	B2	
Chyrsene	1/49	33	1,000	780,000	B2	
Di–n–butylphthalate	1/49	59	120,000	20,000,000	D	
Fluoranthene	1/49	55	980,000	8,200,000	D	
Naphthalene	1/49	4	30,000	8,200,000	D	
Pyrene	1/49	50	1,400,000	6,100,000	D	
TPH (mg/kg)						
Total TPH	31/49	42 – 1,500	–		–	
Total Metals (mg/kg)						
Aluminum	11/11	250 – 2700	–	100,000	–	
Arsenic	3/11	0.86 – 1.1	15	61	–	
Arsenic (as carcinogen)	3/11	0.86 – 1.1	15	3.8	A	
Barium	11/11	1.8 – 19	32	14,000	–	
Cadmium	1/11	0.18	6	1,000	B1	
Calcium	8/11	43 – 980	–	–	–	
Chromium	11/11	1.5 – 4.3	–	100,000	–	
Cobalt	2/11	0.79 – 2.3	–	12,000	–	
Copper	7/11	2.5 – 41	–	8,200	D	
Iron	11/11	400 – 1100	–	–	–	
Lead	11/11	1.3 – 17	–	400	B2	
Magnesium	8/11	56 – 1400	–	–	–	
Manganese	11/11	2.4 – 120	–	1,000	D	
Mercury	1/11	4.6	3	61	D	
Nickel	1/11	0.81	21	4,100	–	
Potassium	2/11	37 – 1200	–	–	–	
Silver	1/11	0.51	–	1,000	D	
Sodium	1/11	11	–	–	–	
Vanadium	10/11	1.2 – 9.2	–	1,400	D	
Zinc	11/11	3 – 33	42,000	61,000	D	

Notes:
(1) EPA Region III Soil Screening Levels for Transfers from Soil to Groundwater (Jun – Dec 1995)
(2) EPA Region III RBC for Industrial Soils (Jun – Dec 1995)
(3) Weight–of–Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in amimals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogencity

exceedance occurred at a depth of 4 to 5 feet below grade which is at the water table interface in this area, and therefore, due to the high percolation rate and mixing in the groundwater, it is unlikely that the PCE at that location still exists or could be detected in groundwater. Therefore, additional impacts to groundwater quality through further leaching would not be anticipated.

Although the methylene chloride concentrations detected in site soils exceeded the SSLs, no methylene chloride has been detected in groundwater at the site which indicates that currently no significant leaching has occurred even though the sands are highly permeable. A more detailed description of methylene chloride leachability is provided on page 5-14.

SOCs and Inorganics

SOC and inorganic concentrations did not exceed EPA RBC for industrial soils or EPA Region III SSLs for Transfers to Groundwater.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in 29 of 49 soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, benzene, toluene, ethyl benzene and xylenes (BTEX) and polynuclear aromatic hydrocarbons (PAHs), which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. As stated previously, their concentrations were less than EPA RBC and SSL criteria.

Chemicals of Potential Concern

COPC identified during the hazard identification of the LARC 60 site media include the following:

Media	COPC
Surface Soils	Arsenic and Manganese
Groundwater	cis 1,2-DCE, ethyl benzene, xylenes PCE, TCE, toluene, arsenic and manganese
Surface Water	Iron and Manganese

Potential risk associated with the COPC will be further evaluated in the exposure assessment section.

6.3.2 Exposure Assessment

The objective of the exposure assessment is to estimate the type and magnitude of exposures to the surface soils, groundwater and surface water COPCs that are present at or migrating from the LARC 60 site.

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 site is currently a heavy equipment maintenance facility with numerous maintenance facilities and outdoor staging areas for heavy equipment. The site is fenced with the two entrance gates locked during off-duty hours (typically 6:00 pm to 6:00 am). Fort Story personnel are present at the site for five days per week. However, because the only surface soils COPCs identified were arsenic and manganese due to exceedance of the residential soils criteria and not the industrial soils criteria, no adverse exposures for Fort Story personnel are anticipated. Because the site is fenced, potential exposures to the general public and/or trespassers are not significant. Therefore, there are **no exposed populations to the surface soils at the LARC 60 site under the current situation.**

The chief potable water supply in the region is the surface water reservoir system operated by the City of Norfolk. The system includes in-town lakes located near the Norfolk International Airport and other reservoirs (Lake Prince, Western Branch and Burnt Mills) located in Suffolk, Virginia. The in-town lakes are located over 5 miles from Fort Story while the Suffolk lakes are located over 20 miles from the facility. As previously stated in Section 3.1.5, several housing communities located within 1 mile of Fort Story are developing drinking water wells in the shallow aquifer, however, none of these communities are located downgradient of the site. Groundwater use at Fort Story is restricted to withdrawal from a single well located at the site of which water is obtained for nonpotable uses only. The well is screened in a deeper aquifer below the confining unit present at a depth of approximately 40 feet below land surface at the site. No COPC were identified in the two deep monitoring wells at the site which are screened at a depth of 30 to 40 feet below land surface. Based on a comparison of data from Montgomery-Watson's study in 1990 and data from Malcolm Pirnie's study in 1995, VOC concentrations have decreased substantially due to numerous subsurface mechanisms such as biodegradation, volatilization, and dispersion. Therefore, there are **currently no exposed populations to the groundwater at the LARC 60 site**.

Based on vertical elevations established for the two surface water locations in the ditch, the ditch intersects the shallow water table. The elevations were consistent with the groundwater elevations in that area as shown on Figure 3-6. Due to shallow water table elevation fluctuations during the dry season, it is expected that at certain times of the year that no surface water will be present in the drainage ditch. No flow or discharge point is present, therefore, no impacts to other surface water bodies or potential receptors have been identified. There are no current personnel exposures to the surface water and no trespassers into this area would be anticipated. The surface water in the ditch when present is not used for drinking water or fish consumption. Therefore, there are **currently no exposed populations to the surface water at the LARC 60 site**.

Future Land Use

Although construction or excavation activities could be conducted in the future, neither surface nor subsurface soil contaminant concentrations exceeded industrial screening criteria. Therefore, no significant exposures during these activities would be expected because these activities are typically very short term and contaminant concentrations were below screening criteria.

Based on master planning issues for Fort Story, the facility is expected to remain government property. However, due to periodic base closure reviews by the federal government, there is the potential for Fort Story to be closed with subsequent development of the land as commercial or residential properties. Therefore, **as for future conditions, potentially exposed populations include residential exposures to the surface soils and groundwater at the LARC 60 site.**

Although the iron and manganese levels in surface water exceeded the Virginia surface water quality standards for consumption of fish and water, it is not expected that even if this drainage area was present after future residential development, that the water would be consumed. Therefore, for the future land use scenario, **no potentially exposed populations** were identified for the surface water in this drainage ditch.

Exposure Pathways

The potential exposure pathways for future land use at the LARC 60 site include:

- Residential exposure (adults and children) to **contaminated groundwater** through ingestion of drinking water, dermal contact with and inhalation of volatilized chemicals while bathing or showering.

- Residential exposure (adults and children) to **contaminated soil** through ingestion of chemicals.

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 practical quantitation limit (PQL). The PQLs are chemical-specific values that laboratories should be able to routinely and reliably detect and quantitate, but which may vary depending on the medium analyzed and the amount expected to be present in the sample. Adjusting non-detects by assigning values at 1/2 the PQL assumes that a chemical may be present at a concentration just below the reported quantitation limit. One-half the PQL is used as a conservative "proxy" concentration consistent with USEPA guidance. This approach would tend to overestimate the risk.

In this evaluation, data which were qualified by indicating that the numerical value is an estimated quantity are treated in this evaluation the same as data without this qualifier.

Estimates of Contaminant 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 contaminant concentrations in the specific media of concern. Table 6-5 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.

The USEPA recommends that estimates of contaminant 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 contaminant 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. Alternatively, the lognormal distribution is a commonly used probability density model for environmental contamination data. The USEPA (USEPA 1989a) recommends that the upper confidence limit [i.e., the 95th percent upper confidence limit (UCL)] on the mean of all the data should be used for evaluating RMEs. Following this guidance, the equation used in this analysis (Gilbert, 1987) is:

$$UCL = e^{\{x + 0.5s*s + Sh/\sqrt{(n-1)}\}}$$

where:

UCL = 95th percent upper confidence limit on the mean
e = constant (natural log)
x = the mean of the log transformed data
s = the standard deviation of the log transformed data
H = statistic for computing a one-sided upper 95% confidence limit on a lognormal mean
n = sample size

As described previously, for all samples in which the COPC is not detected, a value of 1/2 the PQL for that chemical was assigned. Depending upon the number of non-detects and variability in measured concentrations, the UCL on the mean concentration may occasionally exceed the maximum detected value. Since exposure to chemicals having concentrations greater that 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 5 or greater.

Therefore, for the groundwater COPCs of arsenic and manganese, the maximum concentration will be used because only 4 dissolved groundwater samples were collected.

The 95th percentile UCL concentrations were computed for arsenic and manganese in surface soils and the numerous VOCs in groundwater to estimate the mean concentration. These UCL calculations are provided in Appendix I. The results of the UCL calculations with comparison to the maximum concentration detected are provided in Table 6-20.

While the approach used in this evaluation assumes no transformation or loss due to environmental degradation from the current time to the future time when residential development may occur at the site, the environmental fate and transport of chemicals are important in determining the ultimate hazard to people. After a chemical is released to the environment, it may be transformed physically (e.g., by volatilization, precipitation, etc.), chemically (e.g., by photolysis, hydrolysis, oxidation, reduction, etc.), or biologically (e.g., by biodegradation); alternatively, it may be accumulated in one or more media (including biomass) or may be transported (e.g., convected downstream in water or on suspended sediment or through the atmosphere). In Appendix J, the environmental fate and transport mechanisms, as well as a brief toxicological profile, of each of the COPC (only those chemicals where a potential exposure pathway is present) for the HHRA are briefly discussed.

<u>Surface Soil</u>

Table 6-7 presents the parameters and assumptions used in assessing potential exposures to chemicals in surface soil. Minimal exposures due to dermal contact and inhalation are typically

TABLE 6-20
COMPARISON OF EXPOSURE CONCENTRATIONS
LARC 60 MAINTENANCE AREA

POPULATIONS AND PATHWAYS	MAXIMUM CONCENTRATION	95th PERCENTILE UCL
ON-SITE RESIDENTIAL POPULATION - FUTURE LAND USE		
Surface Soils		
Ingestion of Chemicals	mg/kg	mg/kg
Arsenic	1.1	**0.90**
Manganese	**120**	1,623
Groundwater		
Ingestion of and Dermal Contact with Chemicals	ug/l	ug/l
Arsenic	**40**	NA
Manganese	**530**	NA
cis 1,2-DCE	150	**8.9**
Ethylbenzene	530	**16.4**
PCE	170	**9.9**
Toluene	2,200	**28.5**
TCE	260	**18.1**
Xylenes	2,900	**62.3**
Inhalation of Chemicals Volatilized	mg/m^3	mg/m^3
cis 1,2-DCE	1.00E+00	**5.93E-02**
Ethylbenzene	3.53E+00	**1.09E-01**
PCE	1.13E+00	**6.60E-02**
Toluene	1.47E+01	**1.90E-01**
TCE	1.73E+00	**1.21E-01**
Xylenes	1.93E+01	**4.15E-01**

Notes:
NA - Not applicable because insufficient number of samples to calculate the 95th percentile UCL.

present for metals, and therefore, these exposure pathways are not evaluated. In addition, arsenic and manganese did not exceed the EPA Transfer to Air screening criteria further indicating that the inhalation pathway is not significant. The following summarize the assumptions made for exposure to chemicals in soil through ingestion:

- In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), an average ingestion rate of 100 mg of soil/day is used as representative for age groups greater than 6 years old and 200 mg/day for children ages 1 through 6 (USEPA, 1995a).

- The "fraction ingested" (FI) is based on an estimate of the fraction of soil that is presumed to be contaminated. For this analysis, it is assumed that 50 percent (USEPA, 1995a) of the soil contacted is contaminated with concentrations equivalent to the appropriate representative exposure concentration.

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

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg (USEPA, 1995a) and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- 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.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.3.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

Groundwater

Tables 6-8 through 6-10 present the parameters and assumptions used in assessing potential exposures to chemicals in ground water. In the evaluation of exposures resulting from ground water via ingestion of, dermal contact or inhalation, the following factors and assumptions are used.

Ingestion

- For the ingestion of ground water, an ingestion rate (IR) of 2 liters/day is assumed for residential adults. This represents the 90th percentile value for adult daily water consumption (USEPA, 1995a). For children, an IR of 1 liter/day is assumed (USEPA, 1995a).

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

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

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

- o 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.

- o 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.

Dermal Contact

- ➢ For the evaluation of dermal contact with chemicals in ground water, it is assumed that the greatest, but not the exclusive, opportunity for exposure is during showering. The entire surface area (SA) of the body is used to evaluate these exposures. For adults, this value is 19,400 cm^2 which represents the 50th percentile total body surface area for an adult male (USEPA, 1989d). The 50th percentile total body SA for a male child is 7,310 cm^2.

  Since the calculated exposure is designed to be the absorbed dose, not the amount of chemical that comes into contact with the skin, a permeability constant (PC) is necessary to access exposure through dermal contact. The PC reflects movement across the skin to the underlying skin layers and into the bloodstream. Chemical-specific PCs are estimated from the octanol/water partition coefficient for the chemical following USEPA guidance (1992b). PCs for the COPC are provided in Appendix I.

- ➢ An exposure time (ET) of 18 minutes/day (0.3 hours/day) is assumed for dermal contact with chemicals in groundwater. This is a composite of showering activities as well as household tasks. Twelve minutes per day (0.2 hours/day) represents the 90th percentile value for showering for all age groups (USEPA, 1989d). It is assumed that 6 minutes/day (0.1 hours/day) is spent on miscellaneous task which allow for dermal contact with groundwater.

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

- ➢ An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- 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.

Inhalation

- For the evaluation of inhalation of airborne VOCs from the ground water, the contaminant concentration in air is calculated using a simplified approach which assumes that all VOCs of potential concern in the hot water are released during showering. For this calculation, it is assumed that about 200 liters of water are used over the 12 minutes, and the VOCs mix within the volume of the shower area (assumed to be 30m^3 in volume) to achieve an equilibrium concentration of the chemicals in air. In practice, concentrations would probably build up and plateau during the showering event. However, this analysis assumes exposure to the total amount of VOCs present in the water, with uniform dispersion in the room volume, over the entire shower event, with no loss due to ventilation. The following equation is used to determine the chemical concentration in air based on the above assumptions:

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

  CW = chemical concentration in water (ug/l)
  CF = conversion factor (1E-03 mg/ug)
  WV = volume of water (200 liters)
  RV = room volume (30 m^3)

The concentration in air for the chemicals of potential concern are presented in Table 6-20. All concentration-in-air calculations are provided in Appendix I.

- An inhalation rate (IR) of 0.83 m^3/hour for adults is assumed in evaluating the inhalation of vapor phase chemicals in ground water. For a child, ages 1 through 6, the IR is assumed to be 0.5 m^3/hour (USEPA, 1995a).

- Exposure time (ET) for the inhalation pathway is estimated as 12 minutes or 0.2 hours based on the 90th percentile for showering for all ages. There is no information available for differences in the time men, women and children spend showering. Since volatilization may occur from other indoor water uses (such as from the dishwasher, etc.), the 90th percentile for showering for all ages instead of the 50th percentile for all ages is used in estimating exposure time.

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

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- 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.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.3.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

6.3.3 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 contaminant 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 (USEPA, 1992a); (2) USEPA Health Effects Summary Tables (HEAST) which are tabular presentations of toxicity data (USEPA, 1991c); and (3) Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles which contain general toxicity information and levels of exposure associated with lethality, cancer, genotoxicity, neurotoxicity, development and reproductive toxicity, immunotoxicity and systemic toxicity.

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

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 a RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is 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 6-21, 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, the greater 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.

Reference doses for inhalation exposure, referred to as RfDi, are available for few contaminants at this time. A RfDi is only available for ethyl benzene and toluene.

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.

TABLE 6-21
TOXICITY VALUES: NON-CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	Chronic RfD (mg/kg-day)	Confidence Level	Critical Effect	RfD Basis/ Source	Uncertainty Factor	Modifying Factors
ORAL ROUTE						
Arsenic	3.00E-04	Medium	Perpigmentation, keratosis and possible vascular complications	Oral/IRIS	3	1
Manganese	5.00E-03	Medium				
cis 1,2-DCE	1.00E-02					
Ethylbenzene	1.00E-01					
PCE	1.00E-02	Medium	Hepatotoxicity in mice, weight gain in rats	Gavage/IRIS	1,000 for HAS	1
Toluene	2.00E-01					
TCE	6.00E-03					
Xylenes	2.00E+00					
INHALATION ROUTE						
Arsenic	---					
Manganese	1.43E-05			IRIS		
cis 1,2-DCE	---					
Ethylbenzene	2.86E-01					
PCE	---					
Toluene	1.14E-01					
TCE	---					
Xylenes	---					

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
H - Variation in human sensitivity
A - Animal to human extrapolation
S - Extrapolation from Lowest Observed Adverse Effect Level (LOAEL) to No Observed Adverse Effect Level (NOAEL)

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 $(mg/kg\text{-}day)^{-1}$]. This expression incorporates standard pharmacological considerations such as body weight. CPSo data for the COPC are presented in Table 6-22 and are used to estimate finite, upper limits of risk at low dose levels administered over a lifetime. The weight-of-evidence classification for carcinogenicity, the type of cancer associated with each COPC and the basis and source of the CPSo are also presented in Table 6-22.

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

Risk = CDI x CPS
where:

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

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

As with RfDs, there are no assigned CPS values for dermal exposure. In their absence, CPS factors for oral exposures (denoted as CPSo) are used and adjusted to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses. The same absorption factors used to adjust RfDs are applied in adjusting CPSo values.

CPS values for inhalation exposure, referred to as CPSi, are available for few contaminants at this time. A CPSi is only available for PCE and TCE.

TABLE 6-22
TOXICITY VALUES: CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	CPS $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Classification	Type of Cancer	SF Basis	SF Source
ORAL ROUTE					
Arsenic	1.50E+00	A	Gross tumors	Oral	IRIS
PCE	5.20E-02	B2	Liver	Gavage	NCEA
TCE	1.10E-02	B2			
INHALATION ROUTE					
Arsenic	1.51E+01	A			
PCE	2.03E-03	B2	Leukemia, liver	---	NCEA
TCE	6.00E-03	B2			

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
NCEA - EPA Provisional Guidance

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 which 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 contaminant 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 contaminants involved (i.e., that there are no synergistic or antagonistic chemical interactions and all chemicals produce the same effect, i.e., cancer).

6.3.4 Risk Characterization

The final step in the HHRA 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.

Potential non-cancer health effects, those associated with long-term chronic exposure to surface soils and groundwater at the site for potential future residential populations are presented. Carcinogenic risks are similarly presented for the COPC, for each pathway of concern and for each potential exposed population. The cumulative impact of exposure from the various pathways evaluated is estimated, for the residential populations (adults and children) including ingestion of chemicals in surface soils and ingestion of, dermal contact with and inhalation of volatilized chemicals in groundwater.

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 I. As indicated in the following tables, the oral RfDs and CPSs have been adjusted for absorption to match the absorbed dose for dermal exposure.

Non-cancer Risks

Table 6-23 presents the chemical-specific hazard quotients for each pathway involving surface soils and groundwater. In addition, the total pathway risk, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway are presented in Table 6-23. The total exposure risk incorporates all the appropriate exposure pathways for the residential populations.

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 6-23, the total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is greater than the criterion of 1.0 for both adults and children. Thus, adverse non-carcinogen health effects in these residential populations are likely. The majority of this risk is associated with ingestion of arsenic and manganese in groundwater. In addition, exposure to arsenic and manganese in groundwater is the only exposure scenario above the criterion.

Cancer Risks

Table 6-24 presents estimated chemical-specific and total pathway cancer risks calculated for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for the residential populations.

The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 7 in 10 thousand for adults and 3 in 10 thousand for children. These values are greater than the USEPA Superfund remediation goal of 10^{-4} (1 in ten thousand) to 10^{-6} (1 in one million) which serves as the target for site cleanup. The greatest component for adult and child exposures is ingestion

TABLE 6-23
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg-day)	CDI Adjusted For Absorption	RfD (mg/kg-day)	Hazard Quotient	Pathway Hazard Index
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic	6.16E-07	No	3.00E-04	2.05E-03	1.85E-02
	Manganese	8.22E-05	No	5.00E-03	1.64E-02	
Ingestion of COPC in Groundwater	Arsenic	1.10E-03	No	3.00E-04	3.67E+00	6.71E+00
	Manganese	1.45E-02	No	5.00E-03	2.90E+00	
	cis 1,2-DCE	2.44E-04	No	1.00E-02	2.44E-02	
	Ethylbenzene	4.49E-04	No	1.00E-01	4.49E-03	
	PCE	2.71E-04	No	1.00E-02	2.71E-02	
	Toluene	7.81E-04	No	2.00E-01	3.91E-03	
	TCE	4.96E-04	No	6.00E-03	8.27E-02	
	Xylenes	1.71E-03	No	2.00E+00	8.55E-04	
Dermal Contact with COPC in Groundwater	Arsenic	1.59E-06	Yes	3.00E-04	5.30E-03	4.76E-02
	Manganese	2.11E-05	Yes	5.00E-03	4.22E-03	
	cis 1,2-DCE	1.62E-05	Yes	1.00E-02	1.62E-03	
	Ethylbenzene	4.13E-04	Yes	1.00E-01	4.13E-03	
	PCE	1.89E-06	Yes	1.00E-02	1.89E-04	
	Toluene	2.27E-03	Yes	2.00E-01	1.13E-02	
	TCE	1.20E-04	Yes	6.00E-03	2.00E-02	
	Xylenes	1.57E-03	Yes	2.00E+00	7.85E-04	
Inhalation of Volatilized COPC in Groundwater	Ethylbenzene	2.48E-04	No	2.86E-01	8.67E-04	4.66E-03
	Toluene	4.32E-04	No	1.14E-01	3.79E-03	
					Total Exposure Hazard Index	**6.78E+00**

TABLE 6-23
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg-day)	CDI Adjusted For Absorption	RfD (mg/kg-day)	Hazard Quotient	Pathway Hazard Index
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic	5.75E-06	No	3.00E-04	1.92E-02	1.73E-01
	Manganese	7.67E-04	No	5.00E-03	1.53E-01	
Ingestion of COPC in Groundwater	Arsenic	2.56E-03	No	3.00E-04	8.53E+00	1.56E+01
	Manganese	3.39E-02	No	5.00E-03	6.78E+00	
	cis 1,2-DCE	5.69E-04	No	1.00E-02	5.69E-02	
	Ethylbenzene	1.05E-03	No	1.00E-01	1.05E-02	
	PCE	6.33E-04	No	1.00E-02	6.33E-02	
	Toluene	1.82E-03	No	2.00E-01	9.10E-03	
	TCE	1.16E-03	No	6.00E-03	1.93E-01	
	Xylenes	3.98E-03	No	2.00E+00	1.99E-03	
Dermal Contact with COPC in Groundwater	Arsenic	2.80E-06	Yes	3.00E-04	9.33E-03	8.38E-02
	Manganese	3.72E-05	Yes	5.00E-03	7.44E-03	
	cis 1,2-DCE	2.86E-05	Yes	1.00E-02	2.86E-03	
	Ethylbenzene	7.27E-04	Yes	1.00E-01	7.27E-03	
	PCE	3.33E-06	Yes	1.00E-02	3.33E-04	
	Toluene	4.00E-03	Yes	2.00E-01	2.00E-02	
	TCE	2.11E-04	Yes	6.00E-03	3.52E-02	
	Xylenes	2.76E-03	Yes	2.00E+00	1.38E-03	
Inhalation of Volatilized COPC in Groundwater	Ethylbenzene	6.97E-04	No	2.86E-01	2.44E-03	1.31E-02
	Toluene	1.21E-03	No	1.14E-01	1.06E-02	
					Total Exposure Hazard Index	**1.59E+01**

Notes:
CDI = Chronic Daily Intake
RfD = Reference dose
Hazard Quotient = CDI/RfD

TABLE 6-24
CANCER RISK ESTIMATES
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg-day)	CDI Adjusted For Absorption	CPS $(mg/kg-day)^{-1}$	Chemical-Specific Risk	Total Pathway Risk
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic	2.64E-07	No	1.50E+00	3.96E-07	3.96E-07
Ingestion of COPC in Groundwater	Arsenic	4.70E-04	No	1.50E+00	7.05E-04	7.13E-04
	PCE	1.16E-04	No	5.20E-02	6.03E-06	
	TCE	2.13E-04	No	1.10E-02	2.34E-06	
Dermal Contact with COPC in Groundwater	Arsenic	6.83E-07	Yes	1.50E+00	1.02E-06	1.63E-06
	PCE	8.12E-07	Yes	5.20E-02	4.22E-08	
	TCE	5.15E-05	Yes	1.10E-02	5.66E-07	
Inhalation of Volatilized COPC in Groundwater	PCE	6.43E-05	No	2.03E-03	1.31E-07	8.39E-07
	TCE	1.18E-04	No	6.00E-03	7.08E-07	
					Total Exposure Hazard Index	**7.16E-04**
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic	4.93E-07	No	1.50E+00	7.39E-07	7.39E-07
Ingestion of COPC in Groundwater	Arsenic	2.19E-04	No	1.50E+00	3.29E-04	3.32E-04
	PCE	5.42E-05	No	5.20E-02	2.82E-06	
	TCE	9.92E-05	No	1.10E-02	1.09E-06	
Dermal Contact with COPC in Groundwater	Arsenic	2.40E-07	Yes	1.50E+00	3.60E-07	5.74E-07
	PCE	2.86E-07	Yes	5.20E-02	1.49E-08	
	TCE	1.81E-05	Yes	1.10E-02	1.99E-07	
Inhalation of Volatilized COPC in Groundwater	PCE	3.62E-05	No	2.03E-03	7.35E-08	4.71E-07
	TCE	6.63E-05	No	6.00E-03	3.98E-07	
					Total Exposure Hazard Index	**3.34E-04**

Notes:
CDI = Chronic Daily Intake
CPS – Cancer Potency Slope
Chemical specific Risk = CDI x CPS

of the COPC (especially arsenic) in groundwater. In addition, exposure to arsenic, PCE and TCE in groundwater is the only exposure scenario above the criterion.

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 chemicals of potential concern provides uncertainty since the selection process relies heavily on professional judgment. If different chemicals of concern were chosen or if some were excluded the estimates of risk would be affected.

Model input parameters and assumptions that tend to overestimate exposure were used in the exposure assessment. For example, the "representative" concentrations used in /some of the analyses were the maximum concentration detected. This may overestimate risk. Also, frequent exposure to contaminants is considered even though exposures may occur infrequently or not at all. 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 the LARC 60 site, some important uncertainties that may influence the results of the HHRA include:

- ➢ Although a limited data set for arsenic and manganese in soils at the site was available, as previously stated in Section 6.3.1, arsenic and manganese concentrations in soils are consistent with background soils data.

- Limited data set for dissolved arsenic and manganese in groundwater. Only 4 dissolved groundwater samples were collected and analyzed for metals at the site. Therefore, the maximum concentration of 530 ug/ for manganese and 40 ug/l for arsenic were used in the risk analysis which may bias the results high. Additional groundwater analysis for dissolved metals would present a larger data set and provide for a more accurate analysis of risk.

- Dissolved data is a function of filtering efficiency in the field. Some of the monitoring well samples were very turbid and required extensive settling prior to filtering. Dissolved results may be biased high based on the filtering limitations.

- VOC estimates for non-carcinogenic and cancer risk may be biased high because of the use of 2.5 ug/l (which is 1/2 the PQL) in the UCL calculations. These VOCs were detected infrequently (cis 1,2-DCE - 4 of 33 samples, ethyl benzene 4 of 29 samples, PCE - 3 of 33 samples, toluene - 3 of 29 samples, TCE - 4 of 33 samples and xylenes - 3 of 29 samples). Analysis with a lower PQL may more accurately estimate VOC concentrations and subsequent risk.

6.3.5 LARC 60 Site HHRA Summary and Conclusions

The results of the HHRA for non-carcinogenic and carcinogenic risks and associated conclusions are summarized as follows:

- A summary of the **Non-Carcinogenic Risk** future residential is provided below:

    - The total exposure hazard index for ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater is greater than the criterion of 1.0 for adults and children with the majority (approximately 97 percent) of this risk associated with ingestion of arsenic and manganese in groundwater. However, ingestion of arsenic and manganese from groundwater is the only adult and child exposure scenario above the criterion.

- A summary of the **Carcinogenic Risk** is provided below:

    - The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 7 in 10 thousand for adults. The greatest component for adults exposures is ingestion of arsenic in groundwater (98 percent of total risk). In addition, exposure to contaminated groundwater from arsenic, PCE and TCE is the only adult exposure scenario greater than the USEPA remediation goal.

- The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 3 in 10 thousand for children. The greatest components for child exposures are ingestion of arsenic in groundwater (98 percent of total risk). In addition, exposure to contaminated groundwater from arsenic, PCE and TCE is the only child exposure scenario greater than the USEPA remediation goal.

➢ Potential risk ~~above acceptable criteria~~ is only present for the future scenario of residential development at the site, and not for the current situation or future situations involving industrial activities.

➢ Because residential development would not be expected at the site for many years even if base closure were to occur in the future, the concentrations of VOCs in groundwater due to natural attenuation would not be expected to be above USEPA MCLs at that time.

➢ Additional sampling as previously discussed in the Uncertainties Section may also present sufficient data for a more accurate analysis of risk for metals in groundwater.

6.4 AUTO CRAFT BUILDING AREA

6.4.1 Hazard Identification

Numerous groundwater and surface soil samples were collected from this site and analyzed for various chemical contaminants. Figures 2-9 and 2-10 provide the sample locations. While the entire data set is presented in the *QCSR/ARR*, the data are summarized in Tables 6-25 through 6-27 to facilitate the hazard identification. Presented in the tables are the frequency of detection and the range of detected concentrations for each chemical, selected Applicable and Relevant and Appropriate Requirements (ARARs) [i.e., USEPA drinking water Maximum Contaminant Levels (MCLs)], "to be considered" (TBC) criteria and the USEPA weight-of-evidence classification for known or suspected human carcinogens.

The detection frequency, concentration range, ARARs and TBC criteria, and weight-of-evidence classification, along with information on the physical and chemical properties of the chemicals, the number of environmental media impacted and appraisal of the likelihood of human contact with the chemicals in each medium, are used to select chemicals of potential concern for evaluation in the exposure assessment and risk characterization. Recognizing that the list of chemicals detected at the site is quite lengthy, the COPCs represent a manageable subset of chemicals at the site that are used to characterize exposure and risk. For the purposes of this assessment, a detection frequency of 5 percent will be used as a screening tool.

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

Surface Soils

Surface soil sampling was conducted to evaluate the nature and extent of contamination in the surface soils at the site. Surface soil samples were collected from depths of 0 to 12 inches. Because there are no federal or state standards for soil cleanup, EPA Region III RBC Criteria, EPA Region III SSLs, and Virginia Petroleum Program Criteria are included in Table 6-25 as TBC criteria for purposes of comparison. A total of six surface soil samples were collected during the field investigation.

VOCs

All concentrations of VOCs were less than EPA RBC criteria, and therefore, are not selected as COPC.

SOCs

As shown in Table 6-25, the concentrations of several PAHs including benzo(a)anthracene, benzo(b)fluoranthene, benzo(a)pyrene, and indeno(1,2,3-cd)pyrene in surface soils exceeded EPA RBC criteria for residential soils, however, as stated in Section 4.5.1.1, their concentrations are related to the presence of an asphalt parking lot placed on top of surface soils around the former building. Because they are not believed to be related to activities at the site, they are not selected

TABLE 6–25
HAZARD ASSESSMENT FOR SURFACE SOILS – AUTO CRAFT SITE

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: Virginia Petroleum Program(1)	TBC Criteria: EPA SSLs Transfers to Air(2)	TBC Criteria: EPA RBC Criteria Industrial Soils(3)	TBC Criteria: EPA RBC Criteria Residential Soils(3)	EPA Carcinogen Class(4)	Potential Concern?
VOCs (ug/kg)								
Methylene Chloride	1/6	41	–	7,000	760,000	85,000	B2	
Methyl ethyl ketone	1/6	55	–	–	100,000,000	4,700,000	D	
Toluene	6/6	7.9 – 34	–	520,000	41,000,000	1,600,000	D	
Trichloroethene	1/6	33	–	3,000	520,000	58,000	B2	
SOCs (ug/kg)								
Acenaphthene	1/6	440	–	120,000	12,000,000	470,000	–	
Benzo(a)anthracene	1/6	2500	–	27,000	7,800	880	B2	
Benzo(b)fluoranthene	1/6	4100	–	23,000	7,800	880	B2	
Benzo(k)fluoranthene	1/6	490	–	–	78,000	8,800	B2	
Benzo(g,h,i)perylene	1/6	2000	–	–	–	–	–	
Benzo(a)pyrene	1/6	3400	–	11,000	780	88	B2	
Butylbenzyphthalate	1/6	550	–	530,000	410,000,000	16,000,000	C	
Chrysene	1/6	2000	–	3,600	780,000	88,000	B2	
Fluoranthene	1/6	5800	–	68,000	8,200,000	310,000	D	
Indeno(1,2,3–cd)pyrene	1/6	1500	–	280,000	7,800	880	B2	
Phenanthrene	1/6	1300	–	–	–	–	D	
Pyrene	1/6	11,000	–	56,000	6,100,000	230,000	D	
TPH (mg/kg)								
Total TPH	3/6	220 – 390	100	–	–	–	–	
Total Metals (mg/kg)								
Aluminum	1/1	5,200	–	–	100,000	7,800	–	
Arsenic	1/1	1.3	–	380	61	2.3	–	
Arsenic (as carcinogen)	1/1	1.3	–	380	3.8	0.43	A	Yes
Barium	1/1	82	–	350,000	14,000	550	–	
Calcium	1/1	1200	–	–	–	–	–	
Chromium	1/1	8.6	–	–	100,000	7,800	–	
Cobalt	1/1	4.4	–	–	12,000	470	–	
Copper	1/1	18	–	–	7,600	290	D	
Iron	1/1	9,100	–	–	–	–	–	
Lead	1/1	95	–	–	400	–	B2	
Magnesium	1/1	2,400	–	–	–	–	–	
Manganese	1/1	170	–	–	1,000	39	D	Yes
Mercury	1/1	0.022	–	–	61	2.3	D	
Nickel	1/1	4.8	–	6,900				
Potassium	1/1	2,700	–	–	–	–	–	
Sodium	1/1	64	–	–	–	–	–	
Vanadium	1/1	18	–	–	1,400	555	D	
Zinc	1/1	64	–	–	61,000	2,300	D	

Notes:
(1) Virginia Department of Environmental Quality Petroleum Program Manual (March 1995)
(2) EPA Region III Soil Screening Levels for Transfers from Soil to Air (Jun – Dec 1995)
(3) EPA Region III RBC Criteria for Industrial/Residential Soils (Jun – Dec 1995)
(4) Weight of Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no evidence in humans
C = Possible human carcinogen
D = Not classified as to carcinogenicity

as COPC. The presence of PAHs would be expected in all shallow soils beneath asphalted areas at other locations (bowling lanes parking lot, admin building parking lots, etc.) at Fort Story as well. Each of these areas would not be considered a "hazardous waste site" requiring a human health risk assessment and potential remediation.

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in three of six surface soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. BTEX and PAHs, hazardous constituents of petroleum products, will be the compounds evaluated in determining petroleum contamination risk, and as stated previously, their concentrations were less than EPA RBC criteria.

Inorganics

Arsenic and manganese exceeded the RBC values for residential soils but did not exceed the industrial soils criteria.

Arsenic was detected in the only surface soil sample collected at a concentration of 1.3 mg/kg. The background 95th percentile UCL established by Montgomery Watson during performance of the PA/SI was 2.1 mg/kg and USGS regional soils data indicates an observed range of less than 0.2 to 73 mg/kg with a mean of 5.4 mg/kg. Therefore, the arsenic level detected in the surface soils is consistent with Fort Story and regional background soils. A summary of background soils data for the inorganics is provided in Appendix H.

Manganese was detected in the only surface soil sample collected at a concentration of 170 mg/kg. Although no background 95th percentile UCL was established by Montgomery Watson during performance of the PA/SI, the USGS regional soils data indicates an observed range of less than 0.2 to 7,000 mg/kg with a mean of 290 mg/kg. Therefore, the manganese level detected in the surface soils is consistent with regional background soils.

Although consistent with background levels, for the purposes of risk analysis, arsenic and manganese are selected as COPCs based on their exceedance of the residential soils criteria.

No other inorganics exceeded EPA RBC values.

Groundwater

Groundwater quality data are summarized in Table 6-26 along with EPA Maximum Contaminant Levels (MCLs) and Action Levels, Virginia Groundwater Standards, Criteria and Protection Levels, and EPA RBC Criteria. Only the dissolved inorganic data is presented in Table 6-26. Total inorganic data are influenced by the percentage of solids in the monitoring well or DPT sampling point and would not be indicative of groundwater quality if a drinking water well was installed at or near the site. The sediment is not available for transport with flowing groundwater and would also be filtered out if drinking water wells were installed in this area.

Ten (10) groundwater samples (6 DPT and 4 monitoring well samples) were collected from the upper aquifer during the field investigation. The number of results for each chemical may vary due to the analysis of different compounds at different locations.

VOCs

Chloroform was detected in excess of the Virginia Groundwater Protection Level and EPA RBC criteria. Although chloroform was detected in only 1 of 10 samples and in a concentration less than the 100 ug/l MCL for total trihalomethanes, it is selected as a COPC. Although detected, methylene chloride concentrations were less than the EPA screening criteria.

SOCs

Two SOCs were detected during groundwater sampling however only bis(2-ethylhexyl)phthalate was detected in excess of the EPA RBC criteria. Therefore, it is selected as a COPC.

TPH

TPH was not detected in any of the groundwater samples.

Inorganics

Dissolved iron was detected at concentrations greater than EPA Secondary MCLs and Virginia Groundwater Criteria. However, these standards were established for aesthetic qualities only, and therefore, iron is not selected as a COPC.

TABLE 6-26
HAZARD ASSESSMENT FOR GROUNDWATER
AUTO CRAFT BUILDING AREA

Parameters	Frequency of Detection	Range of Detection	ARARs				TBC Criteria		EPA Carcinogen Class(7)	Potential Concern?
			EPA MCLs(1)	EPA Secondary MCLs(2)	Virginia GW Stds(3)	Va GW Protection Levels(4)	Virginia GW Criteria(5)	EPA RBC Criteria(6) Tap Water		
VOCs (ug/l)										
Chloroform	1/10	11	100	–	–	5	–	0.15	B2	Yes
Methylene chloride	1/10	3.9	5	–	–	600	–	4.1	B2	
SOCs (ug/l)										
Bis(2-EH)phthalate	1/10	8	–	–	–	–	–	4.8	B2	Yes
Di-n-butylphthalate	1/10	5	–	–	–	–	–	370	–	
TPH (mg/l)										
Total TPH	0/10	BDL	–	–	1	1	–	–	–	
Dissolved Metals (mg/l)										
Calcium	2/2	5.8 – 31	–	–	–	–	–	–	–	
Iron	2/2	0.11 – 8.1	–	0.30	–	–	0.30	–	–	
Magnesium	2/2	3.7 – 4.6	–	–	–	–	–	–	–	
Manganese	1/2	0.08	–	0.05	–	–	0.05	0.018	D	Yes
Potassium	2/2	2.1 – 15	–	–	–	–	–	–	–	
Sodium	2/2	11 – 15	–	–	270	270	100	–	–	

Notes:
(1) U.S. EPA Maximum Contaminant Levels for Drinking Water (40 CFR 141)
(2) U.S. EPA Secondary Maximum Contaminant Levels for Drinking Water (40 CFR 143)
(3) Virginia Groundwater Quality Standards (VR680-21-04)
(4) Virginia Groundwater Protection Levels from Solid Waste Regulations (VR672-20-10)
(5) Virginia Water Quality Criteria for Groundwater (VR680-21-05)
(6) EPA Region III Risk-based Concentration Table for Tap Water (Jun – Dec 1995)

(7) Weight-of-Evidence Classifications
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B1 = Probable human carcinogen, sufficient data in animals
C = Possible human carcinogen
D = Not classified as to carcinogenicity

Dissolved manganese was detected at a concentration greater than the EPA RBC, and therefore, is selected as a COPC.

Subsurface Soils and Soil Leachability

To evaluate the potential exposures to subsurface soils (i.e., future excavation activities) and for the potential leaching of contaminants form soil to groundwater, as shown in Table 6-27, soil analytical data was compared against EPA Region III SSLs for Transfers from Soil to Groundwater and EPA RBC for industrial soils.

Soil sampling was conducted to evaluate the nature and extent of contamination in the surface and subsurface soils at the site. Soil samples were collected from varying depths. Because there are no federal or state standards for soil cleanup, EPA Region III RBC criteria and SSLs are included in Table 6-27 as TBC criteria for purposes of comparison. A total of 18 soil samples were collected during the field investigation.

VOCs

All VOC concentrations were less than the EPA RBC for industrial soils.

Methylene chloride and PCE exceeded EPA SSLs but were detected in only 1 of 18 samples collected and only in shallow soils (0 to 1 foot depth) at one location beneath the asphalt parking lot. The potential for impacts to groundwater quality through leaching is minimal.

SOCs

Benzo(a)pyrene and dibenz(a,h)anthracene exceeded EPA RBC for industrial soils. However, these contaminants were only detected in shallow soils at one location beneath the asphalt parking lot and as previously discussed, are related to asphalt leaching rather than site conditions..

Benzo(a)anthracene, chrysene, and benzo(b)flouranthene exceeded EPA SSLs. However, these contaminants were only detected in shallow soils (0 to 1 foot depth) at one location beneath the asphalt parking lot. Their concentration greatly decreases with depth and the potential for impacts to groundwater quality through additional leaching is minimal.

TABLE 6-27
HAZARD ASSESSMENT FOR SUBSURFACE SOILS AND SOIL LEACHABILITY
AUTO CRAFT BUILDING AREA

Parameter	Frequency of Detection	Range of Detection	TBC Criteria: EPA SSLs Transfers to Groundwater(1)	TBC Criteria: EPA RBC Industrial Soils(2)	EPA Carcinogen Class(3)	Potential Concern?
VOCs (ug/kg)						
Acetone	1/18	31	8,000	20,000,000	D	
Ethylbenzene	1/18	1.6	5,000	20,000,000	D	
Methylene Chloride	1/18	41	10	760,000	B2	
Methyl ethyl ketone	4/18	55 – 100	–	100,000,000	D	
Styrene	1/18	6	2,000	41,000,000	D	
Toluene	10/18	7.9 – 34	5,000	41,000,000	D	
Trichloroethene	1/18	33	20	520,000	B2	
Xylenes	1/18	16	74,000	100,000,000	D	
SOCs (ug/kg)						
Acenaphthene	2/18	70 – 440	200,000	12,000,000	–	
Anthracene	1/18	250	4,300,000	61,000,000	–	
Benzo(a)anthracene	2/18	360 – 2,500	700	7,800	B2	
Benzo(b)fluoranthene	2/18	480 – 4,100	4,000	7,800	B2	
Benzo(k)fluoranthene	2/18	490 – 770	4,000	78,000	B2	
Benzo(g,h,i)perylene	1/18	2,000	–	–	–	
Benzo(a)pyrene	2/18	940 – 3,400	4,000	780	B2	
Butylbenzyphthalate	2/18	230 – 550	68,000	410,000,000	C	
Chrysene	2/18	520 – 2,000	1,000	780,000	B2	
Dibenz(a,h)anthracene	1/18	130	11,000	0.78	B2	
Fluoranthene	2/18	900 – 5,800	980,000	8,200,000	D	
Fluorene	1/18	65	160,000	8,200,000	D	
Indeno(1,2,3–cd)pyrene	2/18	260 – 1,500	35,000	7,800	B2	
Naphthalene	1/18	8.2	30,000	8,200,000	D	
Phenanthrene	2/18	890 – 1,300	–	–	D	
Pyrene	2/18	1,600 – 11,000	1,400,000	6,100,000	D	
TPH (mg/kg)						
Total TPH	6/18	72 – 390	–		–	
Total Metals (mg/kg)						
Aluminum	4/4	440 – 5200	–	100,000	–	
Arsenic	4/4	1.1 – 1.5	15	61	–	
Arsenic (as carcinogen)	4/4	1.1 – 1.5	15	3.8	A	
Barium	4/4	2.8 – 82	32	14,000	–	
Beryllium	1/4	0.058	180	1.3	B2	
Cadmium	1/4	0.18	6	100	D	
Calcium	3/4	84 – 1200	–	–	–	
Chromium	4/4	2.3 – 8.6	–	100,000	–	
Cobalt	2/4	0.79 – 4.4	–	12,000	–	
Copper	2/4	5 – 18	–	8,200	D	
Iron	4/4	1200 – 9100	–	–	–	
Lead	4/4	1.7 – 95	–	400	B2	
Magnesium	4/4	96 – 2400	–	–	–	
Manganese	4/4	10 – 170	–	1,000	D	
Mercury	3/4	0.011 – 0.10	3	61	D	
Nickel	1/4	1.1	21	4,100	–	
Potassium	3/4	130 – 2700	–	–	–	
Sodium	2/4	20 – 64	–	–	–	
Vanadium	4/4	1.8 – 18	–	1,400	D	
Zinc	4/4	4.5 – 64	42,000	61,000	D	

Notes:
(1) EPA Region III Soil Screening Levels for Transfers from Soil to Groundwater (Jun – Dec 1995)
(2) EPA Region III RBC for Industrial Soils (Jun – Dec 1995)
(3) Weight of Evidence Classification:
A = Human carcinogen
B1 = Probable human carcinogen, limited human data
B2 = Probable human carcinogen, sufficient evidence in animals or no human evidence
C = Possible human carcinogen
D = Not classified as to carcinogenicity

TPH

TPH concentrations exceeded the 100 mg/kg TBC criterion in 6 of 18 soil samples. Because TPH is typically used as an indicator of hydrocarbon contamination, it will not be used during this quantitative risk assessment. Although TPH will be compared against the 100 mg/kg criterion, BTEX and PAHs, which are the hazardous constituents of petroleum products, will be the compounds quantitatively evaluated if necessary in determining petroleum contamination risk. Except for the soils impacted by the asphalt leaching, their concentrations were less than EPA RBC and SSL criteria.

Inorganics

Barium was detected in only 1 of 4 samples (82 mg/kg at surface soil sample at soil boring #4) above the 32 mg/kg EPA SSL. The USGS reports the observed barium range in their study was 15 to 1,000 mg/kg with a mean of 300 mg/kg. The barium concentration of 82 mg/kg was detected in the surface soil sample (0 to 1 foot sample) at soil boring #4 while only 7.9 mg/kg of barium was detected in the subsurface soil at the same boring collected at a depth of 2 to 4 feet below land surface indicating little leaching of barium through the unsaturated zone since the site activities ceased over 7 years ago. Therefore, the barium levels do not indicate a potential leaching problem.

Chemicals of Potential Concern

Arsenic and manganese in surface soils and chloroform, bis(2-ethylhexyl)phthalate, and dissolved manganese in groundwater are the COPCs identified during the hazard identification of the Auto Craft media.

Potential risk associated with the COPC will be further evaluated in the exposure assessment section.

6.5.2 Exposure Assessment

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

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 fenced, paved area of the site is currently used as a vehicle impoundment area. The grassy areas located north of the site are unused properties. Fort Story personnel are present at the site for approximately one day per week for only a few minutes. However, because the only surface soil COPCs identified were arsenic and manganese due to exceedance of the residential soils criteria and not the industrial soils criteria, no adverse exposures for Fort Story personnel are anticipated. Although the grassy areas north of the site are not fenced, potential exposures to the general public and/or trespassers would not be significant because their presence on the site would not be expected to be for only a short time and not routine. There is a sidewalk located along Atlantic Avenue but during our field investigations, little pedestrian traffic was observed. Therefore, there are **no exposed populations to the surface soils at the Auto Craft site under the current situation**.

Groundwater is not used in the vicinity of the site for drinking, process, or production purposes. The chief potable water supply in the region is the surface water reservoir system operated by the City of Norfolk. The system includes in-town lakes located near the Norfolk International Airport and other reservoirs (Lake Prince, Western Branch and Burnt Mills) located in Suffolk, Virginia. The in-town lakes are located over 5 miles from Fort Story while the Suffolk lakes are located over 20 miles from the facility. As previously stated in Section 3.1.5, several housing communities located within 1 mile of Fort Story are developing drinking water wells in the shallow aquifer, however, none of these communities are located downgradient of the site. Groundwater use at Fort Story is restricted to withdrawal from a single well located approximately 4,500 feet (cross groundwater flow gradient) from the site at the LARC 60 Maintenance Area of which water is obtained for nonpotable uses only. Therefore, there are **currently no exposed populations to the groundwater at the Auto Craft site.**

Future Land Use

Although construction or excavation activities could be conducted in the future, except for PAHs resulting from asphalt leaching, neither surface nor subsurface soil contaminant concentrations exceeded industrial screening criteria. Therefore, no significant exposures during these activities would be expected because these activities are typically very short term and contaminant concentrations were below screening criteria.

Based on master planning issues for Fort Story, the facility is expected to remain government property. However, due to periodic base closure reviews by the federal government, there is the potential for Fort Story to be closed with subsequent development of the land as commercial or residential properties. In addition, there are several undeveloped areas adjacent to the site where additional base housing could be constructed. Therefore, **as for future conditions, potentially exposed populations include residential exposures to the surface soils and groundwater at the LARC 60 site.**

Exposure Pathways

The potential exposure pathways for future land use at the Auto Craft site include:

- Residential exposure (adults and children) to **contaminated groundwater** through ingestion of drinking water, dermal contact with and inhalation of volatilized chemicals while bathing or showering.

- Residential exposure (adults and children) to **contaminated soil** through ingestion of chemicals.

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 practical quantitation limit (PQL). The PQLs are chemical-specific values that laboratories should be able to routinely and reliably detect and quantitate, but which may vary depending on the medium analyzed and the amount expected to be present in the sample. Adjusting non-detects by assigning values at 1/2 the PQL assumes that a chemical may be present at a concentration just below the reported quantitation limit. One-half the PQL is used as a conservative "proxy" concentration consistent with USEPA guidance. This approach would tend to overestimate the risk.

In this evaluation, data which were qualified by indicating that the numerical value is an estimated quantity are treated in this evaluation the same as data without this qualifier.

Estimates of Contaminant 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 contaminant concentrations in the specific media of concern. Table 6-5 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.

The USEPA recommends that estimates of contaminant 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 contaminant 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. Alternatively, the lognormal distribution is a commonly used probability density model for environmental contamination data. The USEPA (USEPA 1989a) recommends that the upper confidence limit [i.e., the 95th percent upper confidence limit (UCL)] on the mean of all the data should be used for evaluating RMEs. Following this guidance, the equation used in this analysis (Gilbert, 1987) is:

$$UCL = e^{(x + 0.5s*s + Sh/\sqrt{(n-1)})}$$

where:

UCL = 95th percent upper confidence limit on the mean
e = constant (natural log)
x = the mean of the log transformed data
s = the standard deviation of the log transformed data
H = statistic for computing a one-sided upper 95% confidence limit on a lognormal mean
n = sample size

As described previously, for all samples in which the COPC is not detected, a value of 1/2 the PQL for that chemical was assigned. Depending upon the number of non-detects and variability in measured concentrations, the UCL on the mean concentration may occasionally exceed the maximum detected value. Since exposure to chemicals having concentrations greater that 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 5 or greater.

Therefore, for the surface soil COPCs of arsenic and manganese, the maximum concentration will be used because only 1 surface soil sample was collected.

Therefore, for the groundwater COPC of manganese, the maximum concentration will be used because only 2 dissolved groundwater samples for metals analysis were collected.

The 95th percentile UCL concentrations were computed for chloroform and bis(2-ethylhexyl)phthalate in groundwater to estimate the mean concentration. These UCL calculations are provided in Appendix I. The results of the UCL calculations with comparison to the maximum concentration detected are provided in Table 6-28.

TABLE 6-28
COMPARISON OF EXPOSURE CONCENTRATIONS
AUTO CRAFT AREA

POPULATIONS AND PATHWAYS	MAXIMUM CONCENTRATION	95th PERCENTILE UCL
ON-SITE RESIDENTIAL POPULATION - FUTURE LAND USE		
Surface Soils		
Ingestion of Chemicals	mg/kg	mg/kg
Arsenic	**1.3**	NA
Manganese	**170**	NA
Groundwater		
Ingestion of and Dermal Contact with Chemicals	ug/l	ug/l
Manganese	**80**	NA
Bis(2-ethylhexyl)phthalate	8	**3.99**
Chloroform	11	**4.76**
Inhalation of Chemicals Volatilized	mg/m^3	mg/m^3
Chloroform	7.33E-02	**3.17E-02**

Notes:
NA - Not applicable because insufficient number of samples to calculate the 95th percentile UCL.

While the approach used in this evaluation assumes no transformation or loss due to environmental degradation from the current time to the future time when residential development may occur at the site, the environmental fate and transport of chemicals are important in determining the ultimate hazard to people. After a chemical is released to the environment, it may be transformed physically (e.g., by volatilization, precipitation, etc.), chemically (e.g., by photolysis, hydrolysis, oxidation, reduction, etc.), or biologically (e.g., by biodegradation); alternatively, it may be accumulated in one or more media (including biomass) or may be transported (e.g., convected downstream in water or on suspended sediment or through the atmosphere). In Appendix J, the environmental fate and transport mechanisms, as well as a brief toxicological profile, of each of the COPC (only those chemicals where a potential exposure pathway is present) for the HHRA are briefly discussed.

Surface Soil

Table 6-7 presents the parameters and assumptions used in assessing potential exposures to chemicals in surface soil. Minimal exposures due to dermal contact and inhalation are typically present for metals, and therefore, these exposure pathways are not evaluated. In addition, arsenic and manganese did not exceed the EPA Transfer to Air screening criteria further indicating that the inhalation pathway is not significant. The following summarize the assumptions made for exposure to chemicals in soil through ingestion:

- In evaluating inadvertent ingestion of soil (as might result from hand-to-mouth behavior), an average ingestion rate of 100 mg of soil/day is used as representative for age groups greater than 6 years old and 200 mg/day for children ages 1 through 6 (USEPA, 1995a).

- The "fraction ingested" (FI) is based on an estimate of the fraction of soil that is presumed to be contaminated. For this analysis, it is assumed that 50 percent (USEPA, 1995a) of the soil contacted is contaminated with concentrations equivalent to the appropriate representative exposure concentration.

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

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg (USEPA, 1995a) and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- 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.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.4.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

Groundwater

Tables 6-8 through 6-10 present the parameters and assumptions used in assessing potential exposures to chemicals in ground water. In the evaluation of exposures resulting from ground water via ingestion of, dermal contact or inhalation, the following factors and assumptions are used.

Ingestion

- For the ingestion of ground water, an ingestion rate (IR) of 2 liters/day is assumed for residential adults. This represents the 90th percentile value for adult daily water consumption (USEPA, 1995a). For children, an IR of 1 liter/day is assumed (USEPA, 1995a).

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

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- 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.

Dermal Contact

- For the evaluation of dermal contact with chemicals in ground water, it is assumed that the greatest, but not the exclusive, opportunity for exposure is during showering. The entire surface area (SA) of the body is used to evaluate these exposures. For adults, this value is 19,400 cm^2 which represents the 50th percentile total body surface area for an adult male (USEPA, 1989d). The 50th percentile total body SA for a male child is 7,310 cm^2.

  Since the calculated exposure is designed to be the absorbed dose, not the amount of chemical that comes into contact with the skin, a permeability constant (PC) is necessary to access exposure through dermal contact. The PC reflects movement across the skin to the underlying skin layers and into the bloodstream. Chemical-specific PCs are estimated from the octanol/water partition coefficient for the chemical following USEPA guidance (1992b). PCs for the COPC are provided in Appendix I.

- An exposure time (ET) of 18 minutes/day (0.3 hours/day) is assumed for dermal contact with chemicals in groundwater. This is a composite of showering activities as well as household tasks. Twelve minutes per day (0.2 hours/day) represents the 90th percentile value for showering for all age groups (USEPA, 1989d). It is assumed that 6 minutes/day (0.1 hours/day) is spent on miscellaneous task which allow for dermal contact with groundwater.

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

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages 1 through 6, 50th percentile (USEPA, 1995a).

- 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.

Inhalation

- For the evaluation of inhalation of airborne VOCs from the ground water, the contaminant concentration in air is calculated using a simplified approach which assumes that all VOCs of potential concern in the hot water are released during showering. For this calculation, it is assumed that about 200 liters of water are used over the 12 minutes, and the VOCs mix within the volume of the shower area (assumed to be $30m^3$ in volume) to achieve an equilibrium concentration of the chemicals in air. In practice, concentrations would probably build up and plateau during the showering event. However, this analysis assumes exposure to the total amount of VOCs present in the water, with uniform dispersion in the room volume, over the entire shower event, with no loss due to ventilation. The following equation is used to determine the chemical concentration in air based on the above assumptions:

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

CW = chemical concentration in water (ug/l)
CF = conversion factor (1E-03 mg/ug)
WV = volume of water (200 liters)
RV = room volume (30 m^3)

The concentration in air for the chemicals of potential concern are presented in Table 6-20. All concentration-in-air calculations are provided in Appendix I.

- An inhalation rate (IR) of 0.83 m^3/hour for adults is assumed in evaluating the inhalation of vapor phase chemicals in ground water. For a child, ages 1 through 6, the IR is assumed to be 0.5 m^3/hour (USEPA, 1995a).

- Exposure time (ET) for the inhalation pathway is estimated as 12 minutes or 0.2 hours based on the 90th percentile for showering for all ages. There is no information available for differences in the time men, women and children spend showering. Since volatilization may occur from other indoor water uses (such as from the dishwasher, etc.), the 90th percentile for showering for all ages instead of the 50th percentile for all ages is used in estimating exposure time.

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

- An exposure duration (ED) of 30 years is assumed based on the national upper-bound (90th percentile) at one residence for adults and 6 years for children which assumes that the oldest child is under 6 and has lived at that residence since birth (USEPA, 1995a).

- The average weight of an American adult is approximately 70 kg and 15 kg for children ages

1 through 6, 50th percentile (USEPA, 1995a).

- 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.

The chemical-specific, chronic daily intakes for each pathway for each potentially exposed population are presented in Section 6.4.4, Risk Characterization. The exposure estimates so quantified are then compared with health-protective criteria and used to quantify potential health risks.

6.4.3 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 contaminant 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 (USEPA, 1992a); (2) USEPA Health Effects Summary Tables (HEAST) which are tabular presentations of toxicity data (USEPA, 1991c); and (3) Agency for Toxic Substances and Disease Registry (ATSDR) toxicological profiles which contain general toxicity information and levels of exposure associated with lethality, cancer, genotoxicity, neurotoxicity, development and reproductive toxicity, immunotoxicity and systemic toxicity.

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

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 a RfD derived for a similar exposure period. The RfD is an estimate of a daily exposure level for the human population, including sensitive subpopulations, that is 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 6-29, 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, the greater 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.

Reference doses for inhalation exposure, referred to as RfDi, are available for few contaminants at this time. However, a RfDi is not available for chloroform.

TABLE 6-29
TOXICITY VALUES: NON-CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	Chronic RfD (mg/kg-day)	Confidence Level	Critical Effect	RfD Basis/ Source	Uncertainty Factor	Modifying Factors
ORAL ROUTE						
Arsenic	3.00E-04	Medium	Perpigmentation, keratosis and possible vascular complications	Oral/IRIS	3	1
Manganese	5.00E-03	Medium				
Bis(2-EH)phthalate	2.00E-02					
Chloroform	1.00E-02					
INHALATION ROUTE						
Arsenic	---					
Manganese	1.43E-05			IRIS		
Bis(2-EH)phthalate	---					
Chloroform	---					

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
H - Variation in human sensitivity
A - Animal to human extrapolation
S - Extrapolation from Lowest Observed Adverse Effect Level (LOAEL) to No Observed Adverse Effect Level (NOAEL)

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 $(mg/kg\text{-}day)^{-1}$]. This expression incorporates standard pharmacological considerations such as body weight. CPSo data for the COPC are presented in Table 6-30 and are used to estimate finite, upper limits of risk at low dose levels administered over a lifetime. The weight-of-evidence classification for carcinogenicity, the type of cancer associated with each COPC and the basis and source of the CPSo are also presented in Table 6-30.

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

Risk = CDI x CPS
where:

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

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

TABLE 6-30
TOXICITY VALUES: CARCINOGENIC EFFECTS
ORAL and INHALATION ROUTES

COPC	CPS $(mg/kg\text{-}day)^{-1}$	Weight of Evidence Classification	Type of Cancer	SF Basis	SF Source
ORAL ROUTE					
Arsenic	1.50E+00	A	Gross tumors	Oral	IRIS
Bis(2-EH)phthalate	1.40E-02	B2			
Chloroform	6.10E-03	B2			
INHALATION ROUTE					
Arsenic	1.51E+01	A			
Bis(2-EH)phthalate	---	B2			
Chloroform	8.05E-02	B2			

Notes:
-- - Not available
IRIS - Integrated Risk Information System (USEPA database)
HEAST - Health Effects Assessment Summary Tables
NCEA - EPA Provisional Guidance

As with RfDs, there are no assigned CPS values for dermal exposure. In their absence, CPS factors for oral exposures (denoted as CPSo) are used and adjusted to reflect absorbed dose. This allows for comparison between exposures estimated as absorbed doses and toxicity values expressed as absorbed doses. The same absorption factors used to adjust RfDs are applied in adjusting CPSo values.

CPS values for inhalation exposure, referred to as CPSi, are available for few contaminants at this time. However, a CPSi is available for chloroform.

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 which 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 contaminant 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 contaminants involved (i.e., that there are no synergistic or antagonistic chemical interactions and all chemicals produce the same effect, i.e., cancer).

6.4.4 Risk Characterization

The final step in the HHRA 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.

Potential non-cancer health effects, those associated with long-term chronic exposure to surface soils and groundwater at the site for potential future residential populations are presented. Carcinogenic risks are similarly presented for the COPC, for each pathway of concern and for each potential exposed population. The cumulative impact of exposure from the various pathways evaluated is estimated, for the residential populations (adults and children) including ingestion of chemicals in surface soils and ingestion of, dermal contact with and inhalation of volatilized chemicals in groundwater.

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 I. As indicated in the following tables, the oral RfDs and CPSs have been adjusted for absorption to match the absorbed dose for dermal exposure.

Non-cancer Risks

Table 6-31 presents the chemical-specific hazard quotients for each pathway involving surface soils and groundwater. In addition, the total pathway risk, also referred to as the hazard index, which is the sum of the chemical-specific hazard quotients for each pathway are presented in Table 6-31. The total exposure risk incorporates all the appropriate exposure pathways for the residential populations.

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 6-31, the total exposure hazard index for ingestion of soils and ingestion of and dermal contact with chemicals in groundwater is less than the criterion of 1.0 for adults but greater than the criterion for children. Thus, adverse non-carcinogen health effects in this residential population (children) are likely. The majority of this risk is associated with ingestion of manganese in groundwater. In addition, ingestion of manganese in groundwater is the only exposure scenario above the criterion.

Cancer Risks

Table 6-32 presents estimated chemical-specific and total pathway cancer risks calculated for

TABLE 6-31
CHRONIC HAZARD INDEX ESTIMATES (NONCANCER EFFECTS)
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg-day)	CDI Adjusted For Absorption	RfD (mg/kg-day)	Hazard Quotient	Pathway Hazard Index
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic Manganese	8.90E-07 1.60E-04	No No	3.00E-04 5.00E-03	2.97E-03 3.20E-02	3.50E-02
Ingestion of COPC in Groundwater	Manganese Bis(2-ethylhexyl)phthalate Chloroform	2.19E-03 1.09E-04 1.30E-04	No No No	5.00E-03 2.00E-02 1.00E-02	4.38E-01 5.45E-03 1.30E-02	4.56E-01
Dermal Contact with COPC in Groundwater	Manganese Bis(2-ethylhexyl)phthalate Chloroform	3.19E-06 1.01E-05 1.12E-05	Yes Yes Yes	5.00E-03 2.00E-02 1.00E-02	6.38E-04 5.05E-04 1.12E-03	2.26E-03
Inhalation of Volatilized COPC in Groundwater	Chloroform	7.21E-05	No	---	---	---
					Total Exposure Hazard Index	**4.94E-01**
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic Manganese	8.31E-06 1.09E-03	No No	3.00E-04 5.00E-03	2.77E-02 2.18E-01	2.46E-01
Ingestion of COPC in Groundwater	Manganese Bis(2-ethylhexyl)phthalate Chloroform	5.11E-03 2.55E-04 3.04E-04	No No No	5.00E-03 2.00E-02 1.00E-02	1.02E+00 1.28E-02 3.04E-02	1.07E+00
Dermal Contact with COPC in Groundwater	Manganese Bis(2-ethylhexyl)phthalate Chloroform	5.61E-06 1.77E-04 1.97E-05	Yes Yes Yes	5.00E-03 2.00E-02 1.00E-02	1.12E-03 8.85E-03 1.97E-03	1.19E-02
Inhalation of Volatilized COPC in Groundwater	Chloroform	2.03E-04	No	---	---	---
					Total Exposure Hazard Index	**1.32E+00**

Notes:
CDI = Chronic Daily Intake
RfD = Reference dose
Hazard Quotient = CDI/RfD

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TABLE 6-32
CANCER RISK ESTIMATES
RESIDENTIAL POPULATIONS

Exposure Pathway	COPC	CDI (mg/kg-day)	CDI Adjusted For Absorption	CPS $(mg/kg-day)^{-1}$	Chemical-Specific Risk	Total Pathway Risk
ADULTS						
Ingestion of COPC in Surface Soils	Arsenic	3.82E-07	No	1.50E+00	5.73E-07	5.73E-07
Ingestion of COPC in Groundwater	Bis(2-ethylhexyl)phthalate Chloroform	4.68E-05 5.59E-05	No No	1.40E-02 6.10E-03	6.55E-07 3.41E-07	9.96E-07
Dermal Contact with COPC in Groundwater	Bis(2-ethylhexyl)phthalate Chloroform	4.31E-06 4.80E-06	Yes Yes	1.40E-02 6.10E-03	6.03E-08 2.93E-08	8.96E-08
Inhalation of Volatilized COPC in Groundwater	Chloroform	3.09E-05	No	8.05E-02	2.49E-06	2.49E-06
					Total Exposure Hazard Index	**4.15E-06**
CHILDREN						
Ingestion of COPC in Surface Soils	Arsenic	7.12E-07	No	1.50E+00	1.07E-06	1.07E-06
Ingestion of COPC in Groundwater	Bis(2-ethylhexyl)phthalate Chloroform	2.19E-05 2.61E-05	No No	1.40E-02 6.10E-03	3.07E-07 1.59E-07	4.66E-07
Dermal Contact with COPC in Groundwater	Bis(2-ethylhexyl)phthalate Chloroform	1.52E-06 1.69E-06	Yes Yes	1.40E-02 6.10E-03	2.13E-08 1.03E-08	3.16E-08
Inhalation of Volatilized COPC in Groundwater	Chloroform	1.74E-05	No	8.05E-02	1.40E-06	1.40E-06
					Total Exposure Hazard Index	**2.97E-06**

Notes:
CDI = Chronic Daily Intake
CPS - Cancer Potency Slope
Chemical specific Risk = CDI x CPS

ingestion of soils and ingestion of, dermal contact with, and inhalation of chemicals in groundwater. The estimated total exposure cancer risks are also noted in this table, incorporating all the appropriate exposure pathways for the residential populations.

The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 4 in 1 million for adults and 3 in 1 million for children. These values are within the USEPA Superfund remediation goal of 10^{-4} (1 in ten thousand) to 10^{-6} (1 in one million) which serves as the target for site cleanup. The greatest component for adult exposure is inhalation of chloroform in groundwater which was the only exposure scenario within the USEPA remediation goal. For child exposures, both ingestion of arsenic in soils and inhalation of chloroform in groundwater were within the USEPA remediation goal.

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 chemicals of potential concern provides uncertainty since the selection process relies heavily on professional judgment. If different chemicals of concern were chosen or if some were excluded the estimates of risk would be affected.

Model input parameters and assumptions that tend to overestimate exposure were used in the exposure assessment. For example, the "representative" concentrations used in /some of the analyses were the maximum concentration detected. This may overestimate risk. Also, frequent exposure to contaminants is considered even though exposures may occur infrequently or not at all. 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 the Auto Craft site, some important uncertainties that may influence the results of the HHRA include:

- Limited data set for arsenic and manganese in soils at the site. Only 1 surface soil sample was analyzed for metals. However, these levels were consistent with background soils data as discussed in Section 6.4.1.

- Limited data set for dissolved manganese in groundwater. Only 2 dissolved groundwater samples were collected and analyzed for metals at the site. Therefore, the maximum concentration of 80 ug/ for manganese was used in the risk analysis which may bias the results high. Additional groundwater analysis for dissolved metals would present a larger data set and provide for a more accurate analysis of risk.

- Dissolved data is a function of filtering efficiency in the field. Some of the monitoring well samples were very turbid and required extensive settling prior to filtering. Dissolved results may be biased high based on the filtering limitations.

- VOC estimates for non-carcinogenic and cancer risk may be biased high because of the use of 2.5 ug/l (which is 1/2 the PQL) in the UCL calculations. Chloroform was detected infrequently (1 of 10 samples). Analysis with a lower PQL may more accurately estimate VOC concentrations and subsequent risk. It should be noted that the chloroform concentration (11 ug/l) detected was less than the USEPA MCL (100 ug/l) for total trihalomethanes indicating that the level present in the groundwater would meet acceptable criteria for a drinking water distribution system.

6.4.5 Auto Craft Site HHRA Summary and Conclusions

The results of the HHRA for non-carcinogenic and carcinogenic risks and associated conclusions are summarized as follows:

- A summary of the **Non-Carcinogenic Risk** for future residential land use is provided below:

    - The total exposure hazard index for ingestion of soils and ingestion of and dermal contact with chemicals in groundwater is less than the criterion for adults but greater than the criterion of 1.0 for children with the majority (approximately 77 percent) of this risk associated with ingestion of manganese in groundwater which was the only exposure scenario above the criterion.

- A summary of the **Carcinogenic Risk** [for future residential land use.] is provided below:

  - The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 4 in 1 million for adults. The greatest component for adults exposures is inhalation of chloroform in groundwater (60 percent of total risk) which was ~~the only exposure scenario~~ within the USEPA remediation goal. [remove]

  - The estimated cancer risk for exposure to chemicals in surface soils and groundwater is about 3 in 1 million for children. The greatest components for child exposures are ingestion of arsenic (although levels are consistent with background) in soils (36 percent of total risk) and inhalation of chloroform in groundwater (47 percent of total risk).

- Potential risk above acceptable criteria is only present for the future scenario of residential development at the site, and not for the current situation or future situations involving industrial activities.

- Because residential development would not be expected at the site for many years even if base closure were to occur in the future, the concentration of chloroform in groundwater due to natural attenuation would be expected to decrease. It currently is below the USEPA MCL for total trihalomethanes. [This is true, however chloroform is not the driving risk at the site.]

- Additional sampling as previously discussed in the Uncertainties Section may also present sufficient data for a more accurate analysis of risk for metals in groundwater and surface soils for future residential development.

APPENDIX H

BACKGROUND SOILS DATA

FTA SURFACE SOIL AND SEDIMENT COMPARISON

Parameters	Surface Soil Results (mg/kg)		Sediment Results (mg/kg)		Fort Story Background 95th UCL [1]	USGS Regional Soils Data [2]	
	Surface Soil Range	Mean	Sediment Range	Mean		Observed Range	Mean
Aluminum	420 – 980	676	160 – 7,600	2,120	Not analyzed	7,000 – > 100,000	33,000
Arsenic	1.2 – 1.6	1.3	2.5	1.1	2.1	< 0.2 – 73	5.4
Barium	3.9 – 12	8.4	2.4 – 110	30.6	5	15 – 1,000	300
Calcium	71 – 370	153	64 – 120	95	Not analyzed	< 100 – 160,000	3,200
Chromium	1.7 – 5.8	3.1	21	5.7	2.8	1 – 100	36
Cobalt	Not detected	– –	2.6	1.1	Not analyzed	< 3 – 70	7
Copper	3.2 – 13	5.9	26	7.6	1.4	< 1 – 150	14
Iron	1,200 – 5,400	2,700	230 – 17,000	4,488	Not analyzed	100 – > 100,000	15,000
Lead	7 – 33	24	4.3 – 210	59.1	7.1	< 7 – 300	14
Magnesium	62 – 190	112	960	262	Not analyzed	50 – 50,000	2,300
Manganese	10 – 34	24	1.7 – 42	11.9	Not analyzed	< 2 – 7,000	290
Mercury	0.011 – 0.013	0.008	0.017 – 0.051	0.045	0.01	0.01 – 0.34	0.096
Nickel	Not detected	– –	9.4	4.1	2	< 3 – 700	13
Potassium	160	74	260	110	Not analyzed	50 – 37,000	7,400
Sodium	Not detected	– –	87 – 180	80	Not analyzed	< 200 – 15,000	2,600
Thallium	Not detected	– –	1.4	0.8	Not analyzed	– –	– –
Vanadium	1.8 – 3.7	2.7	2 – 18	5	Not analyzed	< 5 – 300	46
Zinc	14 – 22	18	6 – 76	21	5.7	< 5 – 400	36

0285–588–330

FTA SURFACE SOIL RESULTS

Parameters	Surface Soil Results (mg/kg)					Arithmetic Mean
Aluminum	420.00	850.00	980.00	490.00	640.00	676
Arsenic	0.55	1.50	1.60	1.20	1.40	1.25
Barium	3.90	9.00	12.00	8.00	9.20	8.42
Calcium	71.00	150.00	370.00	26.00	150.00	153.40
Chromium	1.70	2.30	3.10	5.80	2.50	3.08
Copper	3.50	5.70	4.30	13.00	3.20	5.94
Iron	1200.00	3200.00	2100.00	5400.00	1600.00	2700.00
Lead	7.00	33.00	33.00	15.00	31.00	23.80
Magnesium	88.00	100.00	190.00	62.00	120.00	112.00
Manganese	10.00	34.00	25.00	32.00	19.00	24.00
Mercury	0.0055	0.0055	0.0110	0.0050	0.0130	0.0080
Potassium	55.00	55.00	160.00	50.00	50.00	74.00
Vanadium	1.80	3.10	3.70	1.80	3.10	2.70
Zinc	18.00	14.00	22.00	15.00	22.00	18.20

FTA SEDIMENT RESULTS

Parameters	Sediment Results (mg/kg)					Arithmetic Mean
Aluminum	7600.00	560.00	160.00	160.00	[redacted]	2120.00
Arsenic	2.50	0.70	0.55	0.55	[redacted]	1.08
Barium	110.00	6.50	3.60	2.40	[redacted]	30.63
Calcium	120.00	120.00	64.00	77.00	[redacted]	95.25
Chromium	21.00	0.70	0.55	0.55	[redacted]	5.70
Cobalt	2.60	0.70	0.55	0.55	[redacted]	1.10
Copper	26.00	1.80	1.35	1.35	[redacted]	7.63
Iron	17000.00	440.00	230.00	280.00	[redacted]	4487.50
Lead	210.00	15.00	7.20	4.30	[redacted]	59.13
Magnesium	960.00	35.50	26.50	27.00	[redacted]	262.25
Manganese	42.00	0.70	3.10	1.70	[redacted]	11.88
Mercury	0.0510	0.0170	0.0550	0.0550	[redacted]	0.045
Nickel	9.40	2.85	2.15	2.15	[redacted]	4.14
Potassium	260.00	70.00	55.00	55.00	[redacted]	110.00
Sodium	180.00	87.00	26.50	27.00	[redacted]	80.13
Thallium	0.70	1.40	0.55	0.55	[redacted]	0.80
Vanadium	18.00	2.00	0.55	0.55	[redacted]	5.28
Zinc	76.00	6.00	1.05	1.10	[redacted]	21.04

LARC 60 SURFACE SOIL AND SEDIMENT COMPARISON

Parameters	Surface Soil Results (mg/kg)		Sediment Results (mg/kg)		Fort Story Background 95th UCL (1)	USGS Regional Soils Data (2)	
	Surface Soil Range	Mean	Sediment Range	Mean		Observed Range	Mean
Aluminum	250 – 2,700	814	310 – 650	2,120	Not analyzed	7,000 – > 100,000	33,000
Arsenic	1.1	0.6	Not detected	– –	2.1	< 0.2 – 73	5.4
Barium	1.8 – 19	6.9	1.4 – 2.7	2.1	5	15 – 1,000	300
Calcium	56 – 980	266	53 – 210	132	Not analyzed	< 100 – 160,000	3,200
Chromium	1.7 – 4.3	2.8	1.6 – 2.5	2.1	2.8	1 – 100	36
Cobalt	2.3	0.86	Not detected	– –	Not analyzed	< 3 – 70	7
Copper	2.5 – 41	13.2	3.8 – 9	6.4	1.4	< 1 – 150	14
Iron	400 – 1,100	770	310 – 940	675	Not analyzed	100 – > 100,000	15,000
Lead	3.1 – 12	8	8.2 – 14	11.1	7.1	< 7 – 300	14
Magnesium	77 – 1,400	341	110 – 250	180	Not analyzed	50 – 50,000	2,300
Manganese	2.4 – 120	29.4	3.4 – 6.9	5.2	Not analyzed	< 2 – 7,000	290
Mercury	Not detected	– –	Not detected	– –	0.01	0.01 – 0.34	0.096
Nickel	Not detected	– –	Not detected	– –	2	< 3 – 700	13
Potassium	1,200	280	Not detected	– –	Not analyzed	50 – 37,000	7,400
Sodium	Not detected	– –	70	51	Not analyzed	< 200 – 15,000	2,600
Thallium	Not detected	– –	Not detected	– –	Not analyzed	– –	– –
Vanadium	1.2 – 9.2	3.1	1.3 – 2.7	2	Not analyzed	< 5 – 300	46
Zinc	3.8 – 33	16.2	11 – 30	21	5.7	< 5 – 400	36

LARC 60 SURFACE SOIL RESULTS

Parameters	Surface Soil Results (mg/kg)					Arithmetic Mean
Aluminum	2700.00	310.00	440.00	250.00	370.00	814
Arsenic	1.10	0.50	0.50	0.50	0.50	0.62
Barium	19.00	3.90	3.70	1.80	5.90	6.86
Calcium	980.00	160.00	110.00	25.50	56.00	266.30
Chromium	4.30	2.40	2.30	1.70	3.20	2.78
Cobalt	2.30	0.50	0.50	0.50	0.50	0.86
Copper	9.10	41.00	1.30	2.50	12.00	13.18
Iron	510.00	1000.00	1100.00	400.00	840.00	770.00
Lead	7.60	11.00	6.40	3.10	12.00	8.02
Magnesium	1400.00	94.00	110.00	25.50	77.00	341.30
Manganese	120.00	12.00	7.20	2.40	5.60	29.44
Potassium	1200.00	50.00	50.00	50.00	50.00	280.00
Vanadium	9.20	1.60	1.90	1.20	1.80	3.14
Zinc	26.00	33.00	6.40	3.80	12.00	16.24

LARC 60 SEDIMENT RESULTS

Parameters	Sediment Results (mg/kg)					Arithmetic Mean
Aluminum	310.00	650.00	[redacted]			480.00
Barium	1.40	2.70				2.05
Calcium	53.00	210.00				131.50
Chromium	1.60	2.50				2.05
Copper	3.80	9.00				6.40
Iron	410.00	940.00				675.00
Lead	8.20	14.00				11.10
Magnesium	110.00	250.00				180.00
Manganese	3.40	6.90				5.15
Sodium	32.00	70.00				51.00
Vanadium	1.30	2.70				2.00
Zinc	11.00	30.00				20.50

APPENDIX I

RISK ASSESSMENT CALCULATIONS

95th percent UCL Calculations for Groundwater COPCs

Auto Craft Building Area
Fort Story, Virginia

Sample Point	Results	Natural Log	Chloroform	
7MW-2	2.5	0.9163	# Of Samples	9
7MW-3/MW-119*	11	2.3979	Mean of Log Transformed Data	1.080913
MW-120	2.5	0.9163	Standard Deviation	0.465623
DPT #1	2.5	0.9163	Variance	0.216805
DPT #2	2.5	0.9163	H Value	2.251
DPT #3	2.5	0.9163	**95th Percentile UCL**	**4.76**
DPT #4	2.5	0.9163	**for Chloroform**	
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		

Sample Point	Results	Natural Log	Bis(2-ethylhexyl)phthalate	
7MW-2	2.5	0.9163	# Of Samples	9
7MW-3/MW-119*	2.5	0.9163	Mean of Log Transformed Data	1.045530
MW-120	2.5	0.9163	Standard Deviation	0.365543
DPT #1	2.5	0.9163	Variance	0.133622
DPT #2	2.5	0.9163	H Value	2.11
DPT #3	2.5	0.9163	**95th Percentile UCL**	**3.99**
DPT #4	2.5	0.9163	**for Bis(2-ethylhexyl)phthalate**	
DPT #5	8	2.0794		
DPT #6	2.5	0.9163		

* – Highest concentration used for the deep/shallow well cluster at the site

CDI CALCULATIONS FOR SURFACE SOILS

AUTO CRAFT AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	1.3	100	1.00E–06	0.5	350	30	70	8.90E–07
Manganese (Adults)	170	100	1.00E–06	0.5	350	30	70	1.16E–04
Arsenic (Children)	1.3	200	1.00E–06	0.5	350	6	15	8.31E–06
Manganese (Children)	170	200	1.00E–06	0.5	350	6	15	1.09E–03
Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	1.3	100	1.00E–06	0.5	350	30	70	3.82E–07
Arsenic (Children)	1.3	200	1.00E–06	0.5	350	6	15	7.12E–07

CDI CALCULATIONS FOR GROUNDWATER
AUTO CRAFT AREA, FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater

Chemical	Conc	IR	EF	ED	BW	CDI
Manganese (Adults)	0.08	2	350	30	70	2.19E−03
Bis (Adults)	0.00399	2	350	30	70	1.09E−04
Chloroform (Adults)	0.00476	2	350	30	70	1.30E−04
Manganese (Children)	0.08	1	350	6	15	5.11E−03
Bis (Children)	0.00399	1	350	6	15	2.55E−04
Chloroform (Children)	0.00476	1	350	6	15	3.04E−04

Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater

Chemical	Conc	IR	EF	ED	BW	CDI
Bis (Adults)	0.00399	2	350	30	70	4.68E−05
Chloroform (Adults)	0.00476	2	350	30	70	5.59E−05
Bis (Children)	0.00399	1	350	6	15	2.19E−05
Chloroform (Children)	0.00476	1	350	6	15	2.61E−05

Non–Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	SA	PC	ET	EF	ED	CF	BW	CDI
Manganese (Adults)	0.08	19400	5.00E−04	0.3	350	30	0.001	70	3.19E−06
Bis (Adults)	0.00399	19400	3.16E−02	0.3	350	30	0.001	70	1.01E−05
Chloroform (Adults)	0.00476	19400	2.95E−02	0.3	350	30	0.001	70	1.12E−05
Manganese (Children)	0.08	7310	5.00E−04	0.3	350	6	0.001	15	5.61E−06
Bis (Children)	0.00399	7310	3.16E−02	0.3	350	6	0.001	15	1.77E−05
Chloroform (Children)	0.00476	7310	2.95E−02	0.3	350	6	0.001	15	1.97E−05

Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	IR	EF	ET	EF	ED	CF	BW	CDI
Bis (Adults)	0.00399	19400	3.16E−02	0.3	350	30	0.001	70	4.31E−06
Chloroform (Adults)	0.00476	19400	2.95E−02	0.3	350	30	0.001	70	4.80E−06
Bis (Children)	0.00399	7310	3.16E−02	0.3	350	6	0.001	15	1.52E−06
Chloroform (Children)	0.00476	7310	2.95E−02	0.3	350	6	0.001	15	1.69E−06

Non–Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater

Chemical	Conc	SA	ET	EF	ED	BW	CDI
Chloroform (Adults)	0.0317	0.83	0.2	350	30	70	7.21E−05
Chloroform (Children)	0.0317	0.5	0.2	350	6	15	2.03E−04

Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater

Chemical	Conc	IR	ET	EF	ED	BW	CDI
Chloroform (Adults)	0.0317	0.83	0.2	350	30	70	3.09E−05
Chloroform (Children)	0.0317	0.5	0.2	350	6	15	1.74E−05

95th percent UCL Calculations for Soil and Sediment COPC

Firefighter Training Area
Fort Story, Virginia

Surface Soil/Sediment Sample Point	Arsenic Results	Natural Log		
SB-001	0.55	-0.5978	# Of Samples	9
SB-005	1.5	0.4055	Mean of Log Transformed Data	0.017819
SB-010	1.6	0.4700	Standard Deviation	0.534159
SB-015	1.2	0.1823	Variance	0.285326
SB-020	1.4	0.3365	H Value	2.359
SD-001	2.5	0.9163	**95th Percentile UCL**	**1.83**
SD-002	0.7	-0.3567		
SD-003	0.55	-0.5978		
SD-004	0.55	-0.5978		

Surface Soil/Sediment Sample Point	Thallium Results	Natural Log		
SB-001	0.55	-0.5978	# Of Samples	9
SB-005	0.55	-0.5978	Mean of Log Transformed Data	-0.488409
SB-010	0.55	-0.5978	Standard Deviation	0.305776
SB-015	0.5	-0.6931	Variance	0.093499
SB-020	0.5	-0.6931	H Value	2.033
SD-001	0.7	-0.3567	**95th Percentile UCL**	**0.80**
SD-002	1.4	0.3365		
SD-003	0.55	-0.5978		
SD-004	0.55	-0.5978		

95th percent UCL Calculations for Groundwater COPC

Firefighter Training Area
Fort Story, Virginia

Sample Point	PCE Results	Natural Log		
4MW-1	2.5	0.9163	# Of Samples	31
4MW-2S/4MW-2D*	2.5	0.9163	Mean of Log Transformed Data	1.057595
4MW-3	2.5	0.9163	Standard Deviation	0.624787
4MW-4	2.5	0.9163	Variance	0.390359
4MW-5/MW-112*	2.5	0.9163	H Value	2.033
MW-111	2.5	0.9163	**95th Percentile UCL**	**4.41**
MW-113A	2.5	0.9163		
MW-114A	2.5	0.9163		
DPT #1	2.5	0.9163		
DPT #2	6.4	1.8563		
DPT #3	2.5	0.9163		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	78	4.3567		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #14**	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #17	2.5	0.9163		
DPT #18	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #22	2.5	0.9163		
DPT #23	2.5	0.9163		

* – Highest concentration used for the deep/shallow well clusters present at the site.
** – Highest concentration used for two DPT depths sampled at this point.

CDI CALCULATIONS FOR SURFACE SOILS AND SEDIMENT

FIREFIGHTER TRAINING AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	1.83	100	1.00E–06	0.5	350	30	70	1.25E–06
Thallium (Adults)	0.8	100	1.00E–06	0.5	350	30	70	5.48E–07
Arsenic (Children)	1.83	200	1.00E–06	0.5	350	6	15	1.17E–05
Thallium (Children)	0.8	200	1.00E–06	0.5	350	6	15	5.11E–06
Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	1.83	100	1.00E–06	0.5	350	30	70	5.37E–07
Arsenic (Children)	1.83	200	1.00E–06	0.5	350	6	15	1.00E–06

CDI CALCULATIONS FOR GROUNDWATER
FIREFIGHTER TRAINING AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater

Chemical	Conc	IR	EF	ED	BW	CDI
Manganese (Adults)	0.081	2	350	30	70	2.22E–03
PCE (Adults)	0.00441	2	350	30	70	1.21E–04
Manganese (Children)	0.081	1	350	6	15	5.18E–03
PCE (Children)	0.00441	1	350	6	15	2.82E–04

Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater

Chemical	Conc	IR	EF	ED	BW	CDI
PCE (Adults)	0.00441	2	350	30	70	5.18E–05
PCE (Children)	0.00441	1	350	6	15	2.42E–05

Non–Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	SA	PC	ET	EF	ED	CF	BW	CDI
Manganese (Adults)	0.081	19400	5.00E–04	0.3	350	30	0.001	70	3.23E–06
PCE (Adults)	0.00441	19400	2.40E–03	0.3	350	30	0.001	70	8.44E–07
Manganese (Children)	0.081	7310	5.00E–04	0.3	350	6	0.001	15	5.68E–06
PCE (Children)	0.00441	7310	2.40E–03	0.3	350	6	0.001	15	1.48E–06

Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	SA	PC	ET	EF	ED	CF	BW	CDI
PCE (Adults)	0.00441	19400	2.40E–03	0.3	350	30	0.001	70	3.62E–07
PCE (Children)	0.00441	7310	2.40E–03	0.3	350	6	0.001	15	1.27E–07

Non–Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater

Chemical	Conc	IR	ET	EF	ED	BW	CDI
PCE (Adults)	0.0294	0.83	0.2	350	30	70	6.69E–05
PCE (Children)	0.0294	0.5	0.2	350	6	15	1.88E–04

Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater

Chemical	Conc	IR	ET	EF	ED	BW	CDI
PCE (Adults)	0.0294	0.83	0.2	350	30	70	2.87E–05
PCE (Children)	0.0294	0.5	0.2	350	6	15	1.61E–05

95th percent UCL Calculations for Soil COPCs

LARC 60 Maintenance Area
Fort Story, Virginia

Surface Soil Sample Point	Arsenic Results	Natural Log		
SB-001	1.1	0.0953	# Of Samples	5
SB-005	0.5	-0.6931	Mean of Log Transformed Data	-0.535456
SB-010	0.5	-0.6931	Standard Deviation	0.315383
SB-015	0.5	-0.6931	Variance	0.099466
SB-020	0.5	-0.6931	H Value	2.44
			95th Percentile UCL for Arsenic	**0.90**

Surface Soil Sample Point	Manganese Results	Natural Log		
SB-001	120	4.7875	# Of Samples	5
SB-005	12	2.4849	Mean of Log Transformed Data	2.368943
SB-010	7.2	1.9741	Standard Deviation	1.316568
SB-015	2.4	0.8755	Variance	1.733350
SB-020	5.6	1.7228	H Value	6.314
			95th Percentile UCL for Manganese	**1622.98**

95th percent UCL Calculations for Groundwater COPCs – LARC 60 Site

Sample Point	Results	Natural Log	cis 1,2–DCE	
6MW–1	2.5	0.9163	# Of Samples	25
6MW–2/MW–117*	20	2.9957	Mean of Log Transformed Data	1.259879
6MW–2S/6MW–2D*	2.5	0.9163	Standard Deviation	0.950236
6MW–3	2.5	0.9163	Variance	0.902948
MW–115	2.5	0.9163	H Value	2.445
MW–118	2.5	0.9163	**95th Percentile UCL**	**8.90**
DPT #1	2.5	0.9163	**for cis 1,2–DCE**	
DPT #2/DPT #17**	150	5.0106		
DPT #3	20	2.9957		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	3.5	1.2528		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

Sample Point	Results	Natural Log	Ethylbenzene	
6MW–1	2.5	0.9163	# Of Samples	25
6MW–2/MW–117*	66	4.1897	Mean of Log Transformed Data	1.352869
6MW–2S/6MW–2D*	2.5	0.9163	Standard Deviation	1.221658
6MW–3	2.5	0.9163	Variance	1.492448
MW–115	2.5	0.9163	H Value	2.808
MW–118	2.5	0.9163	**95th Percentile UCL**	**16.43**
DPT #1	2.5	0.9163	**for Ethylbenzene**	
DPT #2/DPT #17**	530	6.2729		
DPT #3	2.5	0.9163		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	6.6	1.8871		
DPT #12	2.5	0.9163		
DPT #13	9.3	2.2300		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

Sample Point	Results	Natural Log	PCE	
6MW–1	2.5	0.9163	# Of Samples	25
6MW–2/MW–117*	8.5	2.1401	Mean of Log Transformed Data	1.300377
6MW–2S/6MW–2D*	2.5	0.9163	Standard Deviation	0.987148
6MW–3	2.5	0.9163	Variance	0.974462
MW–115	2.5	0.9163	H Value	2.491
MW–118	2.5	0.9163	**95th Percentile UCL**	**9.87**
DPT #1	2.5	0.9163	**for PCE**	
DPT #2/DPT #17**	25	3.2189		
DPT #3	170	5.1358		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	16	2.7726		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

Sample Point	Results	Natural Log	Toluene	
6MW–1	2.5	0.9163	# Of Samples	25
6MW–2/MW–117*	68	4.2195	Mean of Log Transformed Data	1.357217
6MW–2S/6MW–2D*	2.5	0.9163	Standard Deviation	1.454673
6MW–3	2.5	0.9163	Variance	2.116072
MW–115	2.5	0.9163	H Value	3.143
MW–118	2.5	0.9163	**95th Percentile UCL**	**28.46**
DPT #1	2.5	0.9163	**for Toluene**	
DPT #2/DPT #17**	2200	7.6962		
DPT #3	2.5	0.9163		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	6.4	1.8563		
DPT #10	2.5	0.9163		
DPT #11	2.5	0.9163		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

* – Highest concentration used for the deep/shallow well clusters present at the site.

** – Highest concentration used for two DPT depths sampled at this point.

95th percent UCL Calculations for Groundwater COPCs – LARC 60 Site

Sample Point	Results	Natural Log	TCE	
6MW-1	2.5	0.9163	# Of Samples	25
6MW-2/MW-117*	18	2.8904	Mean of Log Transformed Data	1.426818
6MW-2S/6MW-2D*	2.5	0.9163	Standard Deviation	1.230747
6MW-3	2.5	0.9163	Variance	1.514738
MW-115	2.5	0.9163	H Value	2.822
MW-118	2.5	0.9163	**95th Percentile UCL**	**18.05**
DPT #1	2.5	0.9163	**for TCE**	
DPT #2/DPT #17**	47	3.8501		
DPT #3	260	5.5607		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	62	4.1271		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

Sample Point	Results	Natural Log	Xylenes	
6MW-1	2.5	0.9163	# Of Samples	25
6MW-2/MW-117*	290	5.6699	Mean of Log Transformed Data	1.496466
6MW-2S/6MW-2D*	2.5	0.9163	Standard Deviation	1.687983
6MW-3	2.5	0.9163	Variance	2.849286
MW-115	2.5	0.9163	H Value	3.513
MW-118	2.5	0.9163	**95th Percentile UCL**	**62.27**
DPT #1	2.5	0.9163	**for Xylenes**	
DPT #2/DPT #17**	2900	7.9725		
DPT #3	2.5	0.9163		
DPT #4	2.5	0.9163		
DPT #5	2.5	0.9163		
DPT #6	2.5	0.9163		
DPT #7	2.5	0.9163		
DPT #8	2.5	0.9163		
DPT #9	2.5	0.9163		
DPT #10	2.5	0.9163		
DPT #11	37	3.6109		
DPT #12	2.5	0.9163		
DPT #13	2.5	0.9163		
DPT #15	2.5	0.9163		
DPT #16	2.5	0.9163		
DPT #19	2.5	0.9163		
DPT #20	2.5	0.9163		
DPT #21	2.5	0.9163		
DPT #24	2.5	0.9163		

* – Highest concentration used for the deep/shallow well clusters present at the site.
** – Highest concentration used for two DPT depths sampled at this point.

CDI CALCULATIONS FOR SURFACE SOILS

LARC 60 MAINTENANCE AREA
FORT STORY, VIRGINIA

Non-Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	0.9	100	1.00E-06	0.5	350	30	70	6.16E-07
Manganese (Adults)	120	100	1.00E-06	0.5	350	30	70	8.22E-05
Arsenic (Children)	0.9	200	1.00E-06	0.5	350	6	15	5.75E-06
Manganese (Children)	120	200	1.00E-06	0.5	350	6	15	7.67E-04
Carcinogenic: Residential Population Ingestion of Chemicals in Soil								
Chemical	**Conc**	**IR**	**CF**	**FI**	**EF**	**ED**	**BW**	**CDI**
Arsenic (Adults)	0.9	100	1.00E-06	0.5	350	30	70	2.64E-07
Arsenic (Children)	0.9	200	1.00E-06	0.5	350	6	15	4.93E-07

CDI CALCULATIONS FOR GROUNDWATER

LARC 60 MAINTENANCE AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater

Chemical	Conc	IR	EF	ED	BW	CDI
Arsenic (Adults)	0.04	2	350	30	70	1.10E–03
Manganese (Adults)	0.53	2	350	30	70	1.45E–02
cis 1,2–DCE (Adults)	0.0089	2	350	30	70	2.44E–04
Ethylbenzene (Adults)	0.0164	2	350	30	70	4.49E–04
PCE (Adults)	0.0099	2	350	30	70	2.71E–04
Toluene (Adults)	0.0285	2	350	30	70	7.81E–04
TCE (Adults)	0.0181	2	350	30	70	4.96E–04
Xylenes (Adults)	0.0623	2	350	30	70	1.71E–03
Arsenic (Child)	0.04	1	350	6	15	2.56E–03
Manganese (Child)	0.53	1	350	6	15	3.39E–02
cis 1,2–DCE (Child)	0.0089	1	350	6	15	5.69E–04
Ethylbenzene (Child)	0.0164	1	350	6	15	1.05E–03
PCE (Child)	0.0099	1	350	6	15	6.33E–04
Toluene (Child)	0.0285	1	350	6	15	1.82E–03
TCE (Child)	0.0181	1	350	6	15	1.16E–03
Xylenes (Child)	0.0623	1	350	6	15	3.98E–03

Carcinogenic: Residential Population Ingestion of Chemicals in Groundwater

Chemical	Conc	IR	EF	ED	BW	CDI
Arsenic (Adults)	0.04	2	350	30	70	4.70E–04
PCE (Adults)	0.0099	2	350	30	70	1.16E–04
TCE (Adults)	0.0181	2	350	30	70	2.13E–04
Arsenic (Child)	0.04	1	350	6	15	2.19E–04
PCE (Child)	0.0099	1	350	6	15	5.42E–05
TCE (Child)	0.0181	1	350	6	15	9.92E–05

CDI CALCULATIONS FOR GROUNDWATER

LARC 60 MAINTENANCE AREA
FORT STORY, VIRGINIA

Non-Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	SA	PC	ET	EF	ED	CF	BW	CDI
Arsenic (Adults)	0.04	19400	5.00E-04	0.3	350	30	0.001	70	1.59E-06
Manganese (Adults)	0.53	19400	5.00E-04	0.3	350	30	0.001	70	2.11E-05
cis 1,2-DCE (Adults)	0.0089	19400	2.29E-02	0.3	350	30	0.001	70	1.62E-05
Ethylbenzene (Adults)	0.0164	19400	3.16E-01	0.3	350	30	0.001	70	4.13E-04
PCE (Adults)	0.0099	19400	2.40E-03	0.3	350	30	0.001	70	1.89E-06
Toluene (Adults)	0.0285	19400	1.00E+00	0.3	350	30	0.001	70	2.27E-03
TCE (Adults)	0.0181	19400	8.32E-02	0.3	350	30	0.001	70	1.20E-04
Xylenes (Adults)	0.0623	19400	3.16E-01	0.3	350	30	0.001	70	1.57E-03
Arsenic (Child)	0.04	7310	5.00E-04	0.3	350	6	0.001	15	2.80E-06
Manganese (Child)	0.53	7310	5.00E-04	0.3	350	6	0.001	15	3.72E-05
cis 1,2-DCE (Child)	0.0089	7310	2.29E-02	0.3	350	6	0.001	15	2.86E-05
Ethylbenzene (Child)	0.0164	7310	3.16E-01	0.3	350	6	0.001	15	7.27E-04
PCE (Child)	0.0099	7310	2.40E-03	0.3	350	6	0.001	15	3.33E-06
Toluene (Child)	0.0285	7310	1.00E+00	0.3	350	6	0.001	15	4.00E-03
TCE (Child)	0.0181	7310	8.32E-02	0.3	350	6	0.001	15	2.11E-04
Xylenes (Child)	0.0623	7310	3.16E-01	0.3	350	6	0.001	15	2.76E-03

Carcinogenic: Residential Population Dermal Contact with Chemicals in Groundwater

Chemical	Conc	SA	PC	ET	EF	ED	CF	BW	CDI
Arsenic (Adults)	0.04	19400	5.00E-04	0.3	350	30	0.001	70	6.83E-07
PCE (Adults)	0.0099	19400	2.40E-03	0.3	350	30	0.001	70	8.12E-07
TCE (Adults)	0.0181	19400	8.32E-02	0.3	350	30	0.001	70	5.15E-05
Arsenic (Child)	0.04	7310	5.00E-04	0.3	350	6	0.001	15	2.40E-07
PCE (Child)	0.0099	7310	2.40E-03	0.3	350	6	0.001	15	2.86E-07
TCE (Child)	0.0181	7310	8.32E-02	0.3	350	6	0.001	15	1.81E-05

CDI CALCULATIONS FOR GROUNDWATER

LARC 60 MAINTENANCE AREA
FORT STORY, VIRGINIA

Non–Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater

Chemical	Conc	IR	ET	EF	ED	BW	CDI
cis 1,2–DCE (Adults)	5.93E–02	0.83	0.2	350	30	70	1.35E–04
Ethylbenzene (Adults) *	1.09E–01	0.83	0.2	350	30	70	2.48E–04
PCE (Adults)	6.60E–02	0.83	0.2	350	30	70	1.50E–04
Toluene (Adults) *	1.90E–01	0.83	0.2	350	30	70	4.32E–04
TCE (Adults)	1.21E–01	0.83	0.2	350	30	70	2.75E–04
Xylenes (Adults)	4.15E–01	0.83	0.2	350	30	70	9.44E–04
cis 1,2–DCE (Child)	5.93E–02	0.5	0.2	350	6	15	3.79E–04
Ethylbenzene (Child) *	1.09E–01	0.5	0.2	350	6	15	6.97E–04
PCE (Child)	6.60E–02	0.5	0.2	350	6	15	4.22E–04
Toluene (Child) *	1.90E–01	0.5	0.2	350	6	15	1.21E–03
TCE (Child)	1.21E–01	0.5	0.2	350	6	15	7.74E–04
Xylenes (Child)	4.15E–01	0.5	0.2	350	6	15	2.65E–03

Carcinogenic: Residential Population Inhalation of Volatilized Chemicals in Groundwater

Chemical	Conc	IR	ET	EF	ED	BW	CDI
cis 1,2–DCE (Adults)	5.93E–02	0.83	0.2	350	30	70	5.78E–05
PCE (Adults) *	6.60E–02	0.83	0.2	350	30	70	6.43E–05
TCE (Adults) *	1.21E–01	0.83	0.2	350	30	70	1.18E–04
cis 1,2–DCE (Child)	5.93E–02	0.5	0.2	350	6	15	3.25E–05
PCE (Child) *	6.60E–02	0.5	0.2	350	6	15	3.62E–05
TCE (Child) *	1.21E–01	0.5	0.2	350	6	15	6.63E–05

Notes:
* – Although CDIs are calculated above for all VOCs identified as COPCs in groundwater, only ethylbenzene and toluene have RfDs for inhalation while only PCE and TCE have CPSs for inhalation. Therefore, risks will only be quantified for these VOCs as shown on Tables 6–23 and 6–24 in the HHRA.

CONCENTRATION–IN–AIR CALCULATIONS
FORT STORY SITES, VIRGINIA

Concentration in Air = CW x CF x WV/RV

Chemical	Max	UCL	CF	WV	RV	CA–Max	CA–UCL
FIREFIGHTER TRAINING AREA							
PCE	78	4.41	0.001	200	30	5.20E–01	2.94E–02
LARC 60 MAINTENANCE AREA							
cis 1,2–DCE	150	8.9	0.001	200	30	1.00E+00	5.93E–02
Ethylbenzene	530	16.4	0.001	200	30	3.53E+00	1.09E–01
PCE	170	9.9	0.001	200	30	1.13E+00	6.60E–02
Toluene	2200	28.5	0.001	200	30	1.47E+01	1.90E–01
TCE	260	18.1	0.001	200	30	1.73E+00	1.21E–01
Xylenes	2900	62.3	0.001	200	30	1.93E+01	4.15E–01
AUTO CRAFT BUILDING AREA							
Chloroform	11	4.76	0.001	200	30	7.33E–02	3.17E–02

PERMEABILITY COEFFICIENTS FOR DERMAL ABSORPTION
CHEMICALS OF POTENTIAL CONCERN

HUMAN HEALTH RISK ASSESSMENT
FORT STORY, VIRGINIA

CHEMICALS	MOLECULAR WEIGHT	log(Kow)	PERMEABILITY ALGORITHM	PERMEABILITY COEFFICIENT
Arsenic				5.00E-04**
Bis(2-ethylhexyl)phthalate	390.6	3.98	log Kp = -1.5	3.16E-02
Chloroform	119.38	1.97	log Kp = -3.5+log(Kow)	2.95E-02
cis 1,2-Dichloroethene	96.95	1.86	log Kp = -3.5+log(Kow)	2.29E-02
Ethylbenzene	106.16	3.15	log Kp = -0.5	3.16E-01
Manganese				5.00E-04**
Tetrachloroethene	165.83	2.88	log Kp = -5.5+log(Kow)	2.40E-03
Toluene	92.1	2.75	Published EPA Coefficient	1.00E+00
Trichloroethene	131.4	2.42	log Kp = -3.5+log(Kow)	8.32E-02
Xylenes	106.17	3.16	log Kp = -0.5	3.16E-01

Note:
** - Default to water coefficient.

Permeability algorithm obtained from USEPA document "Dermal Exposure Assessment: Principles and Applications", January 1992, Interim Report.

APPENDIX J

TOXICOLOGICAL DATA

APPENDIX J
TOXICOLOGICAL PROFILES
FOR CHEMICALS OF POTENTIAL CONCERN

HUMAN HEALTH RISK ASSESSMENT
FORT STORY, VIRGINIA

ARSENIC

Low levels of exposure to inorganic arsenic may produce injury in several body tissues (ATSDR, 1989a). When ingested, a common effect is irritation of the digestive tract leading to pain, nausea, vomiting and diarrhea. Other effects characteristic of oral exposure include decreased production of red and white blood cells, abnormal heart function, blood vessel damage, liver and/or kidney injury and impaired nerve function that causes a "pins and needles" sensation in the feet and hands.

Direct dermal contact with arsenic compounds, frequently from inorganic arsenic dusts in the air, may result in mild to severe irritation of the skin, eyes and throat.

The single most characteristic effect of oral exposure to this compound is a pattern of skin abnormalities. Although these skin changes, called hyperkeratoses, are not considered to be a health concern, a small number of hyperkeratoses may ultimately progress to skin cancer. In addition, arsenic ingestion has been reported to increase the risk of cancer in the liver, bladder, kidney and lung.

Of much greater concern is the ability of inhaled arsenic to increase the risk of lung cancer. This has been observed mostly from high levels of airborne arsenic in or around smelters, but lower levels may increase lung cancer as well.

Based on increased lung cancer mortality in populations exposed primarily through inhalation and on increased skin cancer incidence in several areas consuming drinking water with high arsenic concentrations, the USEPA has designated arsenic as a Group A carcinogen (known human carcinogen).

BIS(2-ETHYLHEXYL)PHTHALATE

Subacute oral administration of high doses of bis(2-ethylhexyl)phthalate can produce hepatomegaly, hepatic peroxisome proliferation and induction of peroxisomal enzymes in rats (Fawell and Hunt, 1988). It also has effects on lipid metabolism in the liver and other tissues, and has been shown to induce hepatic mixed function oxidase activity in rats. At low concentration however, prolonged oral exposure of animals have not been shown to cause serious effects.

No information on the toxicity of bis(2-ethylhexyl)phthalate is available for dermal exposure of animals or humans.

The evidence for the genotoxicity of bis(2-ethylhexyl)phthalate is very weak. The International Agency for Research on Cancer indicates that there is sufficient evidence to substantiate the carcinogenicity of bis(2-ethylhexyl)phthalate in experimental animals, but insufficient evidence exist for humans (NTP, 1989).

It has been hypothesized that this compound is a non-genetic carcinogen; its ability to produce tumors may relate to proliferation of peroxisomes. There is evidence that compounds which induce peroxisome proliferation in the liver of rodents do not have the same activity in humans, and hence the hepatocarcinogenicity observed in rodents may not be indicative of a carcinogenic potential in humans (Fawell and Hunt, 1988).

However, it has been classified by USEPA as a Group B2 probable human carcinogen.

CHLOROFORM

Chloroform is toxic to the central nervous system, liver and kidneys (ATSDR, 1989b). Short-term exposure to high concentrations of chloroform in the air can cause fatigue, dizziness and headache. Long-term exposure to high levels of chloroform through inhalation and ingestion can cause jaundice and burning urination.

Limited data from experiments in animals indicate that chloroform may have reproductive and developmental effects. In animals, high doses of chloroform have caused cancer in the liver and kidney.

The USEPA has classified chloroform as a Group B2 probable human carcinogen via both oral and inhalation exposure.

1,2-DICHLOROETHENE

1,2-dichloroethene (1,2-DCE) is a volatile organic compound consisting of a mixture of cis- and trans- isomers. Although the proportion of each depends upon the manufacturer's specification, the properties of the mixture are expected to be similar to those of the individual isomers. Human health effects due to chronic exposure to 1,2-DCE have not been extensively studies. However, liver, heart, and lung effects have been reported for animals subjected to chronic exposures to the trans isomeric form only (ATSDR, 1990a).

Direct skin contact with 1,2-DCE has not been shown to cause serious health effects. Acute exposure to trans 1,2-DCE has been known to cause drowsiness, headache, tiredness and nausea.

1,2-DCE has not been studied for cancer effects in humans and animals.

ETHYL BENZENE

Ethyl benzene is primarily an irritant to the skin, eyes and upper respiratory tract. (Little, 1985) System absorption causes central nervous system depression. Inhalation of ethyl benzene might exacerbate the symptoms of obstructive airway diseases (e.g., emphysema) due to its irritant properties or reflex bronchospasm. Aspiration of small amounts causes extensive edema and hemorrhage of lung tissue. Redness and inflammation may result from skin contact with liquid ethyl benzene.

Ethyl benzene is not known to be toxic to the liver or kidneys, however, concern for these organs has been expressed since they are the primary routes of metabolism and excretion, respectively.

No data are available regarding development of cancer in humans following inhalation, oral or dermal exposure to ethyl benzene. USEPA has classified ethyl benzene in Group D, not classified as to carcinogenicity.

MANGANESE

Manganese poisoning in humans may result from occupational contact where manganese is absorbed via inhalation. Manganese fumes and dusts result in pneumonia development early on and this condition is reversible. The form of pneumonia does not respond to antibiotic therapy but resolves when the insult is removed.

Chronic manganese intoxication results in central nervous system disorders and associated degenerative pathology of the ganglion cells in the putamen, pallidium, central caudate and thalamus. Clinically, chronic manganese intoxication resembles Parkinson's disease with rigor, tremors and akinesia.

There is no human data for the carcinogenicity of manganese or any of its salts. Based on animal studies, the USEPA has classified manganese as Class D.

TETRACHLOROETHENE

Most of the information on chronic effects of tetrachloroethene (PCE) in humans have been established primarily from occupational data. Common symptoms of acute occupational exposure, include dizziness, sleepiness, irritation of the eyes, nose and throat. Effects upon the central nervous system are generally the most noticeable following acute or excessive occupational exposures. Effects upon the kidney and liver have been observed and generally occur after an elapsed period of exposure to high concentrations. Liver effects attributed to exposure to PCE at high levels include cirrhosis of the liver, toxic hepatitis, liver cell necrosis and enlarged liver. However, chronically exposed individuals may develop tolerance (ATSDR, 1990b).

PCE can be absorbed through the human skin, but the toxicological importance is less than for trichloroethene (Fawell and Hunt, 1988).

PCE has been reported to cause cancer in some animal species but not reported evidence currently implicates cancer to human. The USEPA recently classified it as a Group B2 probable human carcinogen.

THALLIUM

Human health effects may be observed through exposure to thallium through inhalation, significant skin absorption and ingestion (ECDIN, 1984). Inhalation of thallium results in nausea, vomiting, loss of hair, abdominal colic, pain in legs and chest, nervousness and irritability. Thallium may be absorbed through the eyes with long term or repeated exposures resulting in effects on vision.

Severe symptoms associated with acute poisoning may result via ingestion with doses as low as 6 mg/kg of body while doses of 14 mg/kg are often fatal. When large doses are taken, paraesthesia, lethargy, delirium, myocardial abnormalities, convulsions, and coma appear soon after ingestion. In less severe cases, the onset of symptoms may be insidious. Vomiting and abdominal pain are common.

Chronic poisoning via ingestion may result in excitation and insomnia as initial symptoms with leg joint pain, weakness, and polyneuritis occuring after exposure for weeks or months. Loss of hair, anorexia, vomiting, weight loss, depression, hysterical laughter, cardiac disturbances and albuminuria are also noted.

Thallium is recognized by NIOSH as a neurotoxic agent which may cause birth defects, specifically skeletal deformities, low birth weight and premature birth.

TOLUENE

Inhalation of toluene results in depression of the central nervous system; toluene does not appear to exert other systemic effects at low concentrations (ATSDR, 1989c). Humans exposed to toluene in the range of 100 to 500 ppm experience fatigue, confusion, incoordination, impairment to reaction time, perception, and motor control and function effects. The liver and kidney do not appear to be primary target organs for toluene exposure.

Because there is no evidence that toluene is a carcinogen, the USEPA designates toluene as Group D.

TRICHLOROETHENE

Kidney and liver are the principal target organs of oral exposure to trichloroethene (TCE). It has been reported that an association may exist between leukemia incidence in humans and exposure to well water contaminated with chlorinated hydrocarbons, including TCE.
TCE has been reported to cause long-term health effects due to dermal exposure by humans. Skin irritation, burns and rashes may result from acute exposure to high levels of this chemical. TCE may act as a sensitizer, as well as a primary irritant.

Acute inhalation exposure to TCE is associated with central nervous system effects including depression (narcosis) (ATSDR, 1989d). Other symptoms include drowsiness, headache, dizziness, nausea, confusion, facial numbness and blurred vision. Liver damage, include necrosis, has resulted from acute occupational exposure. Kidney dysfunction and failure have also been associated with acute occupational and intentional exposure, and anorexia, nausea, vomiting and intolerance of fatty foods have been associated with long-term exposures.

Available evidence indicates that TCE is carcinogenic in animals. The USEPA has classified it as a Group B2 probably human carcinogen.

XYLENES

Short and long term exposure may result in nervous system effects including headache, mental confusion, narcosis, dizziness, and impaired short-term memory (ATSDR, 1990c). Other short-term effects may include nose and throat irritation; at high doses, lung congestion has been reported. Nausea, vomiting and gastric discomfort have been reported as symptoms resulting from inhalation exposure. There are no indications that xylene is associated with adverse hematological effects. Dermal effects may include skin irritation, dryness and scaling. Exposure to vapors may cause ocular irritation.

No data are available regarding development of cancer in humans following inhalation, oral or dermal exposure to xylene.

USEPA has classified xylene in Group D, not classified as to carcinogenicity.

REFERENCES

Agency for Toxic Substances and Disease Registry. 1990a. Toxicological Profile for 1,2-Dichloroethene. Atlanta, GA. U.S. Public Health Service.

Agency for Toxic Substances and Disease Registry. 1990b. Toxicological Profile for Tetrachloroethene. ATSDR/TP-88/22. Atlanta, GA. U.S. Public Health Service.

Agency for Toxic Substances and Disease Registry. 1990c. Toxicological Profile for Total Xylenes. Atlanta, GA. U.S. Public Health Service.

Agency for Toxic Substances and Disease Registry. 1989a. Toxicological Profile for Arsenic. Atlanta, GA. U.S. Public Health Service.

Agency for Toxic Substances and Disease Registry. 1989b. Toxicological Profile for Chloroform. Atlanta, GA. U.S. Public Health Service.

Agency for Toxic Substances and Disease Registry. 1989c. Toxicological Profile for Toluene. Atlanta, GA. U.S. Public Health Service.

Agency for Toxic Substances and Disease Registry. 1989d. Toxicological Profile for Trichloroethene. ATSDR/TP-88/24. Atlanta, GA. U.S. Public Health Service.

Environmental Chemicals Data and Information Network (ECDIN), 1984, Study Contract No. 2380-84-06 EDISPI.

Fawell, J.K., and S. Hunt. 1988. Environmental Toxicology - Organic Pollutants. West Sussex, England. Chichester.

Little, A.D., 1985. Installation Restoration Program Toxicology Guide. Volume 1 - Ethyl Benzene, Cambridge, MA.

National Toxicology Program (NTP). 1989. Fifth Annual Report on Carcinogens. Summary NTP 89-239. Research Triangle Park, NC. U.S. Department of Health and Human Services, Public Health Service.