FINAL

PATHWAYS ANALYSIS REPORT FOR THE FEASIBILITY STUDY/REMEDIAL DESIGN AT THE FORMER CHARLOTTE ARMY MISSILE PLANT (CAMP), MECKLENBURG COUNTY CHARLOTTE, NORTH CAROLINA

Prepared for

US Army Corps of Engineers®

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Prepared for:

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ACRONYMS

BGS	below ground surface
CAMP	Charlotte Army Missile Plant
CBC	criterion background concentration
COPC	constituent of potential concern
DCE	dichloroethene
EPA	U. S. Environmental Protection Agency
FS	feasibility study
HI	hazard index
MCL	maximum contaminant level
MDC	maximum detected concentration
NCAC	North Carolina Administrative Code
NCDEHNR	North Carolina Department of Environment, Health, and Natural Resources
PAR	Pathways Analysis Report
PRG	preliminary remediation goal
RBC	risk-based concentration
RD	remedial design
RI	remedial investigation
SAIC	Science Applications International Corporation
TCE	trichloroethene
UCL	upper confidence limit
VOC	volatile organic compound

1.0 INTRODUCTION

This Pathways Analysis Report (PAR) has been prepared by Science Applications International Corporation (SAIC) Engineering of North Carolina, hereafter referred to as SAIC, in response to the Scope of Work for the Feasibility Study (FS)/Remedial Design (RD) for the Former Charlotte Army Missile Plant (CAMP) under Contract No. DACA21-95-D-0022, Delivery Order No. 0070.

The purpose of this PAR is to re-evaluate the potential for human exposure to contaminants in environmental media at the former CAMP based on the most recent sampling results. More specifically to

- Evaluate risk assessment data reported by Metcalf and Eddy in the Phase I (M&E 1999) and Phase II (M&E 2000) Remedial Investigations (RIs).
- Evaluate maximum detected concentrations (MDCs) in soil and groundwater against background concentrations using 2 times the mean and the 95% upper confidence level (UCL) of the mean as background criteria.
- Evaluate and assess human health exposure and risk for surface soil, subsurface soil, surface water, and groundwater.
- Evaluate all contaminants above background criteria against U. S. Environmental Protection Agency (EPA) Region 9 Preliminary Remediation Goals (PRGs).

Data presented in this PAR include that collected by Metcalf and Eddie during the Phase I (M&E 1999) and Phase II (M&E 2000) RI's and that data collected by SAIC (SAIC 2002 and 2003) in support of the FS/RD.

2.0 REVIEW OF PREVIOUS RISK ASSESSMENTS

Potential exposure and risk have previously been evaluated in the *Final Report for Phase I Remedial Investigation at Former Charlotte Army Missile Plant Charlotte, North Carolina* (M&E 1999) and the *Final Phase II Remedial Investigation Report for the Former Charlotte Army Missile Plant Mecklenburg County, Charlotte, North Carolina* (M&E 2000). In addition, a PAR was prepared and included as an appendix in the Phase II RI report (M&E 2000). The following sections briefly summarize the results of the previous risk assessments and pathways analyses.

2.1 PHASE I REMEDIAL INVESTIGATION

The potential for contaminants detected in environmental media to represent a risk to human health was evaluated using Method I from the *North Carolina Risk Analysis Framework: Methods for determining contaminant target concentrations in soil & groundwater* (NCDEHNR 1996). Method I involves the use of look-up tables of non-site-specific target concentrations that are pre-calculated by the North Carolina Department of Environment, Health, and Natural Resources (NCDEHNR). Target concentrations are available for several common exposure situations and migration pathways. The Phase I analysis used the most conservative screening levels for soil (S-1, residential ingestion of soil) and groundwater (G-1, current or potential drinking water and current or potential non-drinking water exposures such as from swimming pools or irrigation). The results of the Phase I RI risk evaluation are summarized, by media, in the following subsections.

2.1.1 Surface Soil

Surface soil samples were not collected during the Phase I RI activities.

2.1.2 Subsurface Soil

Subsurface soil samples collected from 4 to 52 ft below ground surface (BGS) were included in the Phase I risk analysis. There were no organic constituents identified as constituents of potential concern (COPCs) in the subsurface soils. However, the following metals were reported as COPCs:

- aluminum,
- lead,
- chromium,
- manganese,
- iron, and
- vanadium.

2.1.3 Groundwater

Groundwater samples were collected from permanent monitoring wells installed during the Phase I RI activities. Based on a review of the analytical data, the following COPCs were identified in the CAMP groundwater:

- trichloroethene (TCE),
- bis(2-ethylhexyl)phthalate,
- carbon tetrachloride,

- chloroform, and
- manganese.

2.1.4 Surface Water

Surface water samples were not collected during the Phase I RI activities.

2.1.5 Storm Sewer

Storm water samples were not collected during the Phase I RI activities.

2.2 PHASE II REMEDIAL INVESTIGATION

A quantitative risk assessment was performed on the additional data collected during the Phase II RI (M&E 2000), where all data were compared to the EPA Region 3 risk-based concentrations (RBCs) for industrial land use. The inorganic data were also compared against site criterion background concentrations (CBCs) developed during the Phase II RI (M&E 2000). In addition, the inorganic data collected during the Phase I RI (M&E 1999) were re-evaluated against site CBCs with the results being included in the Phase II RI report (M&E 2000).

In the Phase II RI report (M&E 2000), the potential for contaminants detected in environmental media to represent a risk to human health were evaluated in three steps: (1) identification of COPCs based on comparison of site data to conservative risk-based screening values, (2) identification of potential exposure pathways, and (3) quantification of potential risks using standard EPA methods (EPA 1989). The results of the Phase II risk evaluation are summarized, by media, in the following subsections.

2.2.1 Surface Soil

Surface soil samples collected from 0.5 to 1 ft BGS were evaluated as described above with no organic constituents being detected above the industrial RBCs. One metal (arsenic) was identified above both the RBC and CBC value. However, the surface soil risk evaluation concluded that the surface soil quality was considered marginally affected by commercial/industrial activities in the area and, therefore, no surface soil COPCs were identified. As no COPCs were identified in surface soil, this medium was not considered further in the risk assessment.

2.2.2 Subsurface Soil

The risk evaluation of subsurface soil data provided in the Phase II RI report included analytical results for the soil samples collected from 5 to 92 ft BGS, as well as all of the subsurface data generated during the Phase I RI activities. Based on the data evaluation, there were no contaminants detected above the screening values; thus, no COPCs were identified in subsurface soil. Therefore, this medium was not considered further in the risk assessment.

2.2.3 Groundwater

Groundwater samples collected during the Phase II RI activities were compared to North Carolina Administrative Code (NCAC) groundwater standards (2L standards) and federal maximum contaminant levels (MCLs), both of which are values based on potable (i.e., drinking water) use.

The following COPCs were identified as being present above the screening values:

- carbon tetrachloride;
- chromium;
- chloroform;
- 1,1-dichloroethene (DCE);
- methylene chloride;
- naphthalene;
- 1,1,2-trichloroethane;
- TCE;
- iron;
- lead; and
- manganese.

Bromodichloromethane was also detected, but no screening value was available for comparison.

The former CAMP is zoned for commercial/industrial use. Residential areas are located outside the former CAMP across Woodward Avenue. A well survey conducted as part of the Phase II RI indicated that the former CAMP and adjacent properties are serviced by a municipal water supply and no private wells are present near the former CAMP (M&E 2000). Several wells were identified within a 1-mile radius; however, all were located upgradient of the former CAMP and the operational status is unknown. Due to the availability of municipal water, groundwater ingestion was not considered to be a complete pathway. However, to be conservative, future groundwater ingestion was quantified for an industrial worker. Risk from potential future groundwater ingestion was calculated for all COPCs following standard EPA guidance (1989) using default exposure parameters for an industrial worker.

The total risk for ingestion of groundwater was calculated to be 3.5E-05 (M&E 2000). This result falls within the range for remediation of Superfund sites of 1E-06 to 1E-04. The primary contributors to risk were TCE and 1,1-DCE. The total hazard index (HI) value was calculated to be 0.74 and is below the generally accepted value of 1. The Phase II RI risk assessment concluded that considering the conservative set of assumptions used, the potential risk/hazards calculated were not anticipated to result in adverse human health risks.

2.2.4 Surface Water

One surface water sample was collected from the outfall of a man-made drainage culvert for the Phase II RI. Contaminant concentrations detected in this surface water sample were compared to NCAC 2B standards for Class C waters. These standards are based on protection of surface water for secondary recreation, fishing, aquatic life, and wildlife. The federal MCL was used as a screening value for contaminants with no NCAC 2B standard available.

There were no contaminants detected above the NCAC 2B standards for surface water; therefore, surface water was not considered further in the risk assessment.

2.2.5 Storm Sewer

Storm water samples were not collected during the Phase II RI activities.

3.0 REVISED PATHWAYS ANALYSIS

Following the Phase II RI (M&E 2000), supplemental sampling data (e.g., subsurface soil, groundwater, and storm water) were collected by SAIC (SAIC 2002 and 2003) to support the FS/RD. These additional data were compared to the following risk-based screening levels and site-specific background concentrations:

Soil – Compared to the EPA Region 9 PRGs and the site-specific background concentrations where applicable (metals only).

Groundwater – Compared to the 2005 NCAC groundwater standards and where no NCAC groundwater standard exists, the EPA Region 9 tap water PRGs were used. Groundwater data were also compared to site background concentrations where applicable (metals only).

In order to fully evaluate the risk and revise the pathways analysis for the former CAMP, all historical and current data must be evaluated against currently acceptable risk screening values. As all Phase I (M&E 1999) and Phase II (M&E 2000) RI data were initially compared to the EPA Region 3 RBCs, which the state of North Carolina no longer accepts for potential risk calculations, the revised risk evaluation for the CAMP includes comparing all historical data to the above described risk based screening values for soil and groundwater.

The potential for contaminants detected in environmental media to represent a risk to human health was evaluated in two steps: (1) identification of COPCs based on comparison of site data to conservative risk-based screening values (Section 3.1), and (2) identification of potential exposure pathways (Section 3.2).

3.1 IDENTIFICATION OF CONTAMINANTS OF POTENTIAL CONCERN

During the investigations (SAIC 2002 and 2003) to support the FS/RD, additional soil and groundwater data were collected. COPCs were identified as being above either the 2005 NCAC groundwater standards or the EPA Region 9 PRGs. The following discussion is structured by the specific medium investigated and includes the evaluation of all historical and current data available for the site.

3.1.1 Surface Soil

No surface soil samples were collected during the Phase I RI (M&E 1999); thus, no COPCs were identified during the Phase I investigation. Five surface soil samples were collected during the Phase II investigation, but no COPCs were identified using the conservative, risk-based screening values described in the Phase II RI report (M&E 2000). No additional surface soil samples were collected by SAIC in the subsequent investigations in 2001 and 2003.

SAIC re-evaluated the results of the Phase II surface soil samples by comparing the detected concentrations to the EPA Region 9 PRGs. The following observations were noted:

- Benzo(*a*)anthracene and benzo(*b*)fluoranthene were present at concentrations above the residential PRGs, but below the industrial PRGs.
- Benzo(*a*) pyrene was identified at concentrations above both the industrial and residential PRGs.
- Iron was reported at concentrations above the residential PRG, but below the industrial PRG.

- Arsenic was reported at concentrations above both the residential and industrial PRGs. However, the Phase II RI report (M&E 2000) concluded that the occurrence of arsenic in soil is most likely derived from natural materials and was not considered to be significant in magnitude or frequency. Therefore, arsenic was not included as a COPC in surface or subsurface soils.

It should be noted that the surface soil samples were collected from the landscaped areas near buildings in the southwestern portion of the site and are likely not representative of site-wide conditions (M&E 2000).

3.1.2 Subsurface Soil

As reported in the Phase I and Phase II RIs (M&E 1999, M&E 2000), no COPCs were identified in subsurface soil using conservative, risk-based screening values. Subsequent to further risk screening of the Phase I and Phase II subsurface soil data using the EPA Region 9 PRGs, arsenic was the only compound reported at concentrations exceeding the residential and industrial PRGs. As previously stated the Phase II RI concluded that the occurrence of arsenic in soil is most likely derived from natural materials and was not considered to be significant in magnitude or frequency. Therefore, arsenic was not included as a COPC in subsurface soils (M&E 2000).

During the FS/RD investigation in January 2003, eight subsurface soil samples were collected from 6 to 38 ft BGS and analyzed for volatile organic compounds (VOCs). All of the samples were collected within the saturated zone and, therefore, are considered more representative of groundwater conditions than subsurface soil. Groundwater is evaluated in Section 3.1.3. However, for information purposes, these data were compared to EPA Region 9 PRGs. As seen on Table 1, only three VOCs were detected in the subsurface soil samples collected.

Table 1. 2003 Subsurface Soil Data Comparison

Chemical	Frequency of Detection	Detected Concentration (mg/kg)		EPA Region 3 Industrial RBC (mg/kg)	EPA Region 9 Residential PRGs (mg/kg)	EPA Region 9 Industrial PRGs (mg/kg)
		Minimum	Maximum			
2-Butanone (MEK)	1/8	0.047	0.047	46,929	7,300	27,000
2-Hexanone	1/8	0.042	0.042	None	None	None
Trichloroethene	5/8	0.0089	1	1.6	0.053	0.11

Note: Only detected chemicals are shown.
EPA = U. S. Environmental Protection Agency.
MEK = Methyl ethyl ketone.
RBC = Risk-based concentration.
PRG = Preliminary remediation goal.

TCE was identified at concentrations exceeding the EPA Region 9 PRG for residential and industrial use, but below the EPA Region III RBC. As previously noted, all subsurface soil samples were collected from below the water table, and results are considered more representative of groundwater conditions than subsurface soil.

3.1.3 Groundwater

The revised groundwater evaluation used the latest available analytical results for each permanent monitoring well on-site. It should be noted that latest available data for certain wells was that collected during the Phase I (M&E 1999) and Phase II (M&E 2001) investigations. As discussed earlier, SAIC has compared the historical groundwater data (Phase I and Phase II) to the 2005 NCAC standards and EPA Region 9 PRGs, with the following observations being made:

- Bis(2ethylhyxyl)phthalate was identified as a COPC in the Phase I risk assessment. However, more recent sampling results, including that presented in the Phase II risk assessment, eliminated this chemical as a COPC as all subsequent results were non-detect for this compound.

- Methylene chloride and lead were identified as COPCs in the Phase II risk assessment. However, more recent sampling results (2001 & 2003) indicate concentrations of methylene chloride and lead have decreased to concentrations below the 2005 NCAC groundwater standards and the EPA Region 9 PRGs.

- All remaining groundwater COPCs reported in the Phase I and Phase II RIs are still valid based on the EPA Region 9 PRG screen and the 2005 NCAC groundwater standard screen.

Table 2 presents a summary of the site groundwater organic and inorganic COPCs based on the revised risk evaluation.

Table 2. Comparison of Maximum Concentrations versus Background and EPA Region 9 PRGs for Groundwater COPCs[a]

COPC	Frequency of Detection	Detected Concentrations (µg/L)		Background Concentrations[b] (µg/L)		EPA Region 9 Tap Water PRG (µg/L)	NCAC GS (µg/L)
		Minimum	Maximum	2 × Mean	UCL_{95}		
Metals							
Aluminum	19/19	43.8	**40,600**	66	40.7	36,000	NA
Chromium	4/9	6	**124**	14.6	15.2	110 (Cr^{6+})	50
Copper	16/19	0.212	**1,800**	NA	NA	1,500	1,000
Iron	16/18	87.1	**42,400**	140	1,000,000	11,000	300
Manganese	19/19	9.52	**1,060**	7.53	8.93	880	50
Silver[c]	3/18	20	73	NA	NA	180	17.5
Volatile Organic Compounds							
1,1,2-Trichloroethane	19/41	0.23	**12**	NA	NA	0.20	NA
Benzene	2/41	1	**4.1**	NA	NA	0.35	1
Carbon Tetrachloride	9/26	0.35	**9**	NA	NA	0.17	0.269
Chloroform	31/41	0.45	**18.7**	NA	NA	0.17	70
Tetrachloroethene	15/41	0.22	**18**	NA	NA	0.1	0.7
Trichloroethene	35/41	1.2	**7,500**	NA	NA	0.028	2.8

[a]Groundwater COPCs determined as constituents exceeding the North Carolina 2L standard or the federal maximum contaminant level. Groundwater data collected in 2001 and 2003 are included in this analysis.
[b]Groundwater background concentrations were determined from averaging across three upgradient wells - COEMW08, COEMW09, and COEMW28.
[c]Silver was detected above its 2L standard but below its PRG in samples collected in 2003; however, concentrations were below both drinking water standards prior to 2003.

Bold denotes maximum detected concentrations that exceed the EPA Region 9 PRGs.
COPC = Contaminant of potential concern.
GS = Groundwater standard.
EPA = U. S. Environmental Protection Agency.
NA = Not applicable.
NCAC = North Carolina Administrative Code.
PRG = Preliminary remediation goal.
UCL_{95} = 95% upper confidence limit on the mean.

Two new COPCs were identified during the additional investigations (SAIC 2002 and 2003), which were benzene and copper. As seen in Table 2, benzene was identified in 2 of 41 samples with a maximum concentration of 4.1 µg/L, and copper was identified in 16 of 19 samples at a peak concentration of 1,800 µg/L.

The metal COPCs were also compared against background concentrations (2 times background mean concentrations, as well as the 95% UCL on the background mean concentrations). As seen in Table 2, the MDCs exceed the EPA Region 9 PRGs for most of the COPCs; the exception is silver. The MDCs in recent groundwater samples are greater than both background concentrations for aluminum, chromium, and manganese. For iron, the MDC is greater than the background concentration based on 2 times the background mean, but less than the background concentration based on the 95% UCL on the background mean. No background concentrations are available for copper and silver.

3.1.3.1 Revised Risk Calculations for Groundwater

Based on the COPCs identified, the total risk for groundwater ingestion by an industrial worker was re-calculated using the latest available data for each monitoring well (Table 3). As seen in Table 3, the total carcinogenic risk of 5.8E-05 is within the EPA range of 1.0E-06 to 1.0E-04 for remediation of contaminated sites and the noncarcinogenic HI of 2.9 is above the EPA threshold of 1.0. The total risk and the total hazard are both dominated by TCE. In comparison with those risk values reported in the Phase II RI, the total carcinogenic risk is consistent; however, the re-calculated HI is 2.9, higher than the 0.74 reported in the Phase II RI. The increased risk is due to higher concentrations of TCE identified by SAIC during later investigations.

Table 3. Industrial Worker Risks from Drinking Groundwater[a]

Chemical	Freq. of Det.	EPC (µg/L)	Carcin. Intake (mg/kg-day)	Oral Slope Factor $(mg/kg\text{-}day)^{-1}$	Carcin. Risk	Noncarcin. Intake (mg/kg-day)	Oral Reference Dose (mg/kg-day)	Noncarcin. HQ
Inorganics								
Aluminum	50/55	3.0E+03	1.0E-02	NA	NA	2.9E-02	1.0E+00	2.9E-02
Chromium	19/55	2.4E+01	8.5E-05	NA	NA	2.4E-04	3.0E-03	7.9E-02
Copper	16/19	4.0E+02	1.4E-03	NA	NA	3.9E-03	4.0E-02	9.8E-02
Iron	38/55	3.0E+03	1.1E-02	NA	NA	3.0E-02	3.0E-01	9.8E-02
Manganese	48/55	5.4E+02	1.9E-03	NA	NA	5.3E-03	4.6E-02	1.2E-01
Silver	3/19	1.6E+01	5.6E-05	NA	NA	1.6E-04	5.0E-03	3.1E-02
Organics								
1,1,2-Trichloroethane	22/56	2.5E+00	8.7E-06	5.7E-02	5.0E-07	2.4E-05	4.0E-03	6.1E-03
Benzene	4/56	6.9E-01	2.4E-06	5.5E-02	1.3E-07	6.7E-06	4.0E-03	1.7E-03
Carbon Tetrachloride	11/56	1.3E+00	4.6E-06	1.3E-01	6.0E-07	1.3E-05	7.0E-04	1.8E-02
Chloroform	41/56	5.1E+00	1.8E-05	6.1E-03	1.1E-07	5.0E-05	1.0E-02	5.0E-03
Trichloroethene	46/56	1.5E+03	5.1E-03	1.1E-02	5.7E-05	1.4E-02	6.0E-03	2.4E+00
Pathway Total					5.8E-05			2.9E+00

[a]Using latest groundwater sampling data for each well.
EPC = Exposure point concentration. Value used is the maximum detected value or the 95% upper confidence limit on the mean, whichever is smallest.
HQ = Hazard quotient.
NA = Not applicable.

3.1.4 Surface Water

No additional surface water samples were collected to support the FS/RD.

3.1.5 Storm Sewer

One water sample was collected from the storm sewer manhole between Buildings 2 and 48, near COEMW01. This storm drain is located below the water table and likely receives groundwater in this area. TCE (310 μg/L) was identified in this sample above the NCAC groundwater standard (2.8 μg/L).

3.2 IDENTIFICATION OF POTENTIAL EXPOSURE PATHWAYS

The identification of potential exposure pathways is provided for each medium investigated below. Pursuant to EPA guidance, an exposure pathway is complete if there is: (1) a source or chemical release from a source, (2) an exposure point where contact can occur, and (3) an exposure route by which contact can occur (EPA 1989). If any of these elements are missing, the pathway is considered to be incomplete. Exposure pathways can be characterized as incomplete, complete, or potentially complete. The following discusses each media affected by the chemical release and the potential exposure pathways.

3.2.1 Surface Soil

As reported in the Phase II RI (M&E 2000), no COPCs were identified in surface soil using conservative, risk-based screening values. Based on the re-evaluation of historical data using the EPA Region 9 residential and industrial screening values, benzo(*a*) pyrene was the only organic compound reported at concentrations exceeding the industrial PRGs. As the surface soil data set was collected from the southwestern portion of the site in landscaped beds near existing structures, they were not considered representative of site-wide conditions. Therefore, exposure to contaminants in the surface soil is unlikely based on current data. The surface soil pathway is considered incomplete.

3.2.2 Subsurface Soil

As reported in the Phase I (M&E 1999) and Phase II (M&E 2000) RIs, no COPCs were identified in subsurface soil using conservative, risk-based screening values. More recent data collected by SAIC (SAIC 2003) did identify TCE in the subsurface soil at concentrations exceeding the EPA Region PRG. However, as previously discussed, all soil samples were collected within the saturated zone and are considered more representative of groundwater conditions than subsurface soil. Subsequent to the re-evaluation of the existing soil data no COPCs were identified; therefore, no complete exposure pathway exists for this media.

3.2.3 Groundwater

3.2.3.1 Groundwater ingestion

As noted in the Phase II report, the former CAMP is zoned for commercial/industrial use with residential areas located across Woodward Avenue. A well survey conducted as part of the Phase II RI report indicated that the former CAMP and adjacent properties are serviced by a municipal water supply and no private wells are present nearby; however, several wells were identified within a 1-mile radius of the site. More recently (May 2003), the Mecklenburg County Well Information System (available at http://maps.co.mecklenburg.nc.us) indicates a lack of private wells. It is possible that an undocumented well could exist outside the former CAMP; however, the groundwater plume does not extend off-site and no potable wells are present on the site. Based on this information, exposure to groundwater via potable use (i.e., drinking water and other domestic or industrial use) is not currently a complete pathway.

3.2.3.2 Groundwater vapor intrusion

A second potential exposure route is inhalation through vapor intrusion. As this exposure pathway was not evaluated in the Phase I or Phase II RI's, the groundwater vapor intrusion pathway evaluation is discussed in the following paragraphs.

Exposure to groundwater may occur as a result of vapor movement from the groundwater into overlying buildings. The potential for this pathway to be complete was evaluated using EPA's *OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance)* (EPA 2002). This guidance uses a tiered approach to determine whether the vapor intrusion pathway may be complete for a site.

Tier I Screen

Tier I asks the question – are chemicals present that are sufficiently volatile and toxic to be of concern for vapor intrusion?

The former CAMP fails the Tier I screening criteria and must go on to Tier II because

- six COPCs (benzene; carbon tetrachloride; chloroform; tetrachloroethene; 1,1,2-trichloroethane; and TCE) meet the criteria of being sufficiently volatile and toxic, and
- buildings are present directly above the contaminated groundwater and the water table is approximately 4 to 20 ft BGS.

Because the site fails the Tier I screen, exposure via vapor intrusion may be a potentially complete pathway; therefore, a Tier II screen was performed to further evaluate this possibility.

Tier II Screen

Tier II first compares chemical concentrations in groundwater to generic screening criteria based on cancer risk levels of 1.0E-04 to 1.0E-06 or a hazard quotient of 1.0. If these criteria are exceeded, chemical concentrations are further evaluated in the Tier III screen. Groundwater samples collected at the water table from wells closest to the buildings were used as recommended, per EPA guidance. MDCs of COPCs in shallow groundwater are shown along with Tier II criteria in Table 4.

The former CAMP fails the Tier II screening because

- the MDC of carbon tetrachloride in COEMW18 (9 µg/L in 2001) exceeds the generic criteria at the 10^{-6} and 10^{-5} risk levels (5 µg/L), but not at the 10^{-4} risk level (13 µg/L);
- the MDC of tetrachloroethene in MW01 (14.2 µg/L in 2001) exceeds the generic criteria at the 10^{-6} and 10^{-5} risk levels (11 and 5 µg/L), but not at the 10^{-4} risk level (110 µg/L); and
- the MDCs of TCE in shallow wells MW01, MW03, MW04, MW06, MW07, COEMW2, COEMW5, COEMW6, COEMW7, COEMW12, COEMW13, COEMW14, COEMW15, COEMW17, SAIC-16, and SAIC-19 range from 7.5 to 3,800 µg/L in the 2000, 2001, and 2003 sampling events. These concentrations exceed the generic criteria at the 10^{-6}, 10^{-5}, and 10^{-4} risk levels (5 to 5.3 µg/L).

Table 4. Tier I and Tier II Shallow Well Groundwater Screening Levels and Sampling Results at the Former CAMP Site

COPC	Maximum Concentration in Shallow Groundwater (µg/L)				Groundwater Screening Levels (µg/L)			
						Tier II		
	2000	2001	2003	Well	Tier I[a]	10^{-4}	10^{-5}	10^{-6}
Benzene	5	4.1	NS	MW-01	Yes	1.40E+02	1.40E+01	5.00E+00[b]
Carbon Tetrachloride	**6.2**	9	NS	COEMW18	Yes	1.30E+01	5.00E+00[b]	5.00E+00[b]
Chloroform	35	NS	5.7	MW-04	Yes	8.00E+01[b]	8.00E+01[b]	8.00E+01[b]
Tetrachloroethene	4.6	**14.2**	NS	MW-01	Yes	1.10E+02	1.10E+01	5.00E+00[b]
1,1,2-Trichloroethane	**78**	NS	2.0	COEMW06	Yes	4.10E+02	4.10E+01	5.00E+00[b]
Trichloroethene	NS	NS	**3,800**	SAIC-16	Yes	5.30E+00[c]	5.00E+00[b]	5.00E+00[b]

[a]Tier I = Yes. Chemical is volatile and toxic enough to warrant further evaluation. No chemical is non-volatile or non-toxic.
[b]The target groundwater concentration is the maximum contaminant level (MCL). The MCL for chloroform is the MCL for total trihalomethanes.
[c]The screening level for trichloroethylene (TCE) is based on the upper bound cancer slope factor identified in the U. S. Environmental Protection Agency's draft risk assessment for trichloroethylene. The slope factor is based on state-of-the-art methodology; however, the TCE assessment is still undergoing review. As a result, the slope factor and the target concentration values for TCE may be revised further.
CAMP = Charlotte Army Missile Plant.
COPC = Constituent of potential concern.
NS = Not sampled.
Bolded concentrations exceed Tier II screening levels.

Because the site fails the Tier II screen, exposure via vapor intrusion may be a potentially complete pathway; therefore, a Tier III analysis was performed to further evaluate this possibility.

Tier III Screen

Conditions at the site meet the criteria for using the Johnson Ettinger model (EPA 2000) for calculating Tier III screening levels. TCE; carbon tetrachloride; tetrachloroethene; and 1,1,2-trichloroethane failed the Tier II screen and are addressed in the Tier III screen. Potential risks from vapor intrusion shown in Table 5 were estimated using the Johnson Ettinger model with the input parameters shown in Tables 6 and 7.

Table 5. Results of Tier III Site-Specific Analysis at the Former CAMP Site

COPC	Building	Groundwater Concentration (µg/L)	Estimated Cancer Risk
Carbon Tetrachloride	3	9[a]	1E-07
Trichloroethene	2	686[b]	2E-07
Trichloroethene	48	656[c]	1E-06
Tetrachloroethene	48	14.2[d]	1E-08
1,1,2-Trichloroethane	48	78[e]	1E-07

[a]Concentration detected in COEMW18. This is the only detected concentration of carbon tetrachloride near Building 3 in shallow groundwater.
[b]Average of reported concentrations in samples from wells surrounding Building 2 collected in 2003 (COEMW02, COEMW06, and SAIC19), 2001 (COEMW01, COEMW12, and COEMW17), and 2000 (COEMW05). If a well was not sampled in 2003, the concentration reported in 2001 or 2000 was used.
[c]Average of reported concentrations in samples from wells surrounding Building 48 collected in 2003 (MW04 and COEMW06), 2001 (MW01 andCOEMW01), and 2000 (MW02, MW03, COEMW15, and COEMW20). If a well was not sampled in 2003, the concentration reported in 2001 or 2000 was used.
[d]Concentration detected in well MW01 (2001). This is the highest detected concentration near Building 48 in shallow groundwater.
[e]Concentration detected in well MW04 (2000). This is the highest detected concentration near Building 48 in shallow groundwater.
CAMP = Charlotte Army Missile Plant.
COPC = Constituent of potential concern.

Table 6. Site-Specific Vapor Intrusion Modeling Parameters for Buildings at the Former CAMP Site

Parameter	Value Used			Source
	Building 2	Building 3	Building 48	
Chemical	**Trichloroethene**	**Carbon Tetrachloride**	**Trichloroethene; Tetrachloroethene; and 1,1,2-Trichloroethane**	**Detected in Shallow Groundwater at the Building in Concentrations that Exceed Tier II Screening Levels**
Average groundwater temperature	16.67°C (62°F)	16.67°C (62°F)	16.67°C (62°F)	EPA 2002 (Figure 8)
Depth below grade to bottom of floor	15 cm	15 cm	15 cm	Default (EPA 2002)
Depth below grade to water table	213.4 cm (7.00 ft)	260.6 cm (8.55 ft)	401.4 cm (13.17 ft)	Average from wells near building (see Table 7)
Thickness of Soil Stratum A	213.4 cm (7.00 ft)	260.6 cm (8.55 ft)	401.4 cm (13.17 ft)	Vadose zone is fairly homogeneous, only one stratum is defined
Soil Stratum A SCS soil type	Silt loam (SIL)	Sandy loam (SL)	Sandy loam (SL)	Predominant soil type from wells near building
Soil stratum directly above water table	A	A	A	Vadose zone is fairly homogeneous, only one stratum is defined
Soil type directly above water table	Silt loam (SIL)	Sandy loam (SL)	Sandy loam (SL)	Predominant soil type from wells near building (see Table 7)
Stratum A soil dry bulk density	1.5 g/cm^3	1.5 g/cm^3	1.5 g/cm^3	Default (EPA 2002)
Stratum A soil total porosity	0.439	0.387	0.387	Default for sandy loam from EQM (2000) Table 2
Stratum A soil water-filled porosity	0.33	0.29	0.26	Average from wells near building (see Table 7)
Floor thickness	15 cm	15 cm	15 cm	Default (EPA 2002)
Soil-building pressure differential	40 g/cm-s^2	40 g/cm-s^2	40 g/cm-s^2	Default (EPA 2002.
Enclosed space floor length	35,433 cm (1,162.5 ft)	35,433 cm (1,162.5 ft)	13,716 cm (450 ft)	From USACE (2002) Figures 5 and 6
Enclosed space floor width	5,143.5 cm (168.75 ft)	5,143.5 cm (168.75 ft)	1,143 cm (37.5 ft)	From USACE (2002) Figures 5 and 6
Enclosed space height	365.76 cm (12 ft)	365.76 cm (12 ft)	304.8 cm (10 ft)	Site data
Floor-wall seam crack width	0.1 cm	0.1 cm	0.1 cm	Default (EPA 2002)
Indoor air exchange rate	0.45 hr^{-1}	0.45 hr^{-1}	0.45 hr^{-1}	Average (EPA 2002)
Averaging time for carcinogens	70 years	70 years	70 years	Default (EPA 1989)
Exposure duration	25 years	25 years	25 years	Occupational default (EPA 1989)
Exposure frequency	250 days/year	250 days/year	250 days/year	Occupational default (EPA 1989)

CAMP = Charlotte Army Missile Plant.
EPA = U. S. Environmental Protection Agency.
SCS = Soil Conservation Service.
USACE = U. S. Army Corps of Engineers.

Table 7. Parameters used in Vapor Intrusion Modeling for the Former CAMP Site

Well[a]	Depth to Water Table (ft BGS)	% Moisture	% Sand	% Silt	% Clay	USC	SCS	Groundwater Concentration (µg/L)		
								2003	2001	2000
Building 2 —Trichloroethene										
COEMW12	8.42	44	11.3	73.4	15.3	MH	SIL	NS	10.7	18
COEMW17	4.00	27.9	69	ND	ND	SM	SL	NS	31.6	58
COEMW01	8.33	20.6	52.8	42.7	4.5	SM	SL	NS	0.78	(<1)
COEMW06	4.77	42	37.5	56.9	5.6	ML	SIL	3,400	3,510	660
COEMW05	7.48	29.2	35.9	59.2	4.9	ML	SIL	NS	NS	68
COEMW02	5.62	32.4	41.5	53.2	5.3	ML	SIL	1,200	1,050	1,600
SAIC-05	10.44	NA	NA	NA	NA	NA	NA	NS	NA	NA
SAIC-19	6.97	NA	NA	NA	NA	NA	NA	89	NS	NS
Average	**7.00**	**33**	**41.3**	**57.1**	**7.12**	**--**	**--**	**686[b]**	**778[c]**	**401**
Building 3 —Carbon Tetrachloride										
COEMW18	8.27	25.7	69	ND	ND	SM	SL	NS	9	6.2
COEMW12	8.42	44	11.3	73.4	15.3	MH	SIL	NS	(<1)	(<1)
COEMW17	4.06	27.9	69	ND	ND	SM	SL	NS	(<1)	(<1)
COEMW19	13.43	20.4	44	ND	ND	CH	ND	NS	NS	(<1)
Average	**8.55**	**29**	**48.3**	**73.4**	**15.3**	**--**	**--**	**--**	**--**	**--**
Building 48 —Trichloroethene										
MW-04	14.14	ND	ND	ND	ND	ND	ND	780	NS	3,500
COEMW20	17.39	17.8	56	ND	ND	SM	ND	NS	NS	0.98
COEMW06	4.77	42	37.5	56.9	5.6	ML	SIL	3,400	3,510	660
COEMW01	8.33	20.6	52.8	42.7	4.5	SM	SL	NS	0.78	(<1)
COEMW15	15.57	24.1	60	ND	ND	SM	ND	NS	NS	7.5
MW-03	12.19	ND	ND	ND	ND	ND	ND	NS	NS	11
MW-01	13.55	ND	ND	ND	ND	ND	ND	NS	1,050	720
MW-02	12.00	ND	ND	ND	ND	ND	ND	NS	NS	(<1)
SAIC-13	17.11	NA	NA	NA	NA	NA	NA	NS	NA	NA
SAIC-07	16.66	NA	NA	NA	NA	NA	NA	NS	NA	NA
Average	**13.17**	**26**	**51.6**	**49.5**	**5**	**--**	**--**	**656[b]**	**1,010[c]**	**613**

[a]Soil parameters (% moisture, sand, silt, clay, and USC) taken from USACE 1999 for COEMW01 through COEMW12 and from USACE 2000 for COEMW13 through COEMW26.
[b]Reported results in 2001 or 2000 (most recent available) were used for wells not sampled in 2003 to calculate the average concentration.
[c]Reported result in 2000 was used for wells not sampled in 2001 to calculate the average concentration.
BGS = Below ground surface.
CAMP = Charlotte Army Missile Plant.
CH = Clay.
ML = Silt.
NA = Not applicable, wells are completed in the transition or bedrock zones and are used for depth to water table only.
NS = Not sampled.
ND = No data.
SCS = Soil Conservation Service.
SL = Sandy loam.
SM = Silty sand.
USC = Unified Soil Classification.
(<1) = This sample was non-detect with a detection limit of 1 µg/L.

These input parameters are a combination of standard defaults from the vapor intrusion guidance, average site-specific values, and conservative site-specific values. Buildings 2 and 48 were modeled for TCE because portions of these buildings are located over the highest groundwater TCE concentrations. Building 48 was modeled for tetrachloroethene and 1,1,2-trichloroethane because the maximum concentrations of these chemicals were located near this building and other detections were scattered.

Building 3 was modeled for carbon tetrachloride because the maximum carbon tetrachloride concentration was measured in a monitoring well adjacent to this building. Potential risks are estimated for a standard industrial scenario.

For evaluating contaminated sites, cancer risks below 10^{-6} are considered negligible per EPA (1990). Risks above 10^{-4} are considered unacceptable. Within the range of 10^{-6} to 10^{-4}, the level of risk that is considered to be acceptable at a specific site is a risk management decision and is decided on a case-specific basis. Non-science issues such as technical feasibility, economics, social, political, and legal factors, are all considered in assigning an acceptable risk level. Estimated risks associated with carbon tetrachloride at Building 3, TCE at Building 2, and tetrachloroethene and 1,1,2-trichloroethane at Building 48 are below 1×10^{-6}. The estimated risk associated with TCE at Building 48 is 1×10^{-6}.

These estimated risks are based on the following assumptions:

- The buildings are constructed on a slab-type foundation. This is a conservative assumption because basement/utility tunnels present under portions of these buildings will result in dilution of vapor concentrations.

- Workers are present in the building 8 hrs/day, 250 days/year, for 25 years. This is a conservative assumption because these buildings are currently used for storage.

- Groundwater concentrations of TCE were estimated as the average of the concentration measured in 2003 in the shallow monitoring wells nearest each building. For wells not sampled in 2003, results from 2001 or 2000 were used. This is considered a conservative assumption because the location of the wells is biased toward the area of maximum concentration; therefore, the actual average concentration under the entire building is expected to be lower. The average concentration of TCE near Building 48 was higher in 2001 than 2003 (see Table 7). The risk associated with the average concentration in 2001 is 2×10^{-6}.

- Groundwater concentrations of carbon tetrachloride; tetrachloroethene; and 1,1,2-trichloroethane were estimated as the maximum concentration in shallow monitoring wells because there were very few detections and they were scattered over a relatively large area. This is considered a conservative assumption because many of the wells near the building(s) modeled were not detected for these chemicals; therefore, the actual average concentration under the entire building is expected to be lower.

- Average building ventilation parameters reported for residential buildings were used. These assumptions may over- or under-estimate exposures depending on the actual building construction.

Given the conservative assumptions used in this assessment, all of the estimated risks are considered to be minor and exposure to contaminants in groundwater as a result of vapor intrusion is not considered to be a complete pathway under current conditions. These risk estimates may be refined with more site-specific information regarding building construction and use. These estimated risks are applicable only to: (1) the exposures modeled (i.e., a worker present every day), and (2) the groundwater concentrations measured in

2003. If activities or groundwater concentrations change (especially if groundwater concentrations increase in the future), these estimated risks will change.

3.2.4 Surface Water

Groundwater fate and transport modeling was conducted to determine the potential future extent of TCE contamination and reported in the Draft Final FS (SAIC 2004). The results of this modeling indicated that TCE in the shallow zone could migrate to the man-made drainage outfall and creek sometime in the distant future (i.e., approximately 200 years), but will not exceed surface water standards at the creek. As noted in the Phase II RI (M&E 2000), no human health risk is anticipated for exceedance of a tap water standard since this ditch will not be used for drinking water. As the detected concentration of TCE (45 μg/L) was below the NCAC surface water standard (92 μg/L), this pathway is considered incomplete.

3.2.5 Storm Sewer

Exposure to contaminants in the storm sewer may occur in two ways, as described below.

- Storm water discharges to surface water near the intersection of Woodward Avenue and Statesville Avenue. Children playing in this ditch may be exposed to surface water. The surface water sample collected during the Phase II investigation was taken at this location. Contaminant concentrations in this sample were below applicable surface water standards; therefore, no COPCs were identified and the pathway considered incomplete.

- Workers in the manhole may be exposed by inhalation of vapors. This pathway is considered insignificant because: (1) this type of exposure would be rare (i.e., less than once per year), and (2) worker exposures are addressed by health and safety regulations that require proper ventilation and monitoring while in an enclosed space.

While no current exposures are identified for contaminants in the storm sewer, the sewer may represent a potential migration pathway to surface water if concentrations at the man-made drainage outfall increase in the future.

4.0 SUMMARY AND CONCLUSIONS

The Phase I and II RI assessments did not identify any complete exposure pathways for surface soil, subsurface soil, or surface water. However, based on the comparison of the existing data to the EPA Region 9 PRGs, benzo(*a*)pyrene was identified as a COPC in surface soil and no COPCs were identified in the subsurface soils. Although benzo(*a*)pyrene was reported at concentrations exceeding the industrial PRG, the distribution was limited, with potential exposures unlikely. Therefore, pathways associated with the surface and subsurface soils are considered incomplete.

The Phase I and II risk assessments did not identify any current use of potable groundwater; however, several wells were identified within a 1-mile radius of the former CAMP site. The conclusion that groundwater is not used as a potable water source within the area currently affected by the former CAMP site was confirmed by information from the Mecklenburg County Well Information System. With the exception of chloroform and TCE, elevated concentrations of COPCs are limited to a few scattered wells and are not likely to migrate off-site in the future. Chloroform has been detected above the NCAC 2L standard of 0.19 μg/L in 45 of 57 monitoring wells. TCE has been detected in 42 of 57 monitoring wells at up to 3 orders of magnitude above the NCAC 2L standard of 2.8 μg/L. Based on their prevalence in the groundwater at high concentrations, chloroform and TCE may be considered constituents of concern in groundwater for potential future exposures. However, based on current groundwater use in the area, potential exposure to the groundwater via the ingestion pathway is considered incomplete.

Although exposure through ingestion is considered an incomplete pathway, the total risk for groundwater ingestion by an industrial worker was re-calculated using the latest available data for each monitoring well. A total carcinogenic risk of 5.8E-05 was calculated, which is within the EPA range of 1.0E-06 to 1.0E-04 for remediation of contaminated sites. A noncarcinogenic hazard of 2.9 was calculated and is above the EPA threshold of 1.0. The total risk and the total hazard are both dominated by TCE. In comparison with those risk values reported in the Phase II RI, the total carcinogenic risk is consistent; however, the re-calculated HI is 2.9, higher than the 0.74 reported in the Phase II RI. The increased risk is due to higher concentrations of TCE identified by SAIC during later investigations.

The potential for exposure to groundwater contamination via vapor intrusion into buildings was investigated based on new EPA (2002) guidance. The potential risk from TCE was estimated to be 1×10^{-6} at Building 1. This is equal to the *deminimis* risk level for remedial action. Given the conservative assumptions used in this assessment, all of the estimated risks are considered to be minor and exposure to contaminants in groundwater as a result of vapor intrusion is not considered to be a complete pathway under current conditions.

One water sample was collected from the storm sewer manhole between Buildings 2 and 48, near monitoring well COEMW01. The concentration of TCE detected in this sample is above applicable surface water standards; however, exposure via discharge to surface water is considered incomplete as concentrations at the discharge point were below applicable standards. While no current exposures are identified for contaminants in the storm sewer, the sewer represents a potential migration pathway to surface water should concentrations at the man-made drainage outfall increase in the future.

5.0 REFERENCES

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