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FINAL AREA OF CONCERN 7 (AOC 7) EXPANDED SITE INSPECTION REPORT FISC
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12/01/2014
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Declaration

Site Name and Location

Area of Concern (AOC) 7 – Drum Disposal and Can Pit Area
WPNSTA Yorktown Cheatham Annex (CAX)
Williamsburg, Virginia

Statement of Basis and Purpose

This Statement of Basis and Purpose and stakeholder signatures documents the determination that no further action (NFA) for groundwater is necessary to ensure protection of human health and the environment at CAX AOC 7, the Drum Disposal and Can Pit Area. This determination has been made in accordance with Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), as amended, and to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). This decision is based on the Expanded Site Inspection report and information contained in the Administrative Record for the site. The Navy, in partnership with the United States Environmental Protection Agency (USEPA) Region III, and Virginia Department of Environmental Quality (VDEQ) concur with the NFA determination for groundwater.

Rationale for No Further Action Determination

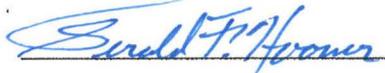
Based on the results of the Expanded Site Inspection, no potentially unacceptable human health or ecological risks were identified for groundwater at CAX AOC 7. As there are no hazardous substances, pollutants, or contaminants remaining onsite above levels that prevent unlimited use and unrestricted exposure of groundwater, no further action is necessary for site groundwater to ensure protectiveness for human health and the environment.

Authorizing Signatures

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Date 12-8-14

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Date 12/09/2014

Final

**Area of Concern 7
Expanded Site Inspection Report**

**Naval Weapons Station Yorktown, Cheatham Annex
Williamsburg, Virginia**

Contract Task Order WE02

December 2014

Prepared for

**Department of the Navy
Naval Facilities Engineering Command
Mid-Atlantic**

Under the

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Prepared by



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Executive Summary

This report presents the findings of the Expanded Site Inspection (ESI) at Area of Concern (AOC) 7, Naval Weapons Station (WPNSTA) Yorktown, Cheatham Annex (CAX), in Williamsburg, Virginia. The ESI was conducted to characterize the nature and extent of potential contamination in groundwater, to assess the potential risks posed to human health and the environment from groundwater contamination, and to determine the need for further investigation or action. A removal action is currently planned to address subsurface debris and surface soil at the site based on results of previous investigations; therefore, contamination in soil is not considered in the ESI.

Monitoring wells were installed to obtain groundwater samples of sufficient quality for risk assessments.

The objectives of the ESI have been achieved: the nature and extent of contamination have been sufficiently defined, human health and ecological risks have been assessed, and the conceptual site model (CSM) has been updated to reflect the findings from ESI activities.

No site-related constituents of concern (COCs) that would pose potential unacceptable risks to human health or the environment were found; therefore, it is recommended no further action be taken to investigate or remediate groundwater at AOC 7. CAX Partnering Team agreement for no further action is documented in the attached Declaration Statement.

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Acronyms and Abbreviations

°F	degree Fahrenheit
µg/L	microgram per liter
ADAF	age-dependent adjustment factor
amsl	above mean sea level
AOC	Area of Concern
ATSDR	Agency for Toxic Substances and Disease Registry
AWQC	ambient water quality criteria
BERA	baseline ecological risk assessment
bgs	below ground surface
BTAG	Biological Technical Assistance Group
CAX	Cheatham Annex
CDI	chronic daily intake
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLEAN	Comprehensive Long-term Environmental Action—Navy
COC	constituent of concern
COPC	constituent of potential concern
CSF	cancer slope factor
CSM	conceptual site model
DO	dissolved oxygen
DPT	direct-push technology
ELCR	excess lifetime cancer risk
EPC	exposure point concentration
ERA	Ecological Risk Assessment
ESI	Expanded Site Inspection
ESV	ecological screening value
ft/ft	feet per foot
HHRA	Human Health Risk Assessment
HI	hazard index
HQ	hazard quotient
ID	inside diameter
IDW	investigation-derived waste
IRIS	Integrated Risk Information System
LOAEL	lowest observed adverse effect level
MCL	maximum contaminant level
mg/L	milligram per liter
MMOA	mutagenic mode of action
MS	matrix spike
MSD	matrix spike duplicate
NAVFAC	Naval Facilities Engineering Command
Navy	Department of the Navy
NJDEP	New Jersey Department of Environmental Protection
NOAEL	no observed adverse effect level
NTU	nephelometric turbidity unit

ORP	oxidation-reduction potential
PCB	polychlorinated biphenyl
ppm	part per million
PVC	polyvinyl chloride
QA	quality assurance
QC	quality control
RfD	reference dose
RME	reasonable maximum exposure
RSL	Regional Screening Level
SAP	Sampling and Analysis Plan
SERA	screening ecological risk assessment
SI	Site Inspection
SMDP	Scientific Management Decision Point
SOP	standard operating procedure
SQL	sample quantitation limit
SVOC	semivolatile organic compound
TCLP	toxicity characteristic leaching procedure
UCL	upper confidence level
UF	uncertainty factor
USEPA	United States Environmental Protection Agency
UTL	upper tolerance limit
VDEQ	Virginia Department of Environmental Quality
VOC	volatile organic compound
WPNSTA	Naval Weapons Station

Introduction

This Expanded Site Inspection (ESI) report presents the data and findings obtained from field activities conducted to characterize the nature and extent of contamination in groundwater and to assess potential risks to human health and the environment at Area of Concern (AOC) 7, Naval Weapons Station (WPNSTA) Yorktown, Cheatham Annex (CAX), Williamsburg, Virginia. This report was prepared for the Department of the Navy (Navy), Naval Facilities Engineering Command (NAVFAC) Mid-Atlantic Division, under the Comprehensive Long-term Environmental Action—Navy (CLEAN) 8012 Contract No. N62470-11-D-8012, Contract Task Order WE02, for submittal to NAVFAC Mid-Atlantic, the United States Environmental Protection Agency (USEPA) Region III, and the Virginia Department of Environmental Quality (VDEQ). The Navy, USEPA, and VDEQ work jointly as the CAX Tier I Partnering Team.

The ESI field activities discussed in this report were conducted in January 2014 and were completed in accordance with the Uniform Federal Policy – Sampling and Analysis Plan (SAP) titled *Tier II Sampling and Analysis Plan, Expanded Site Inspection – Site 9, AOC1, Ammonia Settling Pits Subarea of AOC 6, and AOC 7, Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia* (referred to as the AOC 7 SAP) (CH2M HILL, 2013).

1.1 Objectives and Approach

The objectives of the ESI are to characterize the nature and extent of potential contamination in groundwater, to assess the potential risks posed to human health and the environment, and to determine whether there is a need for further investigation or remedial action.

The activities completed to support the objectives of the ESI activities were as follows:

- Installation of five monitoring wells at AOC 7
- Completion of a groundwater elevation survey and collection of groundwater samples from all monitoring wells at AOC 7
- Quantitative assessment of the potential human health and ecological risks associated with exposure to groundwater¹

1.2 Site Background

This subsection provides a general summary of background information for CAX and AOC 7, including site descriptions and environmental history.

1.2.1 Cheatham Annex

CAX consists of 2,300 acres of land on the York-James Peninsula, northwest of WPNSTA Yorktown (**Figure 1-1**). CAX was the location of the former Penniman Shell Loading Plant, a large powder and shell loading facility operated by DuPont during World War I. The facility closed in 1918, and the property was used for farming or remained idle until CAX was commissioned in 1943 as a satellite unit of the Naval Supply Depot to provide bulk storage facilities and serve as an assembly and overseas shipping point throughout World War II. In 1987, CAX was designated the Hampton Roads Navy Recreational Complex. Today, the mission of CAX includes supplying Atlantic Fleet ships and providing recreational opportunities to military and civilian personnel, with outdoor recreational facilities including cabins, campsites, an 18-hole golf course, swimming pool, ball fields, fishing areas, boating, wildlife watching, and hunting.

¹ Although ecological receptors do not have direct exposure to groundwater, groundwater data were evaluated in this Ecological Risk Assessment (ERA) to provide a conservative evaluation of the potential for significant contaminant transport via groundwater to downgradient receiving water bodies (Cheatham Pond) and the subsequent potential exposure of ecological receptors in this water body.

CAX is bordered by the Colonial National Historical Park on the northwest and east, the Queens Lake subdivision to the west, and the City of Williamsburg to the south and southwest. The majority of CAX is undeveloped and heavily wooded. Major surface water features at CAX consist of Youth Pond, Cheatham Pond, Jones Pond, Penniman Lake, and the York River. Newport News Waterworks provides potable water supplies at CAX (ATSDR, 2004).

Comprehensive environmental restoration activities at CAX began in 1984 under the Navy Assessment and Control of Installation Pollutants program and the Environmental Restoration Program. In October 1998, control of CAX was transferred from the Fleet and Industrial Supply Center to WPNSTA Yorktown. On January 2, 2001, CAX was added to the National Priorities List, which required all subsequent environmental restoration activities to be conducted under the Comprehensive Environmental Response, Compensation, and Liability Act (CECLA). The Navy, Commonwealth of Virginia (through VDEQ), and USEPA executed a Federal Facilities Agreement in March 2005 that identified a total of 12 sites and 7 AOCs to be addressed under CERCLA (Navy, 2005).

1.2.2 AOC 7

AOC 7 is a wooded area approximately 1.5 acres in size located along a popular hiking trail. It contains no wetlands or other surface water bodies. It is located several hundred feet southwest of a finger of Cheatham Pond, a large fresh water body. Although the topography is relatively flat, it generally slopes northeast, toward Cheatham Pond. In April 2004, the Navy identified AOC 7 north of Cheatham Annex Depot, Building 14. A map of AOC 7 is presented on **Figure 1-2**.

AOC 7 consists of two small, debris disposal areas, the Can Pit and the Drum Disposal Area. The Drum Disposal Area contained several rusty pails and two empty 55-gallon drums on the ground surface. The Can Pit is an approximate 30-by-20-foot area that is 4 feet deep and contained approximately 40 5-gallon rusted cans with labeling containing the word "tetrachloroethane." The Can Pit and Drum Disposal Areas are identified on **Figure 1-2**.

1.3 Summary of Previous Investigations

This subsection presents a summary of the findings from investigations conducted prior to the 2014 ESI field activities. Previous investigations helped characterize potential contamination and contaminant sources at AOC 7, and include a housekeeping effort and a Site Inspection (SI).

1.3.1 2006 Housekeeping Effort

In March 2006, surface debris was removed from the Can Pit. In April 2006, approximately 20 rusty pails and two empty 55-gallon drums were removed from the ground surface at the Drum Disposal Area. Following the housekeeping removal effort, all surface debris from AOC 7 was transported offsite to Bethel Landfill for proper disposal (Shaw, 2006). The Can Pit was encircled with an orange safety fence and left open following the housekeeping removal effort.

1.3.2 2008 Site Inspection Activities

In 2008, CH2M HILL performed investigation activities that included the collection of surface soil, subsurface soil, and direct-push technology (DPT) groundwater samples from within and in the immediate vicinity of the Can Pit and Drum Disposal Area. After surface and subsurface soil and groundwater sampling, test pitting activities were conducted and deep subsurface soil samples were collected from within the test pits. Qualitative risk evaluations were conducted using the collected data.

All surface soil, subsurface soil, and DPT groundwater samples were analyzed for a full suite of constituents (volatile organic compounds [VOCs], semivolatile organic compounds [SVOCs], pesticides, polychlorinated biphenyls [PCBs], metals, cyanide, and explosives constituents) and the results were screened against conservative regulatory screening values. The only constituents detected above their respective screening criteria were metals in surface and subsurface soil, metals (total and dissolved) in groundwater, and one VOC (ethylbenzene) in groundwater. A qualitative human health risk evaluation found that exposure to groundwater may result in potentially unacceptable risks attributable to ethylbenzene, aluminum, arsenic, chromium, iron,

manganese, and vanadium; however, these risks were primarily associated with the groundwater sample collected upgradient of AOC 7. The human health risk evaluation also found that potentially unacceptable risks to human health were not expected for surface or subsurface soil. A qualitative ecological risk evaluation found that exposure to surface soil may result in potentially unacceptable risks attributable to lead, manganese, and zinc; potentially unacceptable risks were not expected for subsurface soil or groundwater.

Test pitting activities were conducted to delineate the horizontal and vertical extents of buried debris within and around both the Can Pit and the Drum Disposal Area. Buried debris was encountered within the middle of the Can Pit; debris comprised rusted, flakey, metal shards at the bottom of the Can Pit followed by amber glass Clorox bottles and 4-inch-tall clear bottles between 4 and 12 feet below ground surface (bgs). No debris was encountered in test pits directly to the north, east, south, and west of the Can Pit. The vertical and horizontal extents of debris in the Can Pit were determined to be sufficiently characterized. In the test pits advanced within and around the Drum Disposal Area, no debris was encountered and the 2006 housekeeping effort was determined to have successfully removed all debris from this subarea.

Deep subsurface soil samples from 10 feet bgs within the test pits from each subarea were collected to determine the vertical extent of contamination and the potential for subsurface migration. One constituent (arsenic) was detected above its respective screening criterion in the deep subsurface soil samples. These samples were included in the qualitative risk evaluations of subsurface soil, and no potential for unacceptable risks to human health or ecological receptors was found (CH2M HILL, 2012).

Based on the results of the activities conducted during the SI, an interim removal action was recommended to remove buried debris from the Can Pit, to mitigate surface soil metals contamination in the Can Pit, and to mitigate metals contamination at a localized hotspot within the Drum Disposal Area surface soil. Additionally, an ESI was recommended to determine groundwater flow directions and to verify and characterize the extent of ethylbenzene (VOC) and metals contamination in groundwater.

1.4 Report Organization

The ESI Report is organized as follows:

- **Section 1** – Introduction
- **Section 2** – Field Investigation Methods
- **Section 3** – Physical Characteristics
- **Section 4** – Nature and Extent of Contamination
- **Section 5** – Human Health Risk Assessment
- **Section 6** – Ecological Risk Assessment
- **Section 7** – Conclusions and Recommendations
- **Section 8** – References

Tables and figures are found at the end of the section in which they are first referenced. Appendices follow Section 8. Tables specific to the Human Health Risk Assessment (HHRA) are included in **Appendix F**.



Legend
Study Area Boundary
Cheatham Annex Boundary

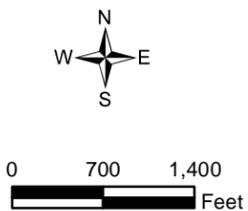


Figure 1-1
Base Location Map
AOC 7 Expanded Site Inspection Report
Cheatham Annex
Williamsburg, Virginia



Legend

- ⊗ Groundwater Sample Locations
- Topographic Surface Contour (feet above mean sea level)
- ➔ Anticipated Surface Water Flow
- Approximate area of the Drum Disposal Area
- Approximate Extent of Buried Debris within the Can Pit (4-16 feet below ground surface)
- Approximate AOC 7 Study Area

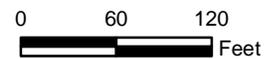


Figure 1-2
AOC 7 Site Features
AOC 7 Expanded Site Inspection Report
Cheatham Annex
Williamsburg, Virginia

Field Investigation Methods

This section describes the approach and methodology for the field activities conducted as part of the ESI at AOC 7. Field activities were performed in January 2014 and included monitoring well installation, well development, water-level measurement, groundwater sampling, and surveying. Specific details of the sampling rationale and objectives are provided in the AOC 7 SAP (CH2M HILL, 2013).

Table 2-1 summarizes all of the environmental samples that were evaluated during this ESI, including the numbers of samples collected, sample nomenclature, the media sampled, the sample collection methods, and the analyses performed. **Figure 1-2** depicts the locations of all groundwater samples collected during the ESI for AOC 7.

The investigation activities were implemented to support:

- Determination of the VOCs and metals concentrations from monitoring wells
- Determination of groundwater flow directions
- Assessment of potential risks to human health and the environment (**Sections 5 and 6** of this report)
- Determination of the need for further investigation or remedial action.

2.1 Pre-investigation Activities

Prior to the 2014 ESI field investigation activities, an underground utility clearance was conducted at AOC 7 by ECLS, Inc., of Jacksonville, North Carolina. In addition, monitoring well locations identified in the SAP were identified in the field by Michael Surveying & Mapping, P.C., of Newport News, Virginia.

2.2 Groundwater Sampling

2.2.1 Monitoring Well Installation

Five permanent monitoring wells (CAA07-MW01 through CAA07-MW05) were installed within the Yorktown-Eastover aquifer to depths up to 27 feet bgs. Each monitoring well was installed in accordance with the standard operating procedure (SOP) entitled *General Guidance for Monitoring Well Installation* (CH2M HILL, 2013). The monitoring well construction details are summarized in **Appendix A**. The location of each well is shown on **Figure 1-2**. The well CAA07-MW01 was installed in the immediate vicinity of the Drum Disposal Area, well CAA07-MW03 was installed downgradient of the Can Pit, and well CAA07-MW04 was co-located with a previous SI soil sample location outside the AOC 7 study area. The remaining two wells were installed in an upgradient and downgradient location within the AOC 7 study area. Five sample locations were selected so that statistical analyses could be completed during evaluations of potential human health and ecological risks.

Parratt-Wolff, Inc., of Hillsborough, North Carolina, provided CME 850 track-mounted well drilling and installation services using a 4.25-inch-inside-diameter (ID) hollow-stem auger. During the lithologic logging of soil cores (collected using 4-foot-long acetate sleeves), soil descriptions, including grain size, color, moisture content, relative density, consistency, soil structure, mineralogy, and other relevant information such as visual or olfactory evidence of contamination, were recorded. Soil boring logs are included in **Appendix A**.

New monitoring wells were constructed with flush-threaded, 2-inch-ID Schedule 40 polyvinyl chloride (PVC) casing and well screen (**Appendix A**). The well screens were 10 feet long with 0.010-inch slot sizes. A silica sand filter pack was placed around the annular space of the well screen from the bottom of the boring and well screen to a depth approximately 2 feet above the top of the screen. A bentonite layer (approximately 2 to 3 feet) was placed immediately above the sand pack. After the bentonite was hydrated and allowed to set up for at least 24 hours, a cement-bentonite grout was placed in the remaining annular space to the ground surface. All monitoring wells were completed with steel stick-up protective casings and surrounded by four protective bollards. A locking, watertight cap was placed on the top of each casing, and the well identification numbers were clearly marked on the well with etched well identification tags.

2.2.2 Monitoring Well Development

Prior to sampling, all monitoring wells were developed in order to restore the permeability of the aquifer material surrounding the well, which may have been reduced by the drilling operations, and to remove fine-grained materials that may have entered and settled in the well during installation. Monitoring well development was performed after the grout used to construct the new monitoring wells was allowed to set up adequately (at least 24 hours or more) to prevent grout contamination of the screened interval. Monitoring wells were developed using a submersible pump and a combination of surging and pumping throughout the well screen, and in accordance with the SOP entitled *Installation of Shallow Monitoring Wells* (CH2M HILL, 2013).

Between 30 and 50 gallons of water were evacuated from each well, with a total of 200 gallons of water purged during the entire monitoring well development event. During monitoring well development, water quality parameters (pH, oxidation-reduction potential [ORP], temperature, conductivity, turbidity, and dissolved oxygen [DO]) were recorded approximately every 5 minutes using a YSI water quality meter. The YSI instrument was calibrated daily, and calibration results were recorded in the field notebook.

Generally, development continued until at least three well volumes were removed and the water produced was free of turbidity, sand, and silt (to the maximum extent practicable). A YSI water quality meter was used to determine when the turbidity was low (preferably less than 10 nephelometric turbidity units [NTUs]). If turbidity continued to decrease after the removal of three well volumes, development was continued until turbidity readings stabilized (that is, until turbidity readings were within 10 percent for three consecutive readings). In addition, development typically ended once three successive measurements of pH, specific conductivity, and temperature within 10 percent of each other were achieved.

2.2.3 Groundwater Elevation Measurement

A groundwater elevation survey was conducted at all five monitoring wells prior to sampling. **Table 2-2** summarizes the water-level measurements from each well. An electronic water-level meter was used to measure the depth to water from the marking on the top of casing to the nearest 0.01 foot.

2.2.4 Groundwater Sampling

Groundwater samples were collected from all monitoring wells via low-flow sampling techniques in order to minimize drawdown and to obtain samples representative of groundwater conditions in the surrounding geologic formation, in accordance with the SOP entitled *Low-Flow Groundwater Sampling from Monitoring Wells* (CH2M HILL, 2013). Prior to groundwater sample collection, monitoring wells were purged in order to remove any stagnant water that may have accumulated within the well. Groundwater samples were collected from monitoring wells using a peristaltic pump and disposable tubing. Groundwater quality parameters comprising pH, conductivity, turbidity, DO, temperature, and ORP were measured during the purging of each well using a YSI water quality meter and a flow-through cell to prevent the purged groundwater from contacting the atmosphere during parameter measurement.

Purging continued until water quality readings collected 5 minutes apart stabilized to within 10 percent of one another. Following parameter stabilization, a CHEMet test kit was used to confirm DO readings measured by the YSI water quality meter (Model Numbers K-7501 for 0 to 1 part per million [ppm] and K-7512 for 1 to 12 ppm). Once DO confirmation was recorded, the flow-through cell was disconnected, and samples were collected directly into laboratory-prepared, pre-preserved sample bottles. The final set of groundwater quality measurements recorded before sample collection for each monitoring well is presented in **Table 2-3**.

Groundwater samples were analyzed for VOCs, total metals, and dissolved metals. As described above, groundwater for the analytical samples was pumped through the tubing directly into the appropriate laboratory-provided bottleware; the exception was the sample for dissolved metals analysis, which was pumped through a 0.45-micrometer filter before being collected directly into the sample bottleware. After preparation in sampling containers, samples were packed on ice. At the end of each day, samples were shipped via overnight service to the laboratory for analysis in accordance with the SOP entitled *Sample Preservation* (CH2M HILL, 2013).

2.2.5 Surveying

Michael Surveying & Mapping, P.C., of Newport News, Virginia (a Virginia-licensed and registered surveyor), conducted a survey of the new monitoring wells. Each of the monitoring wells was surveyed for vertical and horizontal control to an accuracy of ± 0.01 foot and ± 0.1 foot, respectively (**Appendix B**). Monitoring wells were surveyed at the top of the PVC casing (where marked) and at the ground surface. The vertical elevations were referenced to National Geodetic Vertical Datum 88 to remain consistent with the existing WPNSTA Yorktown vertical datum. Horizontal coordinates conformed to North American Datum 83 with ties to the Virginia State Plane Coordinate System.

2.3 Quality Assurance and Quality Control

Samples collected for the ESI were analyzed in accordance with the AOC 7 SAP (CH2M HILL, 2013). The SW-846 program methods were used and reported by the laboratory with the equivalent of USEPA Contract Laboratory Program Level IV quality assurance (QA)/quality control (QC).

Field QA/QC samples were collected during the sampling program. These samples were obtained to:

- Make sure that disposable and reusable sampling equipment were free of contaminants
- Evaluate field methodology
- Establish ambient field background conditions
- Evaluate whether cross-contamination occurred during sampling and/or shipping

Several types of field QA/QC samples were collected and analyzed in accordance with the AOC 7 SAP (CH2M HILL, 2013). They are defined as follows:

- **Equipment Rinse Blank (disposable equipment):** Equipment blanks were collected at the frequency noted in Section 7 of the AOC 7 SAP (once per lot). These samples were obtained by running laboratory-grade deionized water over or through sample collection equipment before using the equipment. These samples were used to determine whether disposable, one-time-use equipment was contaminant-free prior to use.
- **Duplicate Sample:** Duplicate samples were collected at the same time and under identical conditions as their respective associated sample at the frequency noted in Section 7 of the AOC 7 SAP (one per 10 field samples of similar matrix). These samples were collected to evaluate the field and laboratory reproducibility of sample results, and are one way to evaluate field methodology.
- **Trip Blank:** Trip blanks were prepared at the laboratory, shipped with the sample containers, and stored onsite near the empty sample containers. Any time VOC samples were packed and shipped to the laboratory, a trip blank sample was included inside the shipping cooler. The trip blanks were analyzed for VOCs along with the other VOC samples. These samples were used to evaluate whether cross-contamination of VOCs between sampling containers may have occurred during shipping.

In addition to samples collected to monitor field QC, samples were also collected to monitor quality within the laboratory. These included the following:

- **Matrix Spike (MS):** An aliquot of a matrix (that is, soil, surface sediment, subsurface sediment, surface water, groundwater, etc.) was spiked with known quantities of analytes of interest and subjected to the entire analytical procedure. By measuring the recovery of these spiked quantities, the appropriateness of the method for the matrix was demonstrated.
- **Matrix Spike Duplicate (MSD):** These samples were collected as second aliquots of the same matrix as the MS to determine the precision of the method.

The frequency of collection for MS and MSD samples is one of each collected for every 20 environmental samples collected (or greater than or equal to 5 percent of the samples collected) per medium, per site. For the AOC 7 ESI, one MS sample and one MSD sample were collected.

2.4 Decontamination Procedures

All decontamination activities were conducted in accordance with the SOPs entitled *Decontamination of Drilling Rigs and Equipment* and *Decontamination of Personnel and Equipment*, as applicable (CH2M HILL, 2013). Disposable sampling equipment and personal protective equipment, such as Masterflex tubing and nitrile gloves, were not decontaminated after use and were placed in plastic contractor bags and discarded as non-hazardous solid waste in an onsite trash dumpster. Non-disposable sampling equipment, such as hand augers, was decontaminated prior to each use.

Reusable heavy equipment, such as drilling rods and augers, were decontaminated before the initial onsite use and after each monitoring well installation using a high-pressure steam cleaner with potable-grade water. Pressure-washing was conducted at the temporary decontamination pad, which had been constructed prior to the start of drilling activities. The decontamination pad consisted of a raised wood frame lined with a high-density polyethylene tarp, which acted as a basin to collect fluids. These fluids were then pumped into approved 55-gallon drums to await characterization and disposal. All heavy equipment decontamination procedures were conducted in accordance with the SOP entitled *Decontamination of Drilling Rigs and Equipment* (CH2M HILL, 2013).

Water generated during decontamination of sampling equipment was collected and transferred to an approved 55-gallon drum to await characterization and disposal.

2.5 Investigation-derived Waste Management

Investigation-derived waste (IDW) generated during the AOC 7 well installation activities included soil cuttings from well drilling, well development groundwater, groundwater sampling purge water, and decontamination rinse water from all non-disposable sampling equipment and heavy equipment. IDW was contained in approved 55-gallon drums that were properly labeled and stored within secondary containment at the approved IDW staging location at CAX. The IDW for AOC 7, as well as the three other sites also undergoing an ESI investigation (all four sites included in the same SAP [CH2M HILL, 2013], but will have separate reports), was handled collectively; a total of 39 drums of solid IDW and 32 drums of aqueous IDW were generated during the ESI field activities.

Prior to disposal, CH2M HILL field staff collected one composite sample from all aqueous IDW drums and one composite sample from all solid IDW drums. The IDW samples were analyzed for full toxicity characteristic leaching procedure (TCLP) analyses (VOCs, SVOCs, pesticides, herbicides, and metals), ignitability, reactive cyanide, reactive sulfide, and corrosivity. Based on the analytical results, all IDW was identified as non-hazardous and disposed of by Clearfield, MMG, at the company's approved disposal facility located in Chesapeake, Virginia, within 90 days of generation.

All IDW management activities were conducted in accordance with the IDW Management Plan (Baker, 2005b). The analytical data for the aqueous and solid IDW samples are provided in **Table 2-4 and Table 2-5, respectively**. The IDW handling and disposal information is included in **Appendix C**.

2.6 Data Quality Evaluation

The data quality evaluation and validation is a multi-tiered approach. The process begins with an internal laboratory review, continues with an independent review by a third-party validator, and ends with an overall review by the CH2M HILL project chemistry team. The results of the data quality evaluation are included as **Appendix D**.

TABLE 2-1

Comprehensive Sample Summary Table

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Sample ID ¹	Matrix	Sample Interval (bTOC)	VOCs	Metals Including Mercury	Diss Metals including Mercury	Collection Method
CAA07-GW01-0114	Groundwater	21.5	X	X	X	Peristaltic Pump and New Tubing
CAA07-GW01P-0114			X	X	X	
CAA07-GW02-0114		17	X	X	X	
CAA07-GW03-0114		22	X	X	X	
CAA07-GW04-0114		22	X	X	X	
CAA07-GW05-0114		19.5	X	X	X	

Notes:

bTOC - bottom of top of casing

NA - Not Applicable

TABLE 2-2

Groundwater Elevations

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Well ID	Total Depth (TOC)	Well Screen Interval	Ground Elevation	Top of Casing Elevation	8/22/2014		
					Depth to Water	Elevation	
						(feet bgs)	(feet amsl)
CAA07-MW01	26.19	13-23	23.07	25.95	17.90	15.02	8.05
CAA07-MW02	22.11	9-19	16.53	19.50	11.8	8.83	7.70
CAA07-MW03	27.01	14-24	21.83	24.76	16.53	13.60	8.23
CAA07-MW04	26.79	14-24	22.69	25.56	16.37	13.50	9.19
CAA07-MW05	23.04	10-20	21.04	24.48	15.50	12.06	8.98

Notes:

amsl - above mean sea level

bgs - below ground surface

TOC - top of casing

TABLE 2-3

Groundwater Field Parameter Results

*AOC 7 Expanded Site Inspection Report**Cheatham Annex**Williamsburg, Virginia*

Station ID	CAA07-MW01	CAA07-MW02	CAA07-MW03	CAA07-MW04	CAA07-MW05
Sample ID	CAA07-GW01-0114	CAA07-GW02-0114	CAA07-GW03-0114	CAA07-GW04-0114	CAA07-GW05-0114
Sample Date	01/16/14	01/15/14	01/15/14	01/15/14	01/16/14
Field Parameter					
Dissolved Oxygen by CHEMet(mg/L)	2	1	1.5	2	1
Dissolved Oxygen by YSI (mg/L)	0	0	0	0	0
Oxidation Reduction Potential (mV)	193	148	144	152	169
pH	6.82	7.04	6.79	6.99	7
Specific Conductivity (mS/cm)	0.426	0.371	0.552	0.452	0.49
Temperature (°C)	14.54	15.47	16.02	16.35	14.81
Turbidity (NTU)	0	3.5	0	0	0

Notes:

C - Degrees centigrade

mg/L - Milligrams per liter

mS/cm - Milliseimens per centimeter

mV - Millivolts

NTU - Nephelometric turbidity unit

TABLE 2-4

Analytical Results for Aqueous IDW

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Sample ID	CAA07-IDWAQ022714
Sample Date	2/27/2014 12:00
Chemical Name	
TCLP Volatile Organic Compounds (MG/L)	
1,1-Dichloroethene	0.05 U
1,2-Dichloroethane	0.05 U
2-Butanone	0.75 J
Benzene	0.1 U
Carbon tetrachloride	0.1 U
Chlorobenzene	0.05 U
Chloroform	0.1 U
Tetrachloroethene	0.05 U
Trichloroethene	0.1 U
Vinyl chloride	0.05 U
TCLP Semivolatile Organic Compounds (MG/L)	
1,4-Dichlorobenzene	0.01 U
2,4,5-Trichlorophenol	0.05 U
2,4,6-Trichlorophenol	0.05 U
2,4-Dinitrotoluene	0.02 U
2-Methylphenol	0.04 U
3- and 4-Methylphenol	0.04 U
Hexachlorobenzene	0.02 U
Hexachlorobutadiene	0.02 U
Hexachloroethane	0.02 U
Nitrobenzene	0.04 U
Pentachlorophenol	0.1 U
Pyridine	0.2 U
TCLP Pesticides/Polychlorinated Biphenyls (MG/L)	
Endrin	0.005 U
gamma-BHC (Lindane)	0.005 U
Heptachlor	0.005 U
Heptachlor epoxide	0.005 U
Methoxychlor	0.001 U
technical-Chlordane	0.025 U
Toxaphene	0.062 U
TCLP Herbicides (MG/L)	
2,4,5-TP (Silvex)	0.062 U
2,4-D	0.062 U
TCLP Metals (MG/L)	
Arsenic	0.1 U
Barium	0.049 J
Cadmium	0.01 U
Chromium	0.02 U
Lead	0.05 U
Mercury	0.0001 U
Selenium	0.1 U
Silver	0.01 U
Wet Chemistry	
Cyanide (MG/KG)	0.05 U
Flash point (DEG/F)	>200
pH (pH units)	7.5
Reactive sulfide (MG/KG)	10 U

Notes:

Shading indicates detection

DEG/F - Degrees Fahrenheit

J - Analyte present. Value may or may not be accurate or precise

MG/KG - Milligrams per kilogram

MG/L - Milligrams per liter

U - The material was analyzed for, but not detected

> - the sample did not flash at the temperature reported

TABLE 2-5

Analytical Results for Solid IDW

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Sample ID	CAA07-IDWSO022714
Sample Date	2/27/2014 12:30
Chemical Name	
TCLP Volatile Organic Compounds (MG/L)	
1,1-Dichloroethene	0.05 U
1,2-Dichloroethane	0.05 U
2-Butanone	0.2 U
Benzene	0.1 U
Carbon tetrachloride	0.1 U
Chlorobenzene	0.05 U
Chloroform	0.1 U
Tetrachloroethene	0.05 U
Trichloroethene	0.1 U
Vinyl chloride	0.05 U
TCLP Semivolatile Organic Compounds (MG/L)	
1,4-Dichlorobenzene	0.01 U
2,4,5-Trichlorophenol	0.05 U
2,4,6-Trichlorophenol	0.05 U
2,4-Dinitrotoluene	0.02 U
2-Methylphenol	0.04 U
3- and 4-Methylphenol	0.04 U
Hexachlorobenzene	0.02 U
Hexachlorobutadiene	0.02 U
Hexachloroethane	0.02 U
Nitrobenzene	0.04 U
Pentachlorophenol	0.1 U
Pyridine	0.2 U
TCLP Pesticides/Polychlorinated Biphenyls (MG/L)	
Endrin	0.005 U
gamma-BHC (Lindane)	0.005 U
Heptachlor	0.005 U
Heptachlor epoxide	0.005 U
Methoxychlor	0.001 U
technical-Chlordane	0.025 U
Toxaphene	0.062 U
TCLP Herbicides (MG/L)	
2,4,5-TP (Silvex)	0.062 U
2,4-D	0.062 U
TCLP Metals (MG/L)	
Arsenic	0.1 U
Barium	0.2 J
Cadmium	0.01 U
Chromium	0.02 U
Lead	0.076 J
Mercury	0.0001 U
Selenium	0.1 U
Silver	0.01 U
Wet Chemistry	
Cyanide (MG/KG)	0.05 U
Flash point (DEG/F)	>200
pH (pH units)	8.4
Reactive sulfide (MG/KG)	10 U

Notes:

Shading indicates detection

DEG/F - Degrees Fahrenheit

J - Analyte present. Value may or may not be accurate or precise

MG/KG - Milligrams per kilogram

MG/L - Milligrams per liter

U - The material was analyzed for, but not detected

> - the sample did not flash at the temperature reported

Physical Characteristics

This section presents an evaluation of the AOC 7 physical characteristics pertaining to the surface drainage features and conceptual hydrogeology of the site. The physical settings of CAX and AOC 7, including meteorology, topography, land and groundwater use, hydrogeology, and ecological resources, are summarized in this section. This information provides the basis for the hydrologic and hydrogeologic conceptual model of AOC 7, which in turn is a foundational element of the overall conceptual site model (CSM) for the site. A detailed hydrologic and hydrogeologic conceptual model is important to describe the primary mechanisms that control the fate and migration of contaminants in groundwater. The information concerning the physical characteristics also supports the HHRA and Ecological Risk Assessment (ERA).

3.1 Climate

The climate of the Virginia Peninsula is influenced by the moderating effects of the Atlantic Ocean, resulting in mild winters and long, warm summers. High humidity occurs frequently along the coast and less frequently inland. The average relative humidity in mid-afternoon is approximately 60 percent. Humidity is higher at night, and the average humidity at dawn is approximately 80 percent. Ground fog is a frequent weather occurrence in late summer, especially during early morning hours.

Freezing temperatures occur intermittently from October through March. The average monthly temperatures in the area range from approximately 38.8 degrees Fahrenheit (°F) in January to 77.4°F in July (Baker, 2003).

Because of its location near the coastline, York County, which is adjacent to Williamsburg, is subject to easterly storms throughout late summer and early fall that cause high tides and coastal flooding. Intense tropical hurricanes occasionally sweep the coast. Winter storms that move along the eastern seaboard are often associated with high winds and precipitation, occasionally in the form of snow, ice pellets, or rain; however, the snow is seldom prolonged or heavy. The average annual precipitation is approximately 44 inches, with the summer months being the wettest and the winter months being the driest (Baker, 2003).

Spring is a period of contrasting weather, particularly during March. Spring and autumn are periods of occasional frost. Summer is warm and humid with occasional showers and afternoon thunderstorms. Autumn is a season of comfortable temperatures (average temperature 60°F to 81°F) and generally pleasant weather (Baker, 2003).

Winds are highly variable in the area of CAX. Prevailing winds are usually from the south-southwest, but north-northeasterly winds are common in some months. Onshore winds predominate during the spring and summer (Baker, 2003).

3.2 Topography and Surface Drainage Features

The topography at CAX is characterized by gently rolling terrain dissected by ravines and stream valleys trending predominantly northeastward toward the York River. Ground elevations at CAX vary from sea level along the eastern boundary, which borders the York River, to a maximum elevation of approximately 50 feet above mean sea level (amsl) atop a few scattered hills in the western portion of the base. Valleys consisting of 40- to 60-foot deep ravines with steep slopes (slopes exceeding 1:1) occur along the major creeks draining CAX (Baker, 2003).

CAX is bordered on the west by Cheatham Pond, on the north by the mouth of Queen's Creek, on the east by the York River, and on the south by King Creek. In 1943, dams were constructed to create the 108-acre Cheatham Pond from a tributary of Queen's Creek, as well as the 43-acre Penniman Lake from a tributary of King Creek. Both creeks are tidally-influenced; however, Cheatham Pond and Penniman Lake are not. Damming a portion of the Cub Creek watershed formed Jones Pond, a 69-acre freshwater, non-tidally-influenced pond, enclosed by several wooded ravines and located in the northwestern section of CAX. Numerous small creeks flow through wooded ravines throughout CAX and drain into tidal creeks that join the York River. In most areas, forests extend to the marsh and lake margins. The tributaries within CAX all drain into the York River (Baker, 2003).

AOC 7 is vegetated with shrubs and trees. In general, the topography of AOC 7 gently slopes to the northeast toward the southern fingers of Cheatham Pond (**Figure 1-2**). There are no wetlands or surface water bodies located within AOC 7. Surface runoff as a result of heavy rain events is expected to flow toward the northeast to Cheatham Pond.

3.3 Land Use

CAX is a secure military installation, and AOC 7 is completely within the confines of CAX, with access restricted to the general public. However, Navy and United States Department of Defense personnel that are authorized to enter CAX have potential access to AOC 7, because it is a wooded area located along a popular hiking trail that connects CAX's main recreational cabin area along Chase Road with its recreational vehicle park at the end of B Street. Future land use at AOC 7 is not expected to change and will likely continue as a wooded recreational area in the foreseeable future.

3.4 Water Use

Historically, groundwater from the Yorktown-Eastover aquifer was the drinking water source for older individual homes within the vicinity of CAX and was used as a backup water supply for CAX itself. However, groundwater at CAX is not a current or anticipated future source of drinking water at CAX, because drinking water is now supplied to CAX by the City of Newport News Waterworks from off-base surface water sources. In addition, drinking water is publically available, through the City of Newport News Waterworks, to all domestic homes located within the vicinity of CAX. The Commonwealth of Virginia does not employ groundwater use classifications; therefore, groundwater at CAX is considered to be of potential beneficial use. There are no surface freshwater bodies within the vicinity of AOC 7 that could feasibly be used as a potable water supply.

3.5 Hydrogeology

3.5.1 Geology

CAX is located in the Atlantic Coastal Plain Physiographic Province, which is underlain by multiple layers of unconsolidated sediment of Quaternary, Tertiary, and Cretaceous ages (**Figure 3-1**). The igneous and sedimentary rock formations of the Appalachian Mountains to the west were eroded over millennia and sediment was transported from the mountains by rivers and streams to the coast, building up layers of sediment that fanned out onto the Atlantic continental shelf. Successive sea level rises deposited fluvial estuarine and marine sediment further, thereby building the Coastal Plain. Widely fluctuating sea levels sculpted the Coastal Plain into river terraces of different elevations bounded by scarp features that resulted from shoreline erosion. The Coastal Plain in the vicinity of CAX includes four terraces: Lackey Plain, Croaker Flat, Huntington Flat, and Grafton Plain (from highest to lowest), as well as three scarps: Kingsmill, Lee Hall, and Camp Peary. As shown on **Figure 3-2**, CAX is located within the Lackey Plain and Croaker Flat terraces, separated by the Camp Peary scarp located along the York River (Brockman et al., 1997).

A total of 10 geologic formations have been identified (Brockman et al., 1997) beneath CAX. The uppermost geologic formations consist of alluvial, colluvial, and marsh deposits composed of silt, sand, and pebbles with some clay. In terms of the overlying soils, Site 4 and Youth Pond are located within Soil Association Group 2, one of the four soil association groups identified at CAX during a 1985 soil survey report for CAX prepared by the Soil Conservation Service. Soils in Soil Association Group 2, the Dogue, Pamunkey, and Uchee Association (**Figure 3-3**), were formed on river terraces and are deep, well- to poorly drained soils with clayey and loamy subsoils (Baker, 2003). A more detailed description of the soils within Soil Association Group 2 can be found in the 2003 CAX background investigation report (Baker, 2003).

Based on this ESI, in general, the uppermost soil within the vicinity of AOC 7 is predominantly olive and brown silt with varying degrees of sand and clay. A thin layer of organic material (0.5-foot thick) was observed between 7 and 10 feet bgs. Below this layer, olive-yellow and yellowish-brown sands were observed. The first encountered groundwater underlying AOC 7 is the Yorktown-Eastover aquifer. During this ESI, groundwater was encountered

at depths ranging between approximately 8 feet bgs and 14 feet bgs. Groundwater flows northeast toward Cheatham Pond.

3.5.2 Hydrostratigraphy

Each geologic unit was grouped into hydrostratigraphic units based on hydrologic characteristics (Lazniak and Meng, 1988; Brockman et al., 1997). Based on the hydraulic characteristics of the geologic units present, the uppermost eight (Cobham Bay Member of the Eastover formation through the Tabb formation) of the 10 geologic formations have been identified as the York County Shallow Aquifer System. As shown on **Figure 3-1**, the following five hydrogeologic units make up the York County Shallow Aquifer System at CAX (in descending order):

- Columbia aquifer (consisting of the Windsor through Tabb formations)
- Cornwallis Cave confining unit (consisting of the Bacons Castle formation)
- Cornwallis Cave aquifer (consisting of the upper Moore House Member of the Yorktown formation and the Sedley formation)
- Yorktown confining unit (consisting of the upper Morgarts Beach and lower Moore House Members of the Yorktown formation)
- Yorktown-Eastover aquifer (consisting of the Cobham Bay through Rushmere Members of the Yorktown formation)

Beneath AOC 7, the Camp Peary Scarp truncates the York County Shallow Aquifer System; therefore, the Columbia aquifer, Cornwallis Cave confining unit, and Cornwallis Cave aquifer are not present at this site. In addition, the Yorktown confining unit is not present. The first encountered groundwater occurs within the silt, fine- to coarse-grained sand, and shell hash of the Yorktown-Eastover aquifer. The aquifer is unconfined beneath the site (as evident by the absence of the Yorktown confining unit) and is recharged by the infiltration of precipitation.

3.5.3 Groundwater Flow

The first encountered groundwater at AOC 7 is within the Yorktown-Eastover aquifer, and ranged in depth during the ESI from 7.70 amsl (CAA07-GW02) to 9.19 amsl (CAA07-GW04) (**Table 2-2**). Groundwater elevations are not expected to be affected by the tide cycles, and groundwater flows north-northeast toward Cheatham Pond (**Figure 3-4**). The average horizontal hydraulic gradient (I) along the flow path from CAA07-MW04 to CAA07-MW01 is 0.016 feet per foot (ft/ft)².

3.6 Ecological Resources

Terrestrial flora at CAX consist predominantly of woodland species (Baker, 2005a). The following three types of forest are present:

- Pine stands composed primarily of loblolly and Virginia pines
- Mixed pine and hardwood stands
- Hardwood stands

Elevated areas are the predominant locations of pine stands, while hardwood stands are found on slopes and in ravines. Native tree species found at CAX include beech, black cherry, red maple, sweet gum, various pines, white ash, and white oak. The woodland's understory is composed of various seedling trees and vine species, such as Virginia creeper, briars, and honeysuckle. Ferns are found in many moist, shaded areas. Ornamental trees and shrubs have been planted in the improved areas and along major roadways. None of the plant species that occur at CAX are listed on the federal or Commonwealth endangered species lists (Baker, 2005a).

Small, undeveloped tracts of land at CAX support a variety of indigenous wildlife species. Whitetail deer, beaver, skunk, bobcat, red and gray fox, squirrel, raccoon, opossum, and rabbit are present. Game birds, such as wild

² Average horizontal hydraulic gradient was calculated between monitoring wells CAA07-MW05 and CAA07-MW02, whereby I (average hydraulic gradient) = (8.98-7.70 feet)/80 feet = 0.016 ft/ft.

turkey, quail, duck, and pheasant, are also resident. Songbirds common to the eastern Virginia area are in abundance at CAX, along with a raptor population consisting of small hawks, owls, and osprey. Carrion-feeding birds such as crows and turkey vultures are also common. The southern bald eagle (federally and state protected) is known to nest nearby at WPNSTA Yorktown. Suitable habitat exists for roosting and perching at CAX, but only occasional sightings of eagles have been made (Baker, 2005a).

Wetlands are mainly found along principal tributaries to the York River and along the York River shoreline at CAX. The following four major marsh types exist along these margins:

- Saltmarsh cordgrass communities
- Big cordgrass communities
- Cattail communities
- Brackish water mixed communities

Freshwater wetlands are also present within the interior, non-tidal areas of the installation. Salinities in the York River estuary bordering CAX can be characterized as mesohaline (from 15 to 20 parts per thousand), and can fluctuate depending on seasonal impacts, runoff, and rainfall. Of the 295 fish species known from the Chesapeake Bay, only 32 are year-round residents. Nursery areas, foraging areas, and spawning grounds attract the remaining species from the Atlantic Ocean and freshwater tributaries each year. In the York River, resident fish include hogchoker, weakfish, and oyster toadfish. Spot and croaker are common in nursery and foraging areas in the summer and numerous anadromous and catadromous fish use the area during migration, including the alewife, American eel, American shad, blueback herring, striped bass, and white perch. Commercially and recreationally important species from the York River include American shad, bay anchovy, blue crab, bluefish, croaker, spot, striped bass, summer flounder, and weakfish. The York River in the vicinity of CAX is a designated crab pot fishery from March through November of each year; immediately north of CAX is a spawning and nursery ground for blue crabs. Several species of endangered sea turtles (namely the green, hawksbill, leatherback, loggerhead, and Kemp's Ridley) are known to feed in the Chesapeake Bay and occasionally forage in the York River, including the vicinity of CAX, during the summer.

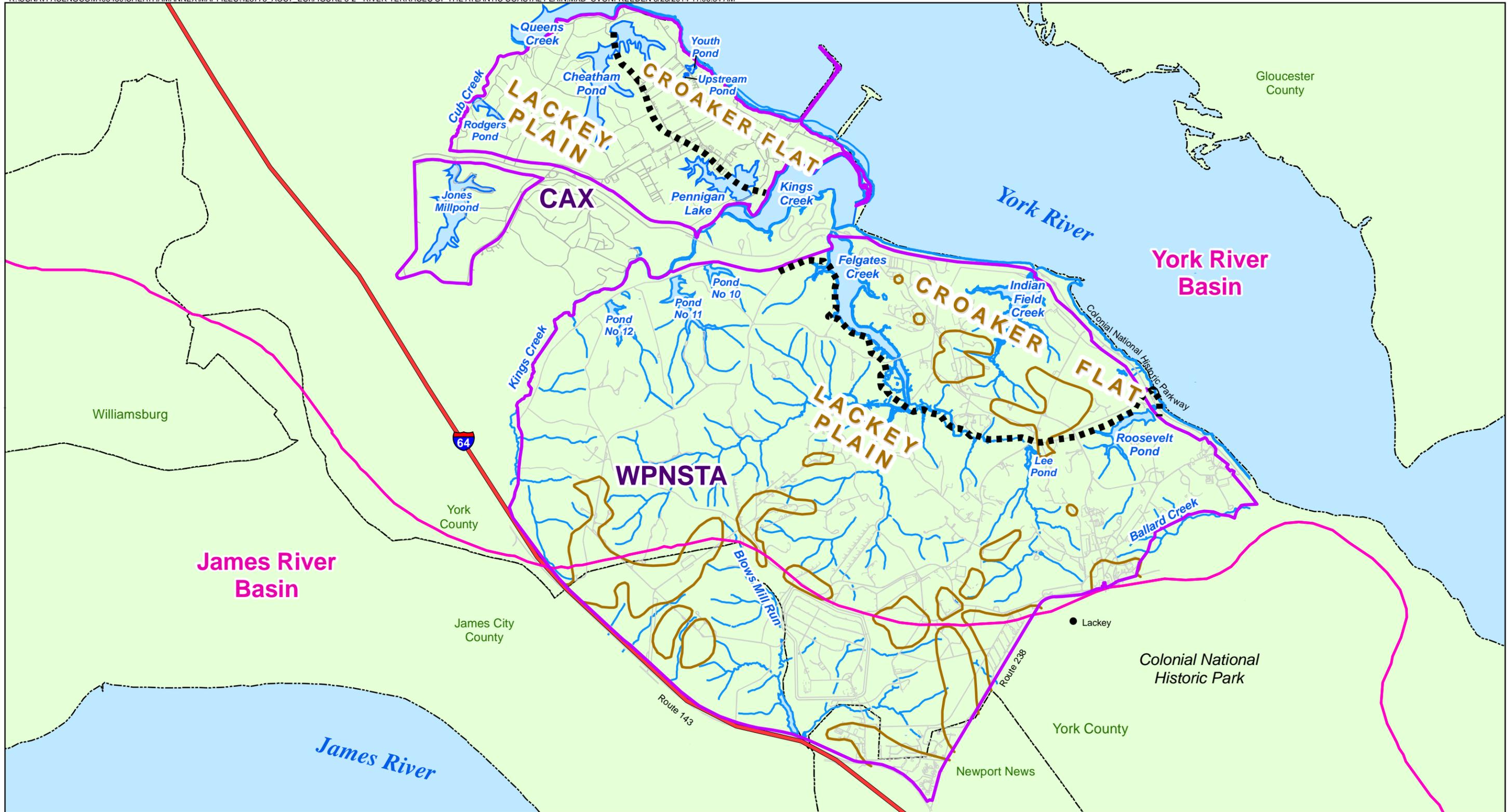
The York River is designated as Essential Fish Habitat for three species of fish managed by the Mid-Atlantic Fishery Management Council: summer flounder, bluefish, and butterfish. Although both bluefish and butterfish use the more open, pelagic waters characteristic of the river, juvenile summer flounder often use unvegetated, nearshore sandy bottoms and salt marsh creeks as nursery areas. Other species likely to use salt marsh creeks include anchovies, blue crabs, juveniles of migratory species, hard- and soft-shell clams, killifish, minnows, mummichogs, oysters, silversides, and weakfish.

No known federally or state-listed endangered or threatened species are currently using CAX habitats. Suitable habitat exists at CAX for both the red-cockaded woodpecker (federally endangered) and the bald eagle (formerly federally threatened and still protected by the Bald and Golden Eagle Protection Act and state threatened/endangered). Bordering the CAX property is the York River, which provides seasonal habitat for federally and state endangered Kemp's Ridley sea turtles and federally threatened loggerhead sea turtles. The shoreline along the York River may also provide habitat for federally threatened piping plovers. Rare resources and communities identified at CAX in the Virginia Department of Conservation and Recreation Natural Heritage Program database and the CAX Natural Heritage Inventory include a significant great blue heron colony, low salt marsh and salt scrub habitats, coastal plain depression ponds, non-riverine wet hardwood forests, and coastal plain calcareous seepage swamps (Baker, 2005a).

SYSTEM	SERIES	GEOLOGIC UNIT	HYDROGEOLOGIC UNIT IN THIS REPORT	HYDROGEOLOGIC UNIT			
QUATERNARY	HOLOCENE	ALLUVIAL AND MARSH DEPOSITS	YORK COUNTY SHALLOW AQUIFER SYSTEM	LACKEY PLAIN	CROAKER FLAT		
	PLEISTOCENE	TABB FORMATION		COLUMBIA AQUIFER (WHERE UNCONFINED)	COLUMBIA AQUIFER	COLUMBIA AQUIFER	
		SHIRLEY FORMATION		CORNWALLIS CAVE CONFINING UNIT	COLUMBIA AQUIFER	YORKTOWN CONFINING UNIT	
		CHUCKATUCK FORMATION			CORNWALLIS CAVE AQUIFER (WHERE CONFINED)	YORKTOWN CONFINING UNIT	
		WINDSOR FORMATION			YORKTOWN CONFINING UNIT	YORKTOWN CONFINING UNIT	
BACONS CASTLE FORMATION	YORKTOWN-EASTOVER AQUIFER	YORKTOWN-EASTOVER AQUIFER					
TERTIARY	PLIOCENE	SEDLEY FORMATION	YORK COUNTY SHALLOW AQUIFER SYSTEM	CORNWALLIS CAVE CONFINING UNIT	YORKTOWN CONFINING UNIT		
		MOORE HOUSE MEMBER		CORNWALLIS CAVE AQUIFER	YORKTOWN CONFINING UNIT		
		MORGARTS BEACH MEMBER		YORKTOWN CONFINING UNIT	YORKTOWN CONFINING UNIT		
		RUSHMERE MEMBER		YORKTOWN-EASTOVER AQUIFER	YORKTOWN-EASTOVER AQUIFER		
		SUNKEN MEADOW MEMBER		YORKTOWN-EASTOVER AQUIFER	YORKTOWN-EASTOVER AQUIFER		
	MIOCENE	EASTOVER FORMATION	COBHAM BAY MEMBER	EASTOVER-CALVERT CONFINING UNIT	EASTOVER-CALVERT CONFINING UNIT		
			CLAREMONT MANOR MEMBER				
		CHESAPEAKE GROUP	ST. MARYS FORMATION			EASTOVER-CALVERT CONFINING UNIT	EASTOVER-CALVERT CONFINING UNIT
			CALVERT FORMATION				

Source: Brockman, ET AL 1997 GEOHYDROLOGY OF THE SHALLOW AQUIFER SYSTEM, NAVAL WEAPONS STATION YORKTOWN, YORKTOWN, VIRGINIA

Figure 3-1
 Hydrogeologic Units in York County/Williamsburg
 AOC 7 Expanded Site Inspection Report
 Cheatham Annex
 Williamsburg, Virginia



- Legend**
- Activity Boundaries
 - Camp Peary Scarp
 - Watershed Boundaries
 - Interstate 64
 - Approximate Boundary of Columbia Aquifer, February 3, 1997
 - Roads
 - Shoreline and Water Bodies
 - City / County Boundaries

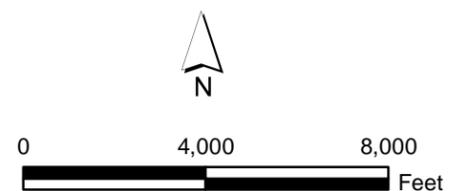
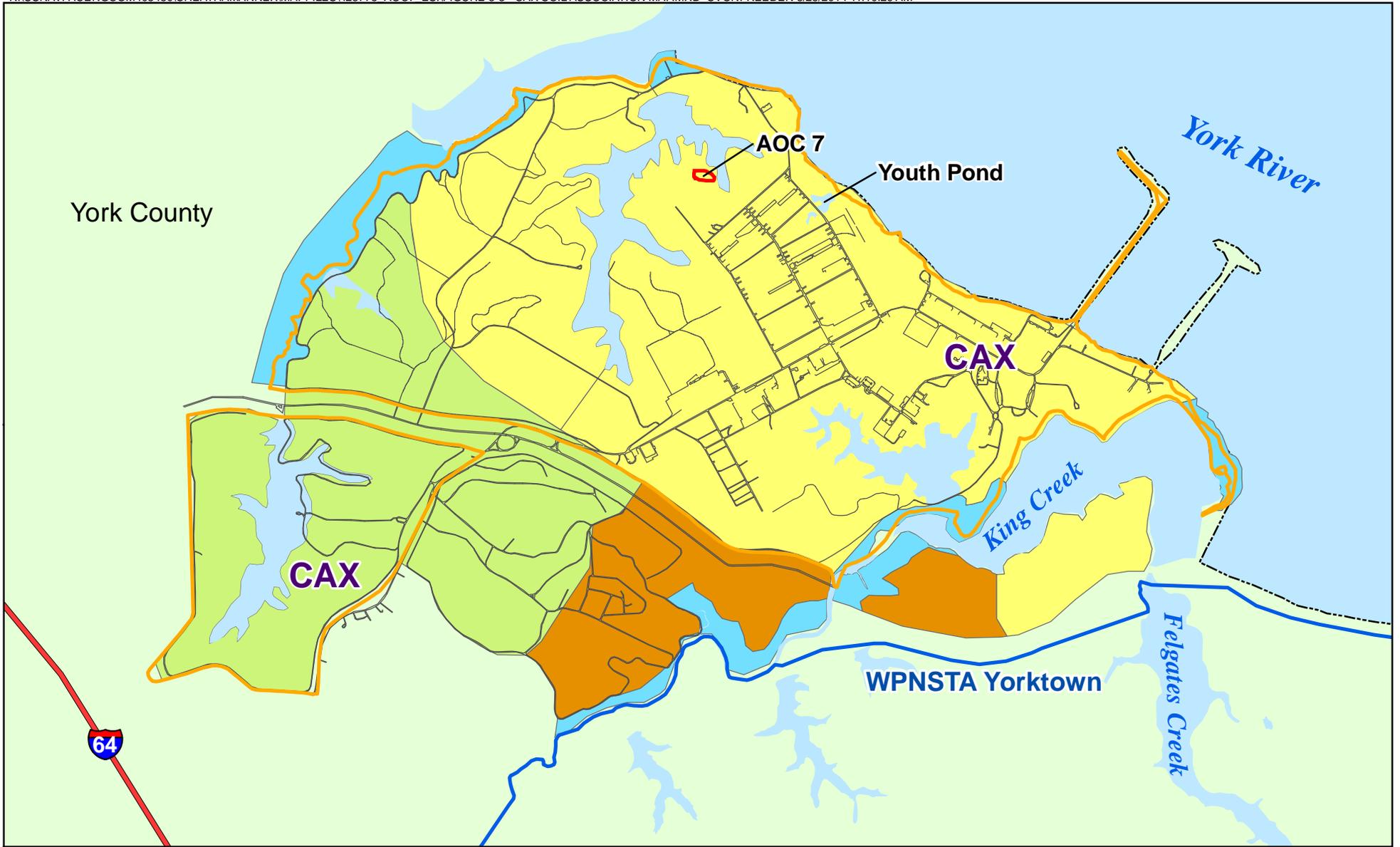


Figure 3-2
River Terraces of the Atlantic Coastal Plain
AOC 7 Expanded Site Inspection Report
Cheatham Annex
Williamsburg, Virginia



Legend

Cheatham Annex Soil Associations

- Bohicket, Johnson, and Axis (1)
- Dogue, Pamunkey, and Uchee (2)
- Slagle, Emporia, and Craven-Uchee Complex (3)
- Emporia, Emporia Complex, Kempsville, and Craven-Uchee Complex (4)
- AOC 7
- CAX Boundary

WPNSTA Yorktown Boundary



Figure 3-3
 General Soil Association Map
 AOC 7 Expanded Site Inspection Report
 Cheatham Annex
 Williamsburg, Virginia



Legend

- ⊗ Groundwater Sample Locations
 - Topographic Surface Contour (feet above mean sea level)
 - Groundwater Contour
 - - - Groundwater Contour (Inferred)
 - ➔ Groundwater Flow
 - Approximate area of the Drum Disposal Area
 - Approximate Extent of Buried Debris within the Can Pit (4-16 feet below ground surface)
 - Approximate AOC 7 Study Area
- (7.70) Groundwater Elevation

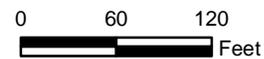


Figure 3-4
Groundwater Elevation Map
AOC 7 Expanded Site Inspection Report
Cheatham Annex
Williamsburg, Virginia

Nature and Extent of Contamination

This section presents an evaluation of the nature and extent of potential groundwater contamination at AOC 7. The purpose of this evaluation is to characterize potential impacts to groundwater from onsite, CERCLA-regulated contaminant releases.

To evaluate the nature and extent of contamination, data from the area are compared to conservative regulatory screening values, and if there are any exceedances of those values, data are subsequently compared to background screening values as a secondary screening to determine if the detected concentrations exceeding screening values are consistent with the base background concentrations. If the results exceed both the conservative screening values and the background screening values, then the results are further considered to determine if they are likely attributable to a site-related release.

The conservative screening values used to evaluate groundwater sampling data at AOC 7 are the values presented in the AOC 7 SAP: USEPA Tap Water Regional Screening Levels (RSLs), which have been adjusted to account for exposure to multiple constituents with the same target organ or target effect; federal maximum contaminant levels (MCLs); literature-based freshwater surface water screening values; and USEPA Region III Biological Technical Assistance Group (BTAG) freshwater screening values.

The background screening values used to evaluate groundwater sampling data at AOC 7 are the Yorktown-Eastover aquifer background 95 percent upper tolerance limits (UTLs) (CH2M HILL, 2011).

Independent of any comparison to background concentrations, all data that exceed conservative screening values are included in the assessments of potential risks to human health and/or ecological receptors. The quantitative assessments of risks to human health and ecological receptors are included in **Sections 5 and 6** of this report, respectively.

This evaluation includes results from the five monitoring well groundwater samples that were collected during this ESI: CAA07-MW01 through CAA07-MW05. Data from these wells include VOCs and total and dissolved metals. Earlier SI data for SVOCs, pesticides, PCBs, cyanide, and explosives constituents are not included because the DPT groundwater sample results from this previous investigation (CH2M HILL, 2012) did not include any detections that exceeded screening criteria for these analytical groups. A summary of detected constituents screened against conservative screening criteria is provided in **Table 4-1**. All laboratory analytical results are included in **Appendix E**.

4.1 Groundwater Geochemistry

Measurements of DO, ORP, pH, temperature, conductivity, and turbidity were collected at each monitoring well following purging and immediately prior to sampling, as detailed in **Section 2.2.4**. The geochemical data are presented in **Table 2-3**. These measurements show similar groundwater geochemistry at each well.

4.2 Organic Constituents

No VOCs were detected at concentrations exceeding the conservative screening values. Refer to **Table 4-1** for data on detected VOCs compared to screening values.

4.3 Inorganic Constituents (Metals)

Eight total metals and four dissolved metals were detected at concentrations exceeding the RSL, MCL, freshwater screening value, or BTAG value (**Table 4-1**). **Figure 4-1** shows the locations of specific exceedances.

- Total iron was detected in three wells (CAA07-MW02 through CAA07-MW04) at concentrations exceeding the BTAG value. The concentration in one well (CAA07-MW02) also slightly exceeds the 95 percent UTL. The maximum total iron detection was 960 micrograms per liter ($\mu\text{g/L}$); the BTAG and 95 percent UTL are 300 $\mu\text{g/L}$ and 894 $\mu\text{g/L}$, respectively. Because dissolved iron was not detected in this well at a concentration exceeding

the background 95 percent UTL, the total iron concentration in CAA07-MW02 likely represents elevated suspended solids in the groundwater sample. This is further supported by the relatively high turbidity measured during the collection of this sample (3.5 NTUs). The iron results appear to be consistent with naturally occurring background conditions.

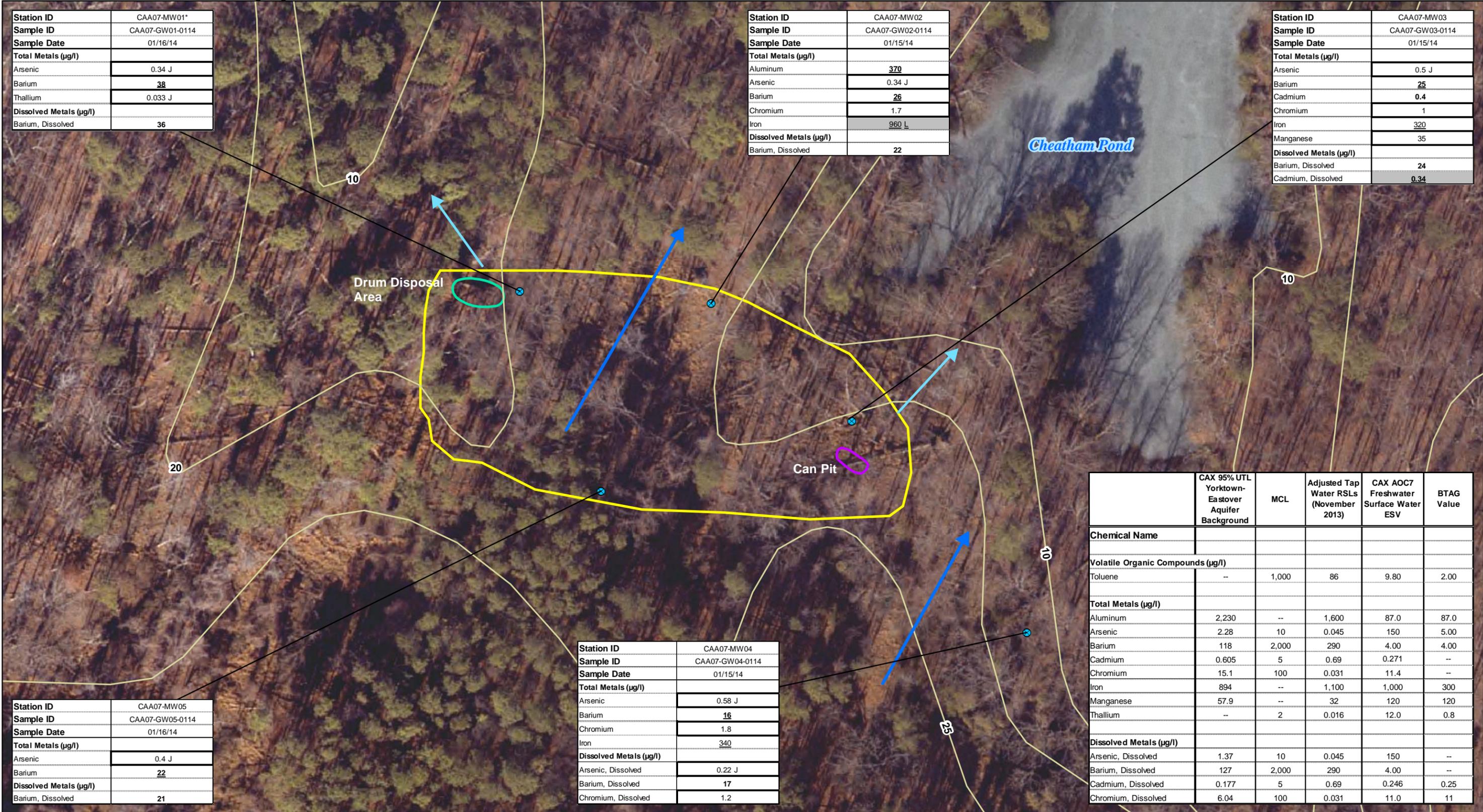
- Total thallium was detected in one well (CAA07-MW01) at an estimated concentration greater than the RSL (detected at 0.033 µg/L; the RSL is 0.016 µg/L). No background 95 percent UTL exists for comparison. Thallium was not detected in the duplicate sample or the dissolved sample from this same well, or in any other samples. The thallium results do not indicate that a contaminant release has occurred.
- Total aluminum, arsenic, barium, cadmium, chromium, and manganese were detected at concentrations exceeding screening values, but less than their respective background 95 percent UTLs; therefore, these results indicate that concentrations of these metals in groundwater are consistent with naturally occurring background conditions.
- Dissolved arsenic, barium, and chromium were detected at concentrations exceeding screening values, but less than their respective background 95 percent UTLs; therefore, these results indicate that concentrations of these metals in groundwater are consistent with naturally occurring background conditions.
- Dissolved cadmium was detected in one well (CAA07-MW03) at a concentration (0.34 µg/L) that exceeds the freshwater screening value (0.246 µg/L) and the BTAG value (0.25 µg/L). This result also exceeds the 95 percent UTL of 0.177 µg/L. However, the total cadmium concentration in the sample from this same well did not exceed the 95 percent UTL (detection of 0.4 µg/L, UTL of 0.605 µg/L). The cadmium results appear to be consistent with naturally occurring background conditions.

Prior to this ESI, the CSM for AOC 7 included the potential for leaching of contaminants from soil to groundwater. However, it is noteworthy that none of the constituents of potential concern (COPCs) in soil (lead, manganese, and zinc) were detected in groundwater at concentrations exceeding screening values and background 95 percent UTLs (CH2M HILL, 2012).

TABLE 4-1
 Groundwater Result Exceedance Summary
 AOC 7 Expanded Site Inspection Report
 Cheatham Annex
 Williamsburg, Virginia

Station ID Sample ID Sample Date	CAX 95% UTL Yorktown- Eastover Aquifer Background	MCL	Adjusted Tap Water RSLs (November 2013)	CAX AOC7 Freshwater Surface Water ESV	BTAG	CAA07-MW01		CAA07-MW02	CAA07-MW03	CAA07-MW04	CAA07-MW05
						CAA07-GW01-0114 01/16/14	CAA07-GW01P-0114 01/16/14	CAA07-GW02-0114 01/15/14	CAA07-GW03-0114 01/15/14	CAA07-GW04-0114 01/15/14	CAA07-GW05-0114 01/16/14
Chemical Name											
Volatile Organic Compounds (µg/l)											
Toluene	--	1,000	86	9.80	2.00	1 U	1 U	0.29 J	1 U	1 U	1 U
Total Metals (µg/l)											
Aluminum	2,230	--	1,600	87.0	87.0	50 U	20 B	370	31 B	35 B	50 U
Arsenic	2.28	10	0.045	150	5.00	0.34 J	0.31 J	0.34 J	0.5 J	0.58 J	0.4 J
Barium	118	2,000	290	4.00	4.00	38	36	26	25	16	22
Cadmium	0.605	5	0.69	0.271	--	0.11 J	0.056 J	0.18 J	0.4	0.084 J	0.063 J
Calcium	169,000	--	--	--	--	150,000	140,000	130,000	190,000	140,000	170,000
Chromium	15.1	100	0.031	11.4	--	0.87 B	0.6 B	1.7	1.1	1.8	1.1 B
Cobalt	20.6	--	0.47	23.0	23	0.22 J	0.23 J	0.25 J	0.38 J	0.22 J	0.21 J
Copper	--	1,300	62	9.33	--	0.35 J	0.35 J	0.4 B	0.33 B	0.42 B	0.35 J
Iron	894	--	1,100	1,000	300	240	300	<u>960 L</u>	<u>320</u>	<u>340</u>	170
Lead	--	15	15	3.18	--	0.5 U	0.5 U	0.24 J	0.15 J	0.19 J	0.5 U
Magnesium	11,500	--	--	--	--	3,400	3,300	2,100	2,600	2,500	2,300
Manganese	57.9	--	32	120	120	5.2	5	3.8	35	3.5	3.7
Nickel	11.4	--	30	52.2	--	1.1	0.92 J	0.79 J	1	0.86 J	0.79 J
Potassium	12,700	--	--	--	--	1,800	1,800	1,000	1,100	2,000	910
Selenium	--	50	7.8	5.00	1	0.88 J	1 U	1.1 B	0.39 B	0.79 B	0.64 J
Sodium	64,500	--	--	--	--	7,700	7,400	5,700	6,300	6,800	5,700
Thallium	--	2	0.016	12.0	0.8	0.033 J	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Vanadium	26.2	--	6.3	20.0	20	0.93 J	0.87 J	2	1.2	1.2	0.8 J
Dissolved Metals (µg/l)											
Arsenic, Dissolved	1.37	10	0.045	150	--	0.5 U	0.5 U	0.5 U	0.5 U	0.22 J	0.32 B
Barium, Dissolved	127	2,000	290	4.00	--	33	36	22	24	17	21
Cadmium, Dissolved	0.177	5	0.69	0.246	0.25	0.046 J	0.041 J	0.15 J	0.34	0.071 J	0.065 J
Calcium, Dissolved	113,000	--	--	--	--	140,000	140,000	120,000	180,000	150,000	170,000
Chromium, Dissolved	6.04	100	0.031	11.0	11	0.35 B	0.38 B	0.41 B	0.4 B	1.2	0.6 B
Cobalt, Dissolved	--	--	0.47	23.0	--	0.18 J	0.18 J	0.12 J	0.31 J	0.15 J	0.16 J
Copper, Dissolved	--	1,300	62	8.96	8.96	0.36 B	0.62 B	0.29 J	0.74 B	0.41 B	0.29 B
Iron, Dissolved	275	--	1,100	1,000	--	21	14	11	10 U	8.2 J	11
Magnesium, Dissolved	11,200	--	--	--	--	3,100	3,300	1,900	2,600	2,700	2,200
Manganese, Dissolved	49.5	--	32	120	--	4.7	4.8	2.3	32	3.1	3
Nickel, Dissolved	--	--	30	52.0	52	1.3	0.86 J	0.57 J	1	0.74 J	0.78 B
Potassium, Dissolved	12,600	--	--	--	--	1,700	1,800	820	980	2,100	910
Selenium, Dissolved	--	50	7.8	4.61	--	1 U	1 U	0.78 J	0.44 J	0.65 J	0.91 J
Sodium, Dissolved	62,800	--	--	--	--	7,200	7,600	5,200	6,200	7,400	5,500
Vanadium, Dissolved	--	--	6.3	20	--	0.45 J	0.4 B	0.66 J	0.53 J	0.56 J	0.52 J

Notes:
 Shading indicates exceedance of background
 Italicized text indicates exceedance of MCLs
 Bold text box indicates exceedance of Adjusted Tap Water RSLs
 Bold text indicates exceedance of ESVs
 Underline indicates exceedance of BTAGs
 RSLs were adjusted for noncarcinogens to account for exposure to multiple constituents
 B - Analyte not detected above the level reported in blanks
 J - Analyte present, value may or may not be accurate or precise
 L - Analyte present, value may be biased low, actual value may be higher
 U - The material was analyzed for, but not detected
 µg/l - Micrograms per liter



Station ID	CAA07-MW01*
Sample ID	CAA07-GW01-0114
Sample Date	01/16/14
Total Metals (µg/l)	
Arsenic	0.34 J
Barium	38
Thallium	0.033 J
Dissolved Metals (µg/l)	
Barium, Dissolved	36

Station ID	CAA07-MW02
Sample ID	CAA07-GW02-0114
Sample Date	01/15/14
Total Metals (µg/l)	
Aluminum	370
Arsenic	0.34 J
Barium	26
Chromium	1.7
Iron	<u>960 L</u>
Dissolved Metals (µg/l)	
Barium, Dissolved	22

Station ID	CAA07-MW03
Sample ID	CAA07-GW03-0114
Sample Date	01/15/14
Total Metals (µg/l)	
Arsenic	0.5 J
Barium	25
Cadmium	0.4
Chromium	1
Iron	320
Manganese	35
Dissolved Metals (µg/l)	
Barium, Dissolved	24
Cadmium, Dissolved	<u>0.34</u>

Station ID	CAA07-MW05
Sample ID	CAA07-GW05-0114
Sample Date	01/16/14
Total Metals (µg/l)	
Arsenic	0.4 J
Barium	22
Dissolved Metals (µg/l)	
Barium, Dissolved	21

Station ID	CAA07-MW04
Sample ID	CAA07-GW04-0114
Sample Date	01/15/14
Total Metals (µg/l)	
Arsenic	0.58 J
Barium	16
Chromium	1.8
Iron	<u>340</u>
Dissolved Metals (µg/l)	
Arsenic, Dissolved	0.22 J
Barium, Dissolved	17
Chromium, Dissolved	1.2

Chemical Name	CAX 95% UTL Yorktown-Eastover Aquifer Background	MCL	Adjusted Tap Water RSLs (November 2013)	CAX AOC7 Freshwater Surface Water ESV	BTAG Value
Volatile Organic Compounds (µg/l)					
Toluene	--	1,000	86	9.80	2.00
Total Metals (µg/l)					
Aluminum	2,230	--	1,600	87.0	87.0
Arsenic	2.28	10	0.045	150	5.00
Barium	118	2,000	290	4.00	4.00
Cadmium	0.605	5	0.69	0.271	--
Chromium	15.1	100	0.031	11.4	--
Iron	894	--	1,100	1,000	300
Manganese	57.9	--	32	120	120
Thallium	--	2	0.016	12.0	0.8
Dissolved Metals (µg/l)					
Arsenic, Dissolved	1.37	10	0.045	150	--
Barium, Dissolved	127	2,000	290	4.00	--
Cadmium, Dissolved	0.177	5	0.69	0.246	0.25
Chromium, Dissolved	6.04	100	0.031	11.0	11

Legend

- ⊗ Groundwater Sample Locations
- Topographic Surface Contour (feet above mean sea level)
- Anticipated Surface Water Flow
- Groundwater Flow
- Approximate area of the Drum Disposal Area
- Approximate Extent of Buried Debris within the Can Pit (4-16 feet below ground surface)
- Approximate AOC 7 Study Area

Notes:
Bold box indicates exceedance of Adjusted Tap Water RSLs
Bold text indicates exceedance of ESVs
Underline indicates exceedance of BTAGs
 RSLs were adjusted for noncarcinogens to account for exposure to multiple constituents
 J - Analyte present, value may or may not be accurate or precise
 L - Analyte present, value may be biased low, actual value may be higher

µg/l - Micrograms per liter
 * a duplicate was collected at this location, the higher of the two results is shown

Figure 4-1
 AOC 7 Groundwater Exceedance Results
 AOC 7 Expanded Site Inspection Report
 Cheatham Annex
 Williamsburg, Virginia

CH2MHILL

Human Health Risk Assessment

This section presents the baseline HHRA for groundwater for CAX AOC 7, the Drum Disposal Area and Can Pit. An evaluation of soil during the SI indicated elevated metals concentrations at AOC 7; however, soil is being addressed separately as part of an interim removal action and was not addressed as part of this risk assessment.

5.1 Introduction

The data evaluated in the HHRA are presented in **Appendix F** and discussed in **Section 4**. The HHRA incorporates the general methodology described in the following USEPA documents:

- *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual Part A* (USEPA, 1989)
- *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual (Part D, Standardized Planning, Reporting, and Review of Superfund Risk Assessment)* (USEPA, 2001a)
- *Risk Assessment Guidance for Superfund: Volume I, Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment)* (USEPA, 2004)
- USEPA Region III Technical Guidance Manuals for Risk Assessment (USEPA, 1992; 1993)

The HHRA consists of the following components:

- Human Health CSM
- Identification of COPCs
- Exposure Assessment
- Toxicity Assessment
- Risk Characterization
- Uncertainty Assessment

These components are described in the following sections. Risk calculation spreadsheets for AOC 7 were prepared in accordance with *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual (Part D)* (USEPA, 2001a) to screen for COPCs and to calculate risk estimates associated with the COPCs. These spreadsheets, and supporting tables and calculations, are presented in **Appendix F**.

5.2 Human Health Conceptual Site Model

The human health CSM showing potential human health exposure scenarios for current and potential future site use is provided in **Table 1** of **Appendix F** and graphically on **Figure 5-1**. The CSM provides a current understanding of the source(s) of contamination, release and transport mechanisms, current and potential future land use, and identifies potentially complete human exposure pathways for AOC 7.

AOC 7 was identified in April 2004 when the Navy discovered two small debris disposal areas in the woods behind the CAX warehouse area. One of the debris disposal areas, referred to as the Drum Disposal Area, contained several empty, rusted pails and two empty, rusted 55-gallon drums on the ground surface. The other debris disposal area, referred to as the Can Pit, is an approximately 30- by 20-foot pit open to a depth of 4 feet bgs. The Can Pit contained numerous empty, 5-gallon rusted cans labeled “tetrachloroethane” on the ground surface within the pit. There are no wetlands or surface water bodies located within AOC 7.

The first encountered groundwater at AOC 7 is within the Yorktown-Eastover aquifer, at depths ranging from 5.36 to 6.79 feet bgs. Groundwater elevations are not expected to be significantly affected by the tide cycles and groundwater predominantly flows northeast toward Cheatham Pond (**Figure 3-4**).

Although groundwater beneath the site is not currently used as a potable water supply, it was conservatively assumed that groundwater could be used as a future residential potable water supply. Additionally, because of the relatively shallow range of depths to groundwater (from approximately 9 feet bgs and deeper), it was

conservatively assumed that construction workers could be exposed to groundwater during future excavation activities. Future land use at AOC 7 is not expected to change and will likely continue as a wooded recreational area in the foreseeable future. There are no buildings currently on the site and it is not likely there will be buildings constructed in the future. Therefore, there is no current exposure to indoor air associated with vapor intrusion from groundwater into indoor air and unlikely to be future exposure to indoor air. Additionally, minimal volatiles were detected in the groundwater, as discussed in the following sections.

5.3 Identification of Groundwater Constituents of Potential Concern

The identification of groundwater COPCs includes data collection, evaluation, and screening to identify those chemicals that contribute the most to the total risk estimates associated with the site. Data collection and evaluation involves gathering and reviewing the available site data and compiling a set of data for the risk assessment that meets project-specific data quality objectives. Once compiled, the data set is further screened against concentrations that are protective of human health to focus the risk assessment efforts on the COPCs for human receptors.

5.3.1 Data Summary

The objectives of the ESI are to characterize the potential impact to groundwater from contaminant releases from the Drum Disposal Area and Can Pit, evaluate the potential risk to human health and the environment, and determine the need for further investigation or action. Only groundwater data collected during the ESI were evaluated in the HHRA. The SI groundwater data were collected using DPT sampling methodology, which is not typically used for HHRAs, because of the generally higher suspended solids and particulates in groundwater samples collected using DPT. All of the ESI analytical data are included in **Appendix E** of this report. The samples evaluated in the baseline HHRA and the laboratory analyses performed for these samples are identified in **Table 5-1**. All data used in the HHRA were validated in accordance with USEPA Region III data validation requirements and meet the project quality requirements.

Groundwater samples were analyzed for both total and dissolved metals. The total and dissolved concentrations of aluminum, iron, and manganese were compared from each monitoring well to determine whether there were significant differences (over an order of magnitude) between the two in any of the wells, following USEPA guidance (USEPA, 1992). Because no significant differences were noted between total and dissolved concentrations in any of the wells for all three of these indicator metals, the total metals data were used to evaluate risks associated with exposure to metals in groundwater.

The data collected during the ESI were evaluated to assess their reliability for use in the quantitative risk assessments. The following criteria were used to assess data usability:

- Estimated values flagged with a J or L qualifier were treated as unqualified, detected concentrations.
- Data qualified with a B (blank contamination) were used in the risk assessment as if the constituents were not detected.
- For duplicate samples, the maximum concentration between the regular and duplicate samples was used as the sample concentration.
- Non-detected values were included in the risk assessment and exposure point concentration (EPC) calculations at the detection limit were performed using ProUCL (USEPA, 2013a).

Detailed results for the groundwater sampling that was performed at AOC 7 are presented in **Section 4** of this report.

5.3.2 Selection of Groundwater Constituents of Potential Concern

The selection of COPCs was based on the criteria presented in the USEPA Region III technical guidance manual *Selecting Exposure Routes and Contaminants of Concern by Risk-Based Screening* (USEPA, 1993) and *Risk Assessment Guidance for Superfund: Volume 1, Human Health Evaluation Manual (Part D)* (USEPA, 2001a). The maximum

detected concentration of each constituent was compared to the criteria discussed in this subsection to select the COPCs. If the maximum detected concentration exceeded the criteria, the constituent was selected as a COPC. Constituents that were not detected in any of the samples or were detected at concentrations less than the criteria were not identified as COPCs. The COPC screening is presented in **Tables 2.1 and 2.2** in **Appendix F**.

The groundwater data were compared to the USEPA RSLs for tap water (USEPA, 2013b). The RSLs for noncarcinogenic effects are based on a hazard quotient (HQ) of 0.1 to account for exposure to multiple constituents with the same target organ or target effect. The RSLs based on carcinogenic effects are based on a 1×10^{-6} carcinogenic risk. Lead concentrations in groundwater were compared to the federal action level of 15 µg/L (USEPA, 2009a).

Constituents that are considered essential nutrients and are toxic only at very high doses were eliminated from the quantitative risk analysis. These constituents are calcium, magnesium, potassium and sodium. Although iron and manganese are also considered essential nutrients and are only toxic at very high doses, iron and manganese were included in the HHRA because toxicity values are available for these two nutrients.

Background concentrations were not used to identify or eliminate COPCs; however, background concentrations are included in the screening tables, if available. Background concentrations are discussed in the risk characterization, if applicable (i.e., constituents resulting in risks above target risk levels may be associated with background conditions). Groundwater background concentrations are the 95 percent UTLs from the CAX/Yorktown background groundwater sample data set (CH2M HILL, 2011).

5.3.3 Groundwater Constituents of Potential Concern

Table 5-2 lists the constituents identified as COPCs for AOC 7 groundwater. The COPCs are:

- Arsenic
- Chromium
- Manganese
- Thallium

5.4 Exposure Assessment

Exposure refers to the potential contact by an individual with a constituent. The exposure assessment identifies pathways and routes by which an individual may be exposed to the COPCs, and estimates the magnitude, frequency, and duration of potential exposure. Constituent intakes and associated health risks are only quantified for complete exposure pathways.

The components of exposure assessment include the following:

- Development of the CSM for human health
- Calculation of EPCs
- Development of exposure assumptions for potentially complete exposure pathways
- Calculation of intake for COPCs using calculated EPCs and exposure assumptions

5.4.1 Conceptual Site Model for Human Health

The CSM for human health is presented in **Section 5.2** and **Figure 5-1**. The potentially exposed populations evaluated in the risk assessment are shown on **Figure 5-1**.

Groundwater at the site is not currently used as a water supply; therefore, there are no current exposure pathways to AOC 7 groundwater. However, although unlikely, it was assumed that groundwater could be used as a future potable water supply. Additionally, it was assumed that construction workers could be exposed to groundwater during excavation activities.

Potential future site use exposure routes for quantitative evaluation are:

- **Resident (adult and child):** Ingestion of and dermal contact with shallow groundwater
- **Industrial worker:** Ingestion of shallow groundwater

- **Construction worker:** Dermal contact with groundwater

No VOCs were identified as COPCs; therefore, inhalation of volatiles from groundwater is not a complete exposure pathway and was not evaluated in the HHRA.

5.4.2 Calculation of Exposure Point Concentrations

Exposure is quantified by estimating the EPCs for COPCs and COPC intake (ingestion, dermal absorption) by the receptor. The EPCs are the estimated constituent concentrations that a receptor may contact. The EPCs for AOC 7 are provided in **Table 3.1** of **Appendix F**.

ProUCL software Version 5.0 (USEPA, 2013a) was used to calculate the EPCs. The recommendations outlined in the ProUCL software documentation were followed to select the appropriate 95 percent upper confidence levels (UCLs) used as the EPC. The maximum detected concentration was used as the EPC when the estimated 95 percent UCL was greater than the maximum detected concentration, or where only one detected concentration was available for an analyte.

5.4.3 Estimation of Chemical Intakes for Individual Pathways

Chemical intake is the amount of the chemical constituent entering the receptor's body. The quantification of exposure is based on an estimate of the chronic daily intake (CDI), which is the average amount of the chemical entering the receptor's body per day. Chemical intake estimates for the ingestion and dermal exposure pathways are generally expressed as follows:

$$CDI = \frac{C \times CR \times EF \times ED}{BW \times AT}$$

Where:

- CDI = chronic daily intake, milligrams per kilogram per day
- C = chemical concentration, milligrams per liter (mg/L)
- CR = contact rate (liters per day)
- EF = exposure frequency (days per year)
- ED = exposure duration (years)
- BW = body weight (kilogram)
- AT = averaging time (days)

Intake equations for the dermal exposure pathway are shown in the **Appendix F, Table 4.1**. Reasonable maximum exposure (RME) levels and incorporate the skin surface area and an absorption or permeability factor. The chemical-specific exposure parameter values used for estimating dermal contact with groundwater, such as the skin permeability coefficient, are shown in the **Appendix F, Table 7 series** supplemental tables.

The intake and exposure equations require exposure parameters that are specific to each exposure pathway. Many of the exposure parameters have default values, which were used for this assessment. These assumptions, based on estimates of body weights, media intake levels, and exposure frequencies and duration are provided in USEPA guidance (USEPA, 1989; 1991; 2004; 2014) and VDEQ guidance (2003). Other assumptions (such as the construction worker scenario) require using professional judgment. **Table 4.1.RME** in **Appendix F** presents the exposure parameters that were used for all exposure scenarios evaluated in the risk assessment.

5.5 Toxicity Assessment

Toxicity assessment defines the relationship between the magnitude of exposure and possible severity of adverse effects, and weighs the quality of available toxicological evidence. Toxicity assessment generally consists of two steps: hazard identification and dose-response assessment. Hazard identification is the process of characterizing the potential adverse effects from exposure to the chemical and the type of health effect involved. Dose-response assessment is the process of quantitatively evaluating the toxicity information and characterizing the relationship between the dose of the constituent administered or received and the incidence of adverse health effects in the exposed population. Toxicity criteria (such as reference doses [RfDs], and cancer slope factors [CSFs]) are derived from the dose-response relationship.

The USEPA recommends a tiered approach be used to obtain the toxicity values (RfDs and CSFs) that are used to estimate noncarcinogenic hazards and carcinogenic risks (USEPA, 2003). The hierarchy of toxicity value sources is as follows:

1. Integrated Risk Information System (IRIS) (USEPA, 2013c)
2. Provisional peer-reviewed toxicity values
3. Other peer-reviewed USEPA and non-USEPA sources (USEPA, 2013d), including the Health Effects Assessment Summary Tables (USEPA, 1997a), New Jersey Department of Environmental Protection (NJDEP) chromium workgroup (NJDEP, 2009), and Agency for Toxic Substances and Disease Registry (ATSDR, 2004)

The use of toxicity values from sources other than IRIS increases the uncertainty of the quantitative risk estimates. Some of the COPCs elicit both systemic (noncarcinogenic) toxic effects and cancer (carcinogenic) effects. Because of this, these constituents are evaluated as both noncarcinogens and carcinogens. The health risks for carcinogenic and noncarcinogenic effects were estimated separately based on different toxicity values.

The noncarcinogenic toxicity values are provided in **Table 5.1** of **Appendix F** and the carcinogenic toxicity values are provided in **Table 6.1** of **Appendix F**.

Chromium is a COPC for groundwater. It was assumed that all of the chromium detected in groundwater is hexavalent chromium for determining if chromium was a COPC (comparing the total chromium concentrations to hexavalent chromium RSLs) and for calculating the risks associated with exposure to chromium. Hexavalent chromium is unstable in the body (in biological tissues) and is ultimately reduced to trivalent chromium by a variety of reducing agents, including ascorbate and glutathione (ATSDR, 2008; USEPA, 2013c). Hexavalent chromium exerts toxicity through direct contact mechanisms rather than bioaccumulation to a critical concentration in tissue. However, the hexavalent chromium toxicity values were used to evaluate the risks associated with chromium. An RfD for hexavalent chromium is available in IRIS; however, IRIS does not include a CSF for hexavalent chromium. The CSF for hexavalent chromium used in the HHRA is the same as that included on the RSL Table (USEPA, 2013b) from NJDEP (2009).

5.5.1 Toxicity Information for Noncarcinogenic Effects

Noncarcinogenic health effects include a variety of toxic effects on body systems, ranging from toxicity to the kidneys to central nervous system disorders. The toxicity of a chemical is assessed through a review of toxic effects noted in short-term (acute) animal studies, long-term (chronic) animal studies, and epidemiological investigations.

The USEPA (1989) defines the chronic RfD as a dose that is likely to be without appreciable risk of deleterious effects during a lifetime of exposure. Chronic RfDs are specifically developed to be protective for long-term exposure to a compound (for example, 7 years to a lifetime) and consider uncertainty in the toxicological database and sensitive receptors. Subchronic RfDs (applicable for exposures less than 7 years), which are all provisional values (that is, not verified by USEPA), were used for the construction worker scenario, if available. Chronic RfDs were used to evaluate noncarcinogenic risks to all other receptors included in the HHRA. In the development of RfDs, all available studies examining the toxicity of a chemical following exposure are considered on the basis of scientific merit. The lowest dose level at which an observed toxic effect occurs is identified as the lowest observed adverse effect level (LOAEL), and the dose at which no effect is observed is identified as the no observed adverse effect level (NOAEL). Several uncertainty factors (UFs) may be applied to account for uncertainties such as limited data, extrapolation of data from animal studies to human exposures, or the use of subchronic studies to develop chronic criteria. These UFs range from 10 to 10,000, and are based on professional judgment. Consequently, there are varying degrees of uncertainty in the toxicity criteria, which range from 1 to 3,000 for the COPCs identified for this site.

In accordance with USEPA guidance, oral RfDs were adjusted from administered dose (oral) to absorbed dose (dermal) to evaluate dermal toxicity. When appropriate, the RfDs were adjusted using oral absorption factors (USEPA, 2004). This adjustment is shown in **Table 5.1** in **Appendix F**.

5.5.2 Toxicity Information for Carcinogenic Effects

Potential carcinogenic effects are quantified as CSFs that convert estimated exposures directly to incremental lifetime carcinogenic risks.

The CSFs may be derived from the results of chronic animal bioassays, human epidemiological studies, or both. Animal bioassays are usually conducted at dose levels that are much higher than are likely to be encountered in the environment. This design detects possible adverse effects in the relatively small test populations used in the studies. The actual risks from exposure to a potential carcinogen are not likely to exceed the estimated risks and are probably much lower or even zero.

As was done for oral RfDs, oral CSFs were adjusted from administered dose (oral) to absorbed dose (dermal) to evaluate dermal toxicity. When appropriate, the CSFs were adjusted using oral absorption factors (USEPA, 2004). This adjustment is shown in **Table 6.1** in **Appendix F**.

5.5.3 Approach for Potential Mutagenic Effects

Consistent with USEPA's Cancer Guidelines and Supplemental Guidance (USEPA, 2005a; 2005b), cancer risks were estimated using age-dependent adjustment factors (ADAFs) for COPCs, which act via a mutagenic mode of action (MMA). Chromium is the only COPC categorized as a chemical with an MMA.

The calculation of cancer risk using ADAFs is presented in **Table 7.4.RME Supplement A** in **Appendix F**. Because chemical-specific data are not available for chromium, default ADAFs, as included in the USEPA Region III memorandum, *Derivation of RBCs for Carcinogens that Act Via a Mutagenic Mode of Action and Incorporate Default ADAFs* (USEPA, 2006a), were used for the MMA evaluation. The default ADAFs used to adjust the CSF are 10 for 0 to 2-year-olds, 3 for 2- to 6-year-olds, 3 for 6- to 12-year-olds, and 1 for 16- to 26-year-olds. The CSF was multiplied by the appropriate ADAF to derive the age-specific CSF for a receptor to calculate the total carcinogenic risk. Additionally, the exposure factors for children 0 to 2 years old and 2 to 6 years old were assumed to be the same as the exposure factors for a child 0 to 6 years old, with the exception of the exposure duration, which was 2 years and 4 years, respectively. The exposure factors for the adult residential receptor were used for residents 6 to 16 years old and 16 to 26 years old, with the exception of the exposure durations, which were 10 years for each age range.

5.5.4 Constituents for Which United States Environmental Protection Agency Toxicity Values Are Not Available

Quantitative oral toxicity criteria are not available for lead. As a screening tool, lead is screened against 15 µg/L in groundwater based on residential exposure. Lead concentrations in groundwater were below this screening level; therefore, no further evaluation of lead was necessary.

5.6 Risk Characterization

Risk characterization combines the results of the previous elements of the risk assessment to evaluate the potential health risks associated with exposure to the COPCs. The risk characterization is then used as an integral component in risk management decision making.

5.6.1 Methods for Estimating Risks

Potential human health risks are discussed independently for carcinogenic and noncarcinogenic constituents, because of the different toxicological endpoints, relevant exposure duration, and methods used to characterize risk. Exposure to some constituents may result in both noncarcinogenic and carcinogenic effects (arsenic); therefore, these constituents were evaluated in both groups. The methodology used to estimate noncarcinogenic hazards and carcinogenic risks is described as follows.

5.6.1.1. Noncarcinogenic Hazard Estimation

Noncarcinogenic health risks are estimated by comparing the calculated exposures to RfDs. The calculated intake divided by the RfD, is equal to the HQ:

$$HQ = \text{Intake} / \text{RfD}$$

The intake and RfD represent the same exposure route (that is, oral intakes are divided by oral RfDs). An HQ that exceeds 1 (that is, intake exceeds the RfD) indicates that there is a potential for adverse health effects associated with exposure to that constituent.

To assess the potential for noncarcinogenic health effects posed by exposure to multiple constituents, a hazard index (HI) approach is used (USEPA, 1986). This approach assumes that noncarcinogenic hazards associated with exposure to more than one constituent are additive (HI = sum of the HQs). Synergistic or antagonistic interactions between constituents are not considered. The HI may exceed 1 even if all of the individual HQs are less than 1. The HIs may be added across exposure routes to estimate the total noncarcinogenic health effects to a receptor posed by exposure through multiple routes. If the HI is greater than 1, separate HIs are estimated for each target organ to assess whether the HI for a specific target organ is greater than 1. A target-organ-specific HI greater than 1 indicates there is some potential for adverse noncarcinogenic health effects associated with exposure to the COPCs, possibly warranting remedial action. If the HI for each target organ does not exceed 1, noncarcinogenic hazards are not expected.

5.6.1.2. Carcinogenic Risk Estimation

The potential for carcinogenic effects resulting from exposure to site-related constituents is evaluated by estimating the excess lifetime cancer risk (ELCR). The ELCR is the incremental increase in the probability of developing cancer during one's lifetime in addition to developing cancer associated with exposure to all non-site-related sources of carcinogens.

Carcinogenic risk is calculated by multiplying the intake by the CSF:

$$\text{ELCR} = \text{Intake} \times \text{CSF}$$

The combined risk from exposure to multiple constituents was evaluated by adding the risks from individual constituents. Risks were also added across the exposure routes if an individual were to be exposed through multiple routes.

As required under the National Oil and Hazardous Substances Pollution Contingency Plan (USEPA, 1994) "[f]or known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} to 10^{-6} using information on the relationship between dose and response." When a cumulative carcinogenic risk to a receptor under the assumed RME exposure conditions exceeds 1 in 10 thousand (that is, 10^{-4} ELCR), CERCLA generally requires remedial action to reduce risks at the site.

5.6.2 Risk Assessment Results

The results of risk estimates for AOC 7 are summarized as follows by receptor. A summary of the RME results is presented in **Table 5-3**. The risk calculations are presented in **Tables 7.1.RME through 7.5.RME in Appendix F**. **Tables 9.1.RME through 9.5.RME in Appendix F** summarize the hazards and risks to each receptor. The constituents of concern (COCs) are identified in the following subsections for each receptor, if applicable. The COCs are those COPCs that contribute an HI greater than 0.1 to a cumulative target organ HI that exceeds 1, or a carcinogenic risk greater than 1×10^{-6} to a cumulative carcinogenic risk that exceeds 1×10^{-4} .

5.6.2.1. Future Industrial Worker (Table 9.1.RME, Appendix F)

The risk assessment assumed that a future industrial worker could be exposed to groundwater used as a potable water supply through ingestion.

- Total HI (RME) = 0.08, which is less than the target HI.
- Total ELCR (RME) = 6×10^{-6} , which is within the target risk range of 1×10^{-6} to 1×10^{-4} .

5.6.2.2. Future Adult Resident (Noncarcinogenic Hazard, Table 9.2.RME, Appendix F)

The risk assessment assumed that a future adult resident could be exposed to groundwater used as a potable water supply through ingestion, and dermal contact while showering. Carcinogenic risks were not calculated for an adult resident; they were calculated for a lifetime child/adult resident following USEPA guidance (see **Section 5.6.2.4**).

- Total HI (RME) = 0.2, which is less than the target HI.

5.6.2.3. Future Child Resident (Noncarcinogenic Hazard, Table 9.3, Appendix F)

The risk assessment assumed that a future child resident could be exposed to groundwater used as a potable water supply through ingestion, and dermal contact while bathing. Carcinogenic risks were not calculated for a child resident; they were calculated for a lifetime child/adult resident in accordance with USEPA guidance (see Section 5.6.2.4).

- Total HI (RME) = 0.4, which is less than the target HI.

5.6.2.4. Future Lifetime Resident (Carcinogenic Risk, Table 9.3.RME, Appendix F)

The risk assessment assumed that a future lifetime child/adult resident could be exposed to groundwater used as a potable water supply through ingestion, and dermal contact while showering or bathing.

- Total ELCR (RME) = 6×10^{-5} , which is within the target risk range of 1×10^{-6} to 1×10^{-4} .

5.6.2.5. Future Construction Worker (Table 9.4.RME, Appendix F)

The risk assessment assumed that a future construction worker could be exposed groundwater during excavation activities through dermal contact.

- Total HI (RME) = 0.01, which is less than the target HI.
- Total ELCR (RME) = 2×10^{-7} , which is below the target risk range of 1×10^{-6} to 1×10^{-4} .

5.7 Uncertainty Associated with Human Health Assessment

The risk measures used in site risk assessments are not fully probabilistic estimates of risk, but are conditional estimates given that a set of assumptions about exposure and toxicity are realized. Thus, it is important to specify the assumptions and uncertainties inherent in the risk assessment to place the risk estimates in proper perspective.

5.7.1 Uncertainty in Data Evaluation and Constituents of Potential Concern Selection

The groundwater sampling focused on areas most likely affected by past site activities and where contamination would most likely be found based on previous DPT groundwater and soil sampling. Therefore, the uncertainty associated with missing a contaminated location is expected to be minimal, because the investigation was focused to find the most likely and potentially highest areas of contamination. This uncertainty associated with the data analysis is minimal, and all of the data were validated prior to being used in the HHRA. A data quality evaluation was performed on all analytical data evaluated in the HHRA, as discussed in **Appendix E** of this ESI.

The general assumptions used in the COPC selection process were conservative to ensure that true COPCs were not eliminated from the quantitative risk assessment, and that the reasonable maximum risk was estimated. RSLs based on residential assumptions were used to select the COPCs for all exposure scenarios, including non-residential scenarios.

A comparison of site concentrations to background concentrations was not used to select the COPCs. Therefore, it is possible that any of the metals identified as COPCs may be associated with background conditions. The arsenic, chromium, and manganese concentrations detected in groundwater samples from AOC 7 monitoring wells are below the 95 percent UTLs from the CAX/Yorktown background groundwater samples (CH2M HILL, 2011); therefore, the calculated risks associated with exposure to arsenic, chromium, and manganese in the groundwater are likely associated with background conditions and not site-related.

Detection limits for constituents that were not detected in groundwater were compared to the screening levels to determine whether there are any non-detected constituents with detection limits above the screening level. One VOC (1,2-dibromo-3-chloropropane), not detected, has a detection limit above the screening level; however, it is within an order of magnitude above the screening.

5.7.2 Uncertainty Associated with Exposure Assessment

Uncertainty in the exposure assessment was generally treated with conservative decision rules and assumptions, and therefore the uncertainty likely overestimates actual exposure to COPCs. Several exposure pathways evaluated by the HHRA, such as residential land use, are hypothetical and are not likely to occur in the future at AOC 7. It is also not likely that shallow groundwater would be used as a potable or industrial water supply because of the availability of better water supplies with respect to both water quality and quantity. Most of the exposure factors used for quantitation of exposure are generally conservative and reflect worst-case, or upper-bound, assumptions for the exposure.

5.7.3 Uncertainty Associated with Toxicity Assessment

Uncertainty associated with the noncarcinogenic toxicity factors is included in the toxicity tables in **Appendix F**. Several UFs were applied to extrapolate dose points from animal studies to humans. These UFs range between 1 and 3,000. Therefore, there is a high degree of uncertainty in the noncarcinogenic toxicity criteria based on the available scientific data for each constituent. The noncarcinogenic toxicity factors are most likely an overestimate of actual toxicity.

The uncertainty associated with CSFs is mostly a result of the low-dose extrapolation where carcinogenicity at low doses is assumed to be a linear response. This is a conservative assumption, which introduces a high uncertainty into slope factors that are extrapolated from this area of the dose-response curve. The CSFs are based on the assumption that there is no threshold level for carcinogenicity; however, most of the experimental studies indicate the existence of a threshold level. Therefore, CSFs developed by USEPA represent upper-bound estimates. Carcinogenic risks generated in this assessment should be regarded as an upper-bound estimate on potential carcinogenic risks, rather than an accurate representation of carcinogenic risk. The true carcinogenic risk is likely to be less than the predicted value (USEPA, 1989). Uncertainty is also associated with the application of the MMOA for chromium; this may overestimate or underestimate risks. Additionally, generic ADAFs were used in the MMOA calculations because no chemical-specific ADAFs are available for the COPCs.

Total chromium was identified as a COPC. The toxicity values for hexavalent chromium were conservatively used to estimate potential noncarcinogenic hazards and carcinogenic risks associated with exposures to total chromium. It is not likely that all of the chromium detected is in the hexavalent form rather than the more common trivalent form; therefore, the hazards and risks are likely overestimated for potential exposures to chromium through direct contact with groundwater.

Use of provisional toxicity factors increases the uncertainty of the quantitative hazard and risk estimates. These provisional values were used to provide a quantitative estimate rather than a merely qualitative risk discussion; however, these values should be interpreted cautiously because USEPA has not approved these toxicity values.

Additional uncertainty lies in the prediction of relative sensitivities of different species of animals and the applicability of animal data to humans.

A large degree of uncertainty is associated with the oral-to-dermal adjustment factors (based on constituent-specific gastrointestinal absorption factors) used to transform the oral RfDs based on administered doses to dermal RfDs based on absorbed doses. It is unknown whether the adjustment factor results in an underestimate or overestimate of the actual toxicity associated with dermal exposure.

5.7.4 Uncertainty in Risk Characterization

The uncertainties identified in each component of risk assessment ultimately contribute to uncertainty in risk characterization. The addition of risks and HIs across pathways and constituents contributes to uncertainty based on chemical interactions such as additivity, synergism, potentiation, and susceptibility of exposed receptors.

5.8 Human Health Risk Summary

The HHRA was conducted to evaluate exposure to contamination associated with groundwater at AOC 7.

Table 9 and **Tables 9.1.RME through 9.4.RME** in **Appendix F** summarize the RME potential hazards and risks to each receptor. The HIs and ELCRs for exposure to groundwater at AOC 7 for all potential human receptors are within USEPA-acceptable levels.

TABLE 5-1

Summary of Data Used in Baseline Human Health Risk Assessment

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Medium/ Sample ID	Date of Sampling	Sample Locations	Parameters
Groundwater			
CAA07-GW01-0114	1/16/2014	CAA07-MW01	VOCs, Total Metals, Dissolved Metals
CAA07-GW01P-0114 ¹	1/16/2014	CAA07-MW01	VOCs, Total Metals, Dissolved Metals
CAA07-GW02-0114	1/15/2014	CAA07-MW02	VOCs, Total Metals, Dissolved Metals
CAA07-GW03-0114	1/15/2014	CAA07-MW03	VOCs, Total Metals, Dissolved Metals
CAA07-GW04-0114	1/15/2014	CAA07-MW04	VOCs, Total Metals, Dissolved Metals
CAA07-GW05-0114	1/16/2014	CAA07-MW05	VOCs, Total Metals, Dissolved Metals

Notes:

VOCs = volatile organic compounds

¹ Duplicate of previous sample.

TABLE 5-2

Summary of Chemicals of Potential Concern for the HHRA

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Groundwater
Arsenic
Chromium
Manganese
Thallium

TABLE 5-3

Summary of RME Cancer Risks and Hazard Indices

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Receptor	Media	Exposure Route	Cancer Risk	Chemicals with Cancer Risks >10 ⁻⁴	Chemicals with Cancer Risks >10 ⁻⁵ and <10 ⁻⁴	Chemicals with Cancer Risks >10 ⁻⁶ and <10 ⁻⁵	Hazard Index	Chemicals with HI>1	COCs ¹
Future Industrial Worker	Groundwater	Ingestion	6E-06			Arsenic, Chromium	0.08		None
		Dermal Contact	N/A				N/A		
		Inhalation	N/A				N/A		
		Total	6E-06			Arsenic, Chromium	0.08		
Future Resident Adult	Groundwater	Ingestion	N/A				0.2		None
		Dermal Contact	N/A				0.02		
		Inhalation	N/A				N/A		
		Total	N/A				0.2		
Future Resident Child	Groundwater	Ingestion	N/A				0.4		None
		Dermal Contact	N/A				0.0		
		Inhalation	N/A				N/A		
		Total	N/A				0.4		
Future Resident Child/Adult	Groundwater	Ingestion	5E-05		Chromium	Arsenic	N/A		None
		Dermal Contact	1E-05			Chromium	N/A		
		Inhalation	N/A				N/A		
		Total	6E-05		Chromium	Arsenic	N/A		
Future Construction Worker	Groundwater	Ingestion	N/A				N/A		None
		Dermal Contact	2E-07				0.01		
		Inhalation	N/A				N/A		
		Total	2E-07				0.01		

Notes:

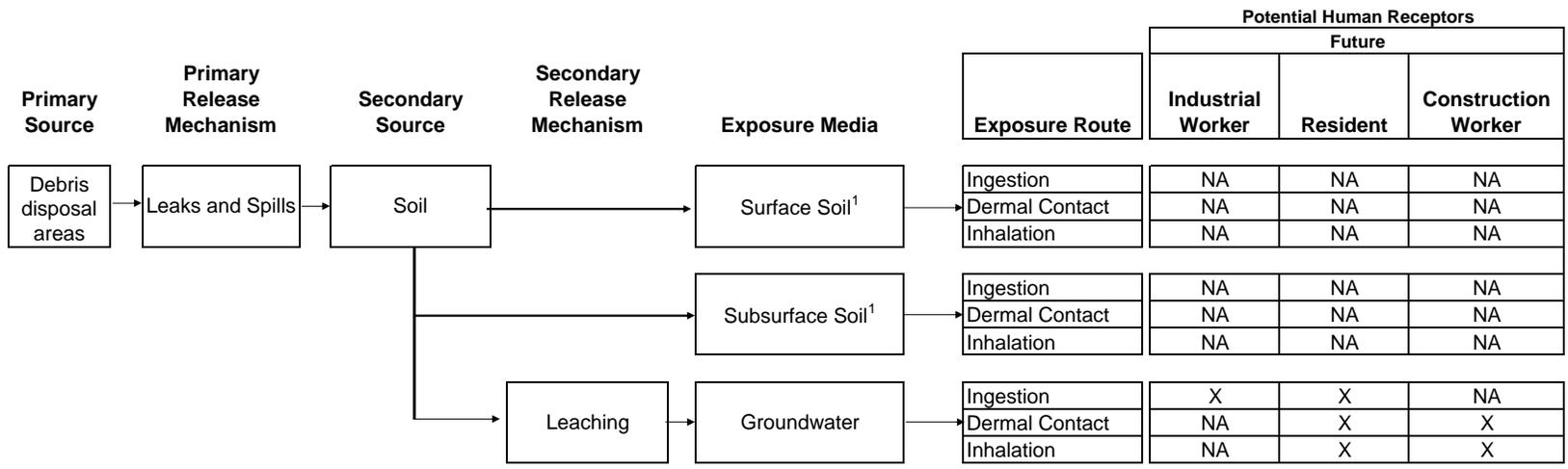
¹ Includes analytes with an ELCR greater than 1E-06 that contribute to a total risk greater than 1E-04 and/or analytes with an HI greater than 0.1 that contribute to a target organ HI greater than 1.

COC = Contaminants of concern

ELCR = Excess Lifetime Cancer Risk

HI = Hazard Index

N/A = Not available/not applicable



¹ Media to be addressed as part of interim removal action.

NA - Not Applicable or pathway is incomplete
 X - Potentially complete exposure pathways

FIGURE 5-1
 Conceptual Site Model for the HHRA
 AOC 7 Expanded Site Inspection Report
 Cheatham Annex
 Williamsburg, Virginia

Ecological Risk Assessment

This section contains a screening ecological risk assessment (SERA), constituting Steps 1 and 2 of the ERA process, and the first step (Step 3A) of a baseline ecological risk assessment (BERA) for AOC 7 groundwater.

6.1 Introduction

The previous ecological risk evaluation of AOC 7 was conducted as part of the SI report (CH2M HILL, 2012) and consisted of an ecological risk screening, constituting a SERA and an abbreviated version of BERA Step 3A. This screening involved a comparison of surface soil, subsurface soil, and groundwater data collected in 2008 with medium-specific ecological screening values (ESVs). Based on the results of the SI, a removal action is currently planned to address subsurface debris and surface soil at the site. The results of the SI were also used to develop the SAP for this ESI of groundwater at AOC 7. The 2008 groundwater data evaluated as part of the 2012 SI are not included in this ERA because they were collected using DPT.

6.1.1 Ecological Risk Assessment Process

The ERA was conducted in accordance with the *Navy Policy for Conducting Ecological Risk Assessments* (CNO, 1999) and the Navy guidance for implementing this ERA policy (NAVFAC, 2003; 2012). The Navy ERA policy and guidance, which describe a process consisting of eight steps organized into three tiers, are conceptually similar to the 8-step ERA process outlined in USEPA ERA guidance for the Superfund program (USEPA, 1997b). For both sets of guidance, Steps 1 and 2 involve conducting a SERA using very conservative assumptions. The BERA represents Steps 3 through 7. The BERA uses less-conservative (but more realistic) assumptions and site-specific data to refine the risk estimates from the SERA for components that fail the initial screening. Step 8 addresses risk management issues. The major differences between the Navy ERA policy/guidance and the USEPA ERA guidance are:

- Navy policy/guidance provide clearly defined criteria for exiting the ERA process at specific points
- Navy policy/guidance divide Step 3 (the first step of the BERA) into two distinct sub-steps (Steps 3A and 3B), with a potential exit point after Step 3A
- Navy policy/guidance incorporate risk management considerations throughout all tiers of the ERA process

The ERAs are conducted using a tiered, step-wise approach and are punctuated with Scientific Management Decision Points (SMDPs). The SMDPs represent points in the ERA process where agreement on conclusions, actions, or methodologies is needed so that the ERA process can continue (or terminate) in a technically defensible manner. The results of the ERA at a particular SMDP are used to determine how the ERA process should proceed (for example, to the next step in the process, or directly to a later step). The process continues until a final decision has been reached (for example, remedial action if unacceptable risks are identified, or no further action if risks are acceptable). The process can also be iterative if data needs are identified at any step; the needed data are collected and the process starts again at the point appropriate to the type of data collected.

Preliminary screening problem formulation is the first step of an ERA and establishes the goals, scope, and focus of the SERA. Step 1 of the ERA process is intended to answer two main questions:

- Do complete exposure pathways exist?
- Are sufficient data available to conduct the SERA?

If no complete exposure pathways exist, the ERA process terminates at Step 1 with a conclusion of negligible (acceptable) risk because exposure, and thus potential risk, can only occur if complete exposure pathways exist. If one or more complete exposure pathways are known to exist, or are likely to exist, the ERA process continues to Step 2 but only evaluates those exposure pathways that have been determined to be “critical” (ecologically important); that is, those pathways that represent exposures to sensitive receptors that are associated with the predominant fate and transport mechanisms at the site (USEPA, 1997b). An evaluation of the available data is

then conducted to determine whether they are adequate to support the SERA. If not, additional data are collected before the ERA process continues. The second step of the ERA process involves conducting a screening exposure assessment, a screening effects assessment, and a screening risk calculation (risk characterization).

The results of the SERA are used to evaluate the potential for unacceptable ecological risks based on very conservative assumptions. If the results of the SERA suggest that further ecological risk evaluation is warranted, the ERA process proceeds to the BERA (Steps 3 through 7), which is a more detailed phase of the ERA process, for the exposure pathways, chemicals, receptors, and areas identified in the SERA. As previously indicated, the first step of the BERA (Step 3) is divided into two distinct sub-steps (3A and 3B) in Navy ERA guidance.

Step 3 of the USEPA ERA guidance consists of the following activities (USEPA, 1997b):

1. Refining the COPCs from the SERA
2. Further characterizing the potential ecological effects of contaminants
3. Refining information on contaminant fate and transport, complete exposure pathways, and receptors potentially at risk
4. Selecting assessment endpoints
5. Refining the CSM and risk hypotheses from the SERA

Step 3A of the Navy policy/guidance (refinement of conservative exposure assumptions) corresponds to the first activity, previously listed, for the USEPA ERA guidance. In Step 3A, a refined evaluation of exposure estimates is conducted using less-conservative (but more realistic) assumptions and additional methods relative to those used in the SERA, which is intended to be a very conservative assessment (NAVFAC, 2003). Examples of less-conservative (but more realistic) exposure assumptions include using central tendency (such as means or medians) estimates (rather than maximums) for media concentrations, bioaccumulation factors, and/or exposure parameters. Examples of additional methods include the consideration of background concentrations, bioavailability, and detection frequency (CNO, 1999; NAVFAC, 2003; 2012).

If risk estimates (and their associated uncertainty) are acceptable following Step 3A, the site will meet the conditions of the exit criterion specified in the Navy policy/guidance. If the Step 3A evaluation does not support a determination of acceptable risk within acceptable uncertainty, the site continues to Step 3B.

Step 3B of the Navy policy/guidance (problem formulation) corresponds conceptually to the last four activities, previously listed, for Step 3 of the USEPA ERA guidance. In Step 3B, the preliminary CSM from the SERA is refined based on the results of the Step 3A evaluation to develop a revised list of key receptors, critical exposure pathways, key COPCs, assessment endpoints, measurement endpoints, and risk hypotheses. Based on the refined CSM, the lines of evidence to be used in characterizing risk are determined. Agreement on the refined CSM, COPCs, exposure pathways, endpoints, and risk hypotheses constitutes the SMDP at the end of Step 3 in both Navy and USEPA ERA guidance.

Following the completion of Step 3, a decision point is reached with two potential outcomes. If the refined risk estimates are acceptable for each selected assessment endpoint, the investigation proceeds to risk characterization (Step 7) to document this conclusion, and the ERA process terminates. If the uncertainties associated with the refined risk estimates are unacceptable and/or the risk estimates indicate that unacceptable risks may exist, site-specific studies might be required and the ERA process continues (Steps 4 through 6). Step 4 is a work-planning step where additional site-specific studies are scoped and designed. Step 5 consists of the verification of the field sampling design developed in Step 4, and Step 6 constitutes the site investigation and data analysis phase of the process. The scope (the spatial extent of sampling) and components (for example, the collection of biological data such as tissue samples and toxicity testing) of any site-specific studies are determined by the conclusions of Step 3 and the pathways and endpoints associated with the potential unacceptable risks.

Step 7 consists of the documentation and synthesis of the information and data identified in Steps 1 through 3 (no additional study) or Steps 1 through 6 (additional study). In this step, ecological risk is evaluated and characterized using both quantitative and qualitative methods. Conclusions are made as to whether or not there is a reasonable

potential for unacceptable ecological risk and, if there is a potential for unacceptable ecological risk, the magnitude of that risk. The results of the completed BERA (Step 7) are used to make any necessary risk management decisions (Step 8) related to current or future risks. Possible decisions include:

- Adequate information is available to conclude that no unacceptable ecological risks exist. The assessment should stop at Step 7.
- Adequate information is available to conclude that unacceptable ecological risks exist for which remedial actions or controls are warranted. Whether remedial actions or controls are taken, and the specific actions or controls taken, will depend on a number of risk management factors, such as the results of any HHRAs (if applicable) and the potential impact of the remedial action or control itself on the habitats and biota present. This analysis would occur as part of Step 8.
- Adequate information is not available to estimate risk or the risk estimate is believed to be too conservative or uncertain to recommend remediation. The assessment should be refined.

6.2 Problem Formulation

Problem formulation establishes the goals, scope, and focus of the ERA. As part of problem formulation, the ecological setting of AOC 7 is characterized in terms of the habitats and biota known or likely to be present. The types and concentrations of chemicals that are present in ecologically relevant media are also described based on available analytical data. For this ESI, groundwater is evaluated as a potential transport medium to downgradient water bodies.

A CSM is developed that describes source areas, transport pathways and exposure media, exposure pathways and routes, and receptors. Assessment endpoints, measurement endpoints, and risk hypotheses are developed to evaluate those receptors for which critical exposure pathways exist. The fate, transport, and toxicological properties of the chemicals present at AOC 7 are also considered during this process.

6.2.1 Environmental Setting

AOC 7 is approximately 1.5 acres in size and consists of several small surface debris disposal areas containing 55-gallon drums (the Drum Disposal Area) and numerous cans (the Can Pit) (**Figure 1-2**). AOC 7 is a wooded area located along a popular hiking trail and contains no wetlands or other water bodies. It is located several hundred feet southwest of a finger of Cheatham Pond, a large freshwater body. Although the topography of AOC 7 is relatively flat, the topography generally slopes northeast, toward Cheatham Pond (**Figure 1-2**). Surface runoff as a result of heavy rain is expected to flow northeast toward Cheatham Pond, but there are no defined channels or ditches connecting the site with Cheatham Pond. The first encountered groundwater at AOC 7 is within the Yorktown-Eastover aquifer, at depths ranging from 5.36 to 6.79 feet bgs. Groundwater elevations are not expected to be affected by the tide cycles and groundwater flows north toward Cheatham Pond (**Figure 3-4**).

In March 2006, surface debris was removed from the Can Pit. In April 2006, approximately 20 rusty pails and two empty 55-gallon drums were removed from the ground surface at the Drum Disposal Area. Following the housekeeping removal effort, all surface debris from AOC 7 was transported offsite to Bethel Landfill for proper disposal (Shaw, 2006). The Can Pit was encircled with an orange safety fence and left open following the housekeeping removal effort. Based on the results of the 2012 SI, a removal action is currently planned to address subsurface debris in the Can Pit and surface soil at the site.

6.2.2 Data Used in the ERA

Although ecological receptors do not have direct exposure to groundwater, groundwater data collected as part of this ESI were evaluated in this ERA. This process was done to provide a conservative evaluation of the potential for significant contaminant transport via groundwater to downgradient receiving water bodies (Cheatham Pond) and the subsequent potential exposure of ecological receptors in this water body.

Only the groundwater data collected (from permanent monitoring wells) in 2014 for this ESI were quantitatively evaluated in this ERA. The historical (2008) groundwater data used in the 2012 SI were not included because they were DPT samples.

The samples used in this ERA are listed in **Table 6-1** and are shown on **Figure 1-2**. The analytical data for these samples is in **Appendix E**.

6.2.3 Conceptual Site Model

The CSM relates potentially exposed receptor populations with potential source areas based on physical site characteristics and complete exposure pathways. Important components of the CSM are the identification of potential source areas, transport pathways, exposure media, exposure pathways and routes, and receptors. Actual or potential exposures of ecological receptors associated with a site are determined by identifying the most likely, and most important, mechanisms and pathways of contaminant release and transport. A complete exposure pathway has three components: 1) a source or sources of contamination that results in a release to the environment, 2) a pathway and mechanism of chemical transport through an environmental medium, and 3) an exposure or contact point for an ecological receptor. **Figure 6-1** illustrates a diagrammatic CSM for AOC 7. Key components of this CSM are discussed in the following subsections.

6.1.1.1. Source Areas

The sources of potential contamination at AOC 7 are the small surface debris disposal areas containing 55-gallon drums (the Drum Disposal Area) and cans and other debris (the Can Pit).

6.1.1.2. Transport Pathways and Exposure Media

A transport pathway describes the mechanisms whereby site-related chemicals, once released, may be transported from a source to ecologically relevant media where exposures may occur. These transport pathways are shown on **Figure 6-1**.

The primary release mechanisms and transport pathways at the site include:

- Infiltration, percolation, and leaching of contaminants to groundwater and subsequent discharge to the surface water and sediment of Cheatham Pond
- Surface runoff from site-related source areas to other terrestrial areas of AOC 7
- Uptake from the surface soil and accumulation in the tissues of terrestrial biota

Only the first of these mechanisms/pathways is evaluated in this ESI. The remaining two, related to soil, were evaluated in the 2012 SI. Site soil will be addressed as part of a future removal action.

Exposure media for ecological receptors are typically limited to surface water, surface sediment, and surface soil. Surface water and sediment are not evaluated in this ERA because the site does not contain wetlands or water bodies. As previously noted, soil at the site and subsurface debris within the Can Pit will be addressed by a future removal action. Groundwater is generally considered only as a transport medium because there are no ecological exposures to groundwater until it discharges to a water body or surfaces as a seep. In this ERA, groundwater is evaluated as a potential transport medium to a downgradient water body (Cheatham Pond).

6.1.1.3. Exposure Pathways and Routes

An exposure pathway links a source of contamination with one or more receptors through exposure via one or more media and exposure routes. Exposure, and thus potential risk, can only occur if complete exposure pathways exist. **Figure 6-1** shows the potentially complete exposure pathways to ecological receptors associated with AOC 7, which include:

- Direct contact with site-related chemicals in surface soil for lower-trophic-level receptors (such as plants and soil invertebrates); soil and subsurface debris will be addressed as part of a future removal action
- Potential ingestion of site-related chemicals via the food chain by avian, mammalian, and reptilian terrestrial receptors; soil and subsurface debris will be addressed as part of a future removal action

As previously discussed, there are no complete exposure pathways for aquatic receptors on the site because of the lack of wetland and aquatic habitats. However, groundwater is evaluated as a potential transport medium to a downgradient water body (Cheatham Pond).

An exposure route describes the specific mechanism(s) by which a receptor is exposed to a chemical present in an environmental medium. The most common exposure routes are dermal contact, direct uptake, ingestion, and inhalation. Terrestrial plants may be exposed to chemicals present in surface soil through their root surfaces during water and nutrient uptake. Unrooted, floating aquatic plants, rooted submerged vascular aquatic plants, and algae may be exposed to chemicals directly from the water or (for rooted plants) from sediment. Terrestrial and aquatic and benthic invertebrates may be exposed to chemicals in surface soil, surface sediment, and/or surface water through direct contact and ingestion.

Animals may be exposed to chemicals through the following pathways: 1) inhalation of gaseous chemicals or of chemicals adhered to airborne particulate matter, 2) incidental ingestion of contaminated abiotic media (soil or sediment) during feeding or preening activities, 3) ingestion of contaminated water, 4) ingestion of contaminated plant and/or animal tissues for chemicals that have entered food webs, and/or 5) dermal contact with contaminated abiotic media. These routes, where applicable, are depicted on **Figure 6-1**.

6.1.1.4. Receptors

Because of the complexity of natural systems, it is generally not practical to directly assess the potential impacts to all ecological receptors present at a site. Therefore, specific receptor species (such as red-tailed hawk) or species groups (such as plants) are selected as surrogates to evaluate potential risks to larger components of the ecological community (for example, guilds, such as carnivorous birds) used to represent the assessment endpoints (survival and reproduction of carnivorous birds). Selection criteria typically include those species that:

- Are known to occur or are likely to occur at the site
- Have a particular ecological, economic, or aesthetic value
- Are representative of taxonomic groups, life history traits, and/or trophic levels in the habitats present for which complete exposure pathways are likely to exist
- Can, because of toxicological sensitivity or potential exposure magnitude, be expected to represent potentially sensitive populations

Lower-trophic-level receptors were evaluated based on those taxonomic groupings for which medium-specific ESVs have been developed. As such, specific species of aquatic biota were not chosen as receptors because of the limited information available for specific species and because aquatic biota (plants, fish, aquatic and benthic invertebrates, amphibians, and reptiles) were evaluated on a community level via a comparison of site groundwater concentrations with surface water ESVs.

6.1.1.5. Endpoints and Risk Hypotheses

The conclusion of the problem formulation includes the selection of ecological endpoints and risk hypotheses, which are based on the CSM. Two types of endpoints, assessment endpoints and measurement endpoints, are defined as part of the ERA process (USEPA, 1997b). An assessment endpoint is an explicit expression of the environmental component or value that is to be protected. A measurement endpoint is a measurable ecological characteristic that is related to the component or value chosen as the assessment endpoint. The considerations for selecting assessment and measurement endpoints are summarized in USEPA (1997b) and discussed in detail in Suter (1989; 1990; 1993). Risk hypotheses are testable hypotheses about the relationship among the assessment endpoints and their predicted responses when exposed to contaminants.

Endpoints define ecological attributes that are to be protected (assessment endpoints) and measurable characteristics of those attributes (measurement endpoints) that can be used to gauge the degree of impact that has or may occur. Assessment endpoints most often relate to attributes of biological populations or communities, and are intended to focus the risk assessment on particular components of the ecosystem that could be adversely affected by chemicals attributable to a site (USEPA, 1997b). Assessment endpoints contain an entity (such as hawk

population) and an attribute of that entity (such as survival rate). Individual assessment endpoints usually encompass a group of species or populations (the receptor) with some common characteristic, such as specific exposure route or contaminant sensitivity, with the receptor then used to represent the assessment endpoint in the risk evaluation.

Assessment and measurement endpoints may involve ecological components from any level of biological organization, from individual organisms to the ecosystem itself. Effects on individual organisms are important for some receptors, such as rare and endangered species; population- and community-level effects are typically more relevant to ecosystems. Population- and community-level effects are usually difficult to evaluate directly without long-term and extensive study. However, measurement endpoint evaluations at the individual level, such as an evaluation of the effects of chemical exposure on reproduction, can be used to predict effects on an assessment endpoint at the population or community level. In addition, use of criteria values designed to protect the majority of the components of a community (such as the ambient water quality criteria [AWQC] for the protection of aquatic life) can be useful in evaluating potential community- and/or population-level effects.

Table 6-2 shows the assessment endpoints, risk hypotheses, and measurement endpoints used in the ERA, and includes the receptors associated with each endpoint.

6.3 Exposure Assessment

The principal activity associated with the exposure assessment is the estimation of chemical concentrations in applicable media (EPCs) to which the receptors may be exposed. This is accomplished through the selection of appropriate sets of the available analytical data using a set of criteria (such as validation status and sampling date). Once the analytical data sets are selected, the EPCs are calculated as a particular point on the distribution of concentrations. At the screening level (SERA: Step 2), the EPC is the maximum detected concentration. At the baseline level (BERA: Step 3A), the EPCs are central tendency estimates (such as the arithmetic mean).

For conservatism, the maximum (SERA) and mean (BERA) reporting limits for chemicals analyzed for but not detected were also compared to medium-specific ESVs. This comparison was done to determine if reporting limits were less than chemical concentrations at which potential adverse effects to ecological receptors may occur.

6.3.1 Selection Criteria for Analytical Data

Available analytical data (described in **Section 6.2.2**) were selected for use in the ERA based on the following:

- Data must have been validated by a qualified data validator using acceptable data validation methods. Rejected (R) values were not used in the ERA. Unqualified data and data qualified as J (estimated), L (biased low), or K (biased high) were treated as detected. Data qualified as U (undetected) or B (blank contamination) were treated as non-detected.
- For samples with duplicate analyses, the higher of the two concentrations was used, for conservatism, when both values were detects or when both values were non-detects. In cases where one result was a detection and the other a non-detect, the detected value was used in the assessment.
- For non-detected results, the sample quantitation limit (SQL) (or reporting limit) was used to represent the concentration. When calculating statistics (such as the arithmetic mean), one-half of the SQL was used for non-detected results.

6.3.2 Exposure Point Concentrations

The EPCs are calculated as a particular point on the distribution of concentrations. At the screening level (SERA; Step 2), the EPC is the maximum detected concentration. At the baseline level (BERA; Step 3A), the EPCs are central tendency estimates, which provide a more representative estimate of potential exposures and risks to receptor populations (the focus of the selected assessment endpoints). In this ERA, the maximum, arithmetic mean, and 95 percent UCL of the arithmetic mean concentrations were evaluated for direct exposures.

6.4 Effects Assessment

One of the purposes of the effects assessment is to establish chemical exposure levels (ESVs) that represent conservative thresholds for adverse ecological effects. Typically, one set of ESVs is developed for each selected assessment endpoint. Based on the CSM, indirect exposure to groundwater is the complete pathway at the site relevant to this ESI.

The effects assessment defines the methods and data used to define an adverse ecological effect. Effects data are available from multiple lines of evidence, which are reflected in the measurement endpoints, and include:

- **ESVs for Surface Water** – Analytical groundwater data are compared to literature-based surface water ESVs developed in **Section 6.4.1**
- **Bioavailability Measures** – Additional data were collected to help evaluate chemical-specific bioavailability in abiotic media

In addition, a comparison of site groundwater concentrations to facility background concentrations was conducted as an additional line of evidence (see Section 6.5).

6.4.1 Surface Water Ecological Screening Values

Medium-specific ESVs were established for each ecologically relevant medium. Based on the CSM (**Figure 6-1**), possible indirect exposure to groundwater (upon discharge to Cheatham Pond) is the potentially complete pathway relevant to this ESI.

Cheatham Pond is a freshwater body, so freshwater ESVs were used. The surface water ESVs used in the ERA considered Region III BTAG screening values (USEPA, 2006c), as well as other ESVs available from the literature. When more than one ESV was available (such as fauna and flora) from a particular source for a chemical, the lowest of these values was typically selected. The ESVs for chemicals known to bioaccumulate in aquatic food webs were based on the final chronic value (rather than the final residue value) in accordance with USEPA (1996, 2009b) and Suter and Tsao (1996). The use of final chronic values is intended to protect aquatic receptors from direct exposures to chemicals in surface water, rather than from exposure via food webs.

Surface water ESVs for several divalent metals require site-specific adjustment based on water hardness. Hardness was not measured in groundwater samples, so the default hardness (100 mg/L) was used. The surface water ESVs used in the ERA are listed in **Table 6-3**.

6.4.2 Bioavailability Measures

Data collected to evaluate the potential chemical-specific bioavailability in abiotic media included:

- **Groundwater** – Dissolved metals

6.5 Risk Characterization

The risk characterization portion of the ERA uses the information generated during the three previous parts of the ERA (problem formulation, exposure assessment, and effects assessment) to estimate potential risks to ecological receptors at the level of conservatism applied (screening or baseline).

6.5.1 Screening Ecological Risk Assessment Approach

The main objective of risk characterization at the screening level (termed risk calculation) is to derive a list of COPCs. As part of this risk calculation, the maximum exposure concentrations in groundwater are compared with the corresponding ESVs to derive risk estimates using the HQ method. The HQs are calculated by dividing the chemical concentration in the medium being evaluated (in this case groundwater) by the corresponding medium-specific ESV. The HQs equaling or exceeding 1 indicate the potential for unacceptable risk because the chemical concentration (exposure) equals or exceeds the ESV (effect); these chemicals are identified as COPCs at Step 2. However, the ESVs and exposure estimates are derived using intentionally conservative assumptions at the screening level such that HQs greater than or equal to 1 do not necessarily indicate that unacceptable risks are

present. Rather, it identifies chemical-pathway-receptor combinations requiring further evaluation using less-conservative (but more realistic) exposure scenarios and assumptions. The HQs less than 1 indicate that unacceptable risks are unlikely, enabling a conclusion of negligible (acceptable) risk to be reached with high confidence.

In addition to chemicals that equaled or exceeded ESVs based on maximum detected concentrations, the following also applied to COPC selection at Step 2:

- Non-detected chemicals were retained as COPCs if the maximum detection limit equaled or exceeded the ESV
- All detected chemicals lacking an ESV were retained as COPCs
- The essential nutrients calcium, magnesium, potassium and sodium were excluded as potential COPCs because they are essential macronutrients that are needed in relatively high concentrations for normal metabolism, growth, and reproduction

6.5.2 Baseline Ecological Risk Assessment Approach

The COPCs from the SERA were reevaluated in the BERA (Step 3A). As previously discussed, this re-evaluation involved using less-conservative (but more realistic) assumptions about exposures and a comparison of these revised exposure estimates (based on central tendency estimates of media concentrations) with ESVs.

In addition to chemicals that equaled or exceeded ESVs based on mean and/or 95 percent UCL detected concentrations, the following also applied to COPC selection at Step 3A:

- All detected chemicals lacking an ESV were retained as COPCs for risk evaluation

For Step 3A, the following additional factors were also considered:

- **Background Concentrations.** Facility-specific background concentrations were also considered in the evaluation of groundwater. The background evaluation consisted of a direct comparison of site concentrations to the UTLs developed for metals in the background study in a manner analogous to the comparison to ESVs. The background UTLs are facility-specific values derived for Yorktown/CAX. The background UTL values for groundwater that are applicable to AOC 7 are those from the Yorktown-Eastover aquifer.

6.5.3 Comparison With Ecological Screening Values

As discussed in **Section 6.3.2**, the maximum, arithmetic mean, and 95 percent UCL of the arithmetic mean groundwater concentrations were compared with ESVs. Chemicals were excluded from further consideration in the SERA if the HQ based on the maximum concentration was less than 1. Chemicals were excluded from further consideration in the BERA if the HQ based on the mean concentration was less than 1 (without dilution).

Although ecological receptors do not typically have direct exposure to groundwater, surface water ESVs were compared to site groundwater data in order to provide a conservative evaluation of the potential for significant contaminant transport via groundwater to the water body (Cheatham Pond) located downgradient of the site. All comparisons were performed assuming no dilution.

Although both total and dissolved groundwater data were included in the screening tables, only dissolved metals data were used when selecting Step 3A COPCs, since chemicals in groundwater are most likely to travel dissolved in water rather than adhered to particles, because they must travel through soil pores or fractured rock. Similarly, when groundwater discharges to a water body (at which time ecological exposures become possible), the bulk of the discharged chemicals are likely to be dissolved in water, because the discharge must pass through the pores in the underlying sediments. Thus, the dissolved concentrations are likely to be more representative of what would be transported via the groundwater than the total concentrations. Once discharged, the dissolved metal fraction in water (filtered samples) is more representative of the bioavailable fraction to aquatic receptors than the total metal fraction (unfiltered samples) (USEPA, 1996). This view is reflected in how the most recent AWQC have been developed for many metals; that is, they are based on the dissolved fraction (USEPA, 2009b).

Three metals (aluminum, barium, and cadmium) equaled or exceeded ESVs based on maximum detected concentrations in unfiltered samples collected from site monitoring wells (**Tables 6-4 and 6-5**). Only barium and cadmium equaled or exceeded ESVs based on maximum detected concentrations in filtered samples. Thus, aluminum, barium, and cadmium were identified as Step 2 COPCs. One VOC (carbon disulfide) was not detected, but maximum detection limits exceeded ESVs. This chemical was also identified as a Step 2 COPC.

Maximum detected concentrations of Step 2 COPCs are compared with facility-specific background UTLs in **Table 6-4**. Only dissolved cadmium equaled or exceeded background UTLs. The mean and 95 percent UCL concentrations of dissolved cadmium in groundwater were then compared with ESVs (**Table 6-4**). The 95 percent UCL HQ slightly exceeded 1 (1.02), but the mean HQ was well below 1 (0.55). Thus, no chemicals were identified as Step 3A COPCs. No undetected chemical had a mean detection limit that exceeded its ESV.

6.5.4 Risk Evaluation

In this section, the various lines of evidence discussed in the previous section are integrated in order to evaluate the potential for unacceptable risks. No chemical detected in site groundwater wells, except dissolved cadmium, exceeded both its ESV and its background UTL. The 95 percent UCL HQ for dissolved cadmium slightly exceeded 1 (1.02), but the mean HQ was well below 1 (0.55). Thus, no chemicals were identified as Step 3A COPCs for further risk evaluation. No undetected chemical had a mean detection limit that exceeded its ESV.

Based on the results of this evaluation, groundwater is not a significant transport medium for site-related constituents to Cheatham Pond, and site-related constituents that might reach this water body via groundwater would not pose an unacceptable risk to aquatic biota.

6.5.5 Risk Summary and Conclusions

Groundwater is not a significant transport medium for site-related constituents to Cheatham Pond, and site-related constituents in groundwater would not pose a significant risk to aquatic biota.

6.6 Uncertainties

Uncertainties are present in all ERAs because of the limitations of the available data and the need to make certain assumptions and extrapolations based on incomplete information. Because conservative assumptions were generally used in the exposure and effects assessments, these uncertainties are more likely to result in an overestimation rather than an underestimation of the likelihood and magnitude of risks to ecological receptors.

The ERA used “standard” methods and typical ranges of values for EPCs (maximum, mean, and 95 percent UCL), which results in risk estimates that adequately span the risk range from extremely conservative (screening estimates) to central tendency (mean baseline estimates). What constitutes an unacceptable risk within this risk range is ultimately a risk management decision.

The uncertainties in this ERA are mainly attributable to the following factors:

- **Reporting Limits** – Reporting limits for one undetected analyte (carbon disulfide) slightly exceeded ESVs in site groundwater (ratio of 1.09), but the mean ratio was less than 1. This result suggests that the associated uncertainties are relatively low. Because standard analytical methods were used and the sample reporting limits were not elevated relative to the method reporting limits for the majority of samples and analytes, these uncertainties are considered acceptable and are unlikely to affect the conclusions of the ERA.
- **Duplicate Analyses** – When evaluating samples with field duplicates, the value used in the ERA was always the detect, when one result was a detect and the duplicate was a non-detect, regardless of whether or not the non-detected value was higher. In these cases, the use of the detect has less uncertainty, because it represents an actual measured value (versus an upper-bound limit), and the two samples will typically have identical or similar reporting limits.
- **Selection of COPCs** – Chemicals without available ESVs were not retained as COPCs for risk evaluation unless they were detected. These uncertainties are unlikely to affect the conclusions of the ERA because these chemicals are not known to be present on the site.

- Chemical Mixtures – Information on the toxicological effects of chemical interactions is generally lacking for ecological receptors, because this requires (as is standard for ERAs) that the chemicals be evaluated on a compound-by-compound basis during the comparison to ESVs. This method could result in an underestimation of risk (if there are additive or synergistic effects among chemicals) or an overestimation of risks (if there are antagonistic effects among chemicals).
- Evaluation of the Groundwater Transport Pathway – Potential ecological risks from groundwater discharged to downgradient surface water bodies (Cheatham Pond) were indirectly evaluated through a comparison of groundwater concentrations from site wells with surface water ESVs. Surface water, pore water, and/or sediment samples were not collected from this water body as part of this investigation. The direct screening of groundwater data is normally the first step in such an evaluation (USEPA, 2008), with surface water, pore water, and/or sediment samples only collected from the receiving water body or bodies if the initial screening indicates the potential for significant transport and exposure from this pathway. Based on the results of the groundwater screening, potential ecological risks were not high enough to warrant further evaluation or sample collection in the receiving water body.
- Comparisons to Background Concentrations – Background concentrations were used to judge the site-relatedness of individual chemicals. If site concentrations were consistent with background levels, it was assumed that the concentrations were not related to known site-related source areas. There exists the possibility that concentrations below background were indeed site-related, rendering the assumption false. However, the potential impact of this possibility is minimal because chemicals at concentrations consistent with background should exhibit no different ecological effects than those commonly occurring in areas not affected by releases, regardless of their source.

TABLE 6-1

Samples Used in the Ecological Risk Assessment

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Station ID	Sample ID	Date
Groundwater		
CAA07-MW01	CAA07-GW01-0114	1/16/2014
CAA07-MW01	CAA07-GW01P-0114	1/16/2014
CAA07-MW02	CAA07-GW02-0114	1/15/2014
CAA07-MW03	CAA07-GW03-0114	1/15/2014
CAA07-MW04	CAA07-GW04-0114	1/15/2014
CAA07-MW05	CAA07-GW05-0114	1/16/2014

Notes:

Shaded cells indicate field duplicates

TABLE 6-2

Assessment Endpoints, Risk Hypotheses, and Measurement Endpoints

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Assessment Endpoint	Risk Hypothesis	Measurement Endpoint	Receptor
Aquatic Habitats			
Survival, growth, and reproduction of aquatic and wetland plant communities	Are site-related chemical concentrations in groundwater sufficient to adversely affect aquatic or wetland plant communities?	Comparison of maximum (SERA) and central tendency (BERA) chemical concentrations in <u>groundwater with surface water ESVs</u>	Aquatic and wetland plants
Survival, growth, and reproduction of aquatic and benthic invertebrate communities	Are site-related chemical concentrations in groundwater sufficient to adversely affect aquatic and benthic invertebrate communities?	Comparison of maximum (SERA) and central tendency (BERA) chemical concentrations in <u>groundwater with surface water ESVs</u>	Aquatic and benthic invertebrates
Survival, growth, and reproduction of fish communities	Are site-related chemical concentrations in groundwater sufficient to adversely affect fish communities?	Comparison of maximum (SERA) and central tendency (BERA) chemical concentrations in <u>groundwater with surface water ESVs</u>	Fish
Survival, growth, and reproduction of amphibian populations	Are site-related chemical concentrations in groundwater sufficient to adversely affect amphibian populations?	Comparison of maximum (SERA) and central tendency (BERA) chemical concentrations in <u>groundwater with surface water ESVs</u>	Amphibians
Survival, growth, and reproduction of wetland/aquatic reptile populations	Are site-related chemical concentrations in groundwater sufficient to adversely affect aquatic/wetland reptile populations?	Comparison of maximum (SERA) and central tendency (BERA) chemical concentrations in <u>groundwater with surface water ESVs</u>	Reptiles

TABLE 6-3

Ecological Screening Values (ESVs) for Freshwater

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Analytical Group	Chemical	Type	Basis ¹	ESV	Units	Hardness (mg/L)	Reference	Comments
Filtered Metals	Aluminum	Freshwater	AWQC	87.0	ug/L		USEPA 2009	
Filtered Metals	Antimony	Freshwater	FCV	30.0	ug/L		Suter and Tsao 1996	
Filtered Metals	Arsenic	Freshwater	AWQC	150	ug/L		USEPA 2009	
Filtered Metals	Barium	Freshwater	SCV	4.00	ug/L		Suter and Tsao 1996	
Filtered Metals	Beryllium	Freshwater	SCV	0.66	ug/L		Suter and Tsao 1996	
Filtered Metals	Cadmium	Freshwater	AWQC	0.25	ug/L	100	USEPA 2009	
Filtered Metals	Chromium	Freshwater	AWQC	11.0	ug/L		USEPA 2009	
Filtered Metals	Cobalt	Freshwater	SCV	23.0	ug/L		Suter and Tsao 1996	
Filtered Metals	Copper	Freshwater	AWQC	8.96	ug/L	100	USEPA 2006a	
Filtered Metals	Iron	Freshwater	AWQC	1,000	ug/L		USEPA 2009	
Filtered Metals	Lead	Freshwater	AWQC	2.52	ug/L	100	USEPA 2009	
Filtered Metals	Manganese	Freshwater	SCV	120	ug/L		Suter and Tsao 1996	
Filtered Metals	Mercury	Freshwater	AWQC	0.77	ug/L		USEPA 2009	
Filtered Metals	Nickel	Freshwater	AWQC	52.0	ug/L	100	USEPA 2009	
Filtered Metals	Selenium	Freshwater	AWQC	4.61	ug/L		USEPA 2009	
Filtered Metals	Silver	Freshwater	SCV	0.36	ug/L		Suter and Tsao 1996	
Filtered Metals	Thallium	Freshwater	SCV	12.0	ug/L		Suter and Tsao 1996	
Filtered Metals	Vanadium	Freshwater	SCV	20.0	ug/L		Suter and Tsao 1996	
Filtered Metals	Zinc	Freshwater	AWQC	118	ug/L	100	USEPA 2009	
Inorganics	Aluminum	Freshwater	AWQC	87.0	ug/L		USEPA 2009	
Inorganics	Antimony	Freshwater	FCV	30.0	ug/L		Suter and Tsao 1996	
Inorganics	Arsenic	Freshwater	AWQC	150	ug/L		USEPA 2009	
Inorganics	Barium	Freshwater	SCV	4.00	ug/L		Suter and Tsao 1996	
Inorganics	Beryllium	Freshwater	SCV	0.66	ug/L		Suter and Tsao 1996	
Inorganics	Cadmium	Freshwater	AWQC	0.27	ug/L	100	USEPA 2009	
Inorganics	Chromium	Freshwater	AWQC	11.4	ug/L		USEPA 2009	
Inorganics	Cobalt	Freshwater	SCV	23.0	ug/L		Suter and Tsao 1996	
Inorganics	Copper	Freshwater	AWQC	9.33	ug/L	100	USEPA 2006a	
Inorganics	Iron	Freshwater	AWQC	1,000	ug/L		USEPA 2009	
Inorganics	Lead	Freshwater	AWQC	3.18	ug/L	100	USEPA 2009	
Inorganics	Manganese	Freshwater	SCV	120	ug/L		Suter and Tsao 1996	
Inorganics	Mercury	Freshwater	AWQC	0.91	ug/L		USEPA 2009	
Inorganics	Nickel	Freshwater	AWQC	52.2	ug/L	100	USEPA 2009	
Inorganics	Selenium	Freshwater	AWQC	5.00	ug/L		USEPA 2009	
Inorganics	Silver	Freshwater	SCV	0.36	ug/L		Suter and Tsao 1996	
Inorganics	Thallium	Freshwater	SCV	12.0	ug/L		Suter and Tsao 1996	
Inorganics	Vanadium	Freshwater	SCV	20.0	ug/L		Suter and Tsao 1996	
Inorganics	Zinc	Freshwater	AWQC	120	ug/L	100	USEPA 2009	
VOCs	1,1,1-Trichloroethane	Freshwater	SCV	11.0	ug/L		Suter and Tsao 1996	

TABLE 6-3

Ecological Screening Values (ESVs) for Freshwater

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Analytical Group	Chemical	Type	Basis ¹	ESV	Units	Hardness (mg/L)	Reference	Comments
VOCs	1,1,2,2-Tetrachloroethane	Freshwater	SCV	610	ug/L		Suter and Tsao 1996	
VOCs	1,1,2-Trichloro-1,2,2-trifluoroethane(Freon-113)	Freshwater		NSV	--		--	
VOCs	1,1,2-Trichloroethane	Freshwater	SCV	1,200	ug/L		Suter and Tsao 1996	
VOCs	1,1-Dichloroethane	Freshwater	SCV	47.0	ug/L		Suter and Tsao 1996	
VOCs	1,1-Dichloroethene	Freshwater	SCV	25.0	ug/L		Suter and Tsao 1996	
VOCs	1,2,3-Trichlorobenzene	Freshwater		8.00	ug/L		USEPA 2006b	
VOCs	1,2,4-Trichlorobenzene	Freshwater	SCV	110	ug/L		Suter and Tsao 1996	
VOCs	1,2-Dibromo-3-chloropropane	Freshwater		NSV	--		--	
VOCs	1,2-Dibromoethane	Freshwater		NSV	--		--	
VOCs	1,2-Dichlorobenzene	Freshwater	SCV	14.0	ug/L		USEPA 1996	
VOCs	1,2-Dichloroethane	Freshwater	SCV	910	ug/L		Suter and Tsao 1996	
VOCs	1,2-Dichloroethene (total)	Freshwater	SCV	590	ug/L		Suter and Tsao 1996	
VOCs	1,2-Dichloropropane	Freshwater		525	ug/L		USEPA 2001	
VOCs	1,3-Dichlorobenzene	Freshwater	SCV	71.0	ug/L		USEPA 1996	
VOCs	1,4-Dichlorobenzene	Freshwater	SCV	15.0	ug/L		USEPA 1996	
VOCs	2-Butanone	Freshwater	SCV	14,000	ug/L		Suter and Tsao 1996	
VOCs	2-Hexanone	Freshwater	SCV	99.0	ug/L		Suter and Tsao 1996	
VOCs	4-Methyl-2-pentanone	Freshwater	SCV	170	ug/L		Suter and Tsao 1996	
VOCs	Acetone	Freshwater	SCV	1,500	ug/L		Suter and Tsao 1996	
VOCs	Benzene	Freshwater	SCV	130	ug/L		Suter and Tsao 1996	
VOCs	Bromochloromethane	Freshwater		NSV	--		--	
VOCs	Bromodichloromethane	Freshwater		NSV	--		--	
VOCs	Bromoform	Freshwater	SCV	320	ug/L		USEPA 1996	
VOCs	Bromomethane	Freshwater		110	ug/L		USEPA 2001	
VOCs	Carbon disulfide	Freshwater	SCV	0.92	ug/L		Suter and Tsao 1996	
VOCs	Carbon tetrachloride	Freshwater	SCV	240	ug/L		USEPA 1996	
VOCs	Chlorobenzene	Freshwater	SCV	64.0	ug/L		Suter and Tsao 1996	
VOCs	Chloroethane	Freshwater		NSV	--		--	
VOCs	Chloroform	Freshwater	SCV	28.0	ug/L		Suter and Tsao 1996	
VOCs	Chloromethane	Freshwater		5,500	ug/L		USEPA 2001	
VOCs	cis-1,2-Dichloroethene	Freshwater	SCV	590	ug/L		Suter and Tsao 1996	
VOCs	cis-1,3-Dichloropropene	Freshwater		24.4	ug/L		USEPA 2001	
VOCs	Cyclohexane	Freshwater		NSV	--		--	
VOCs	Dibromochloromethane	Freshwater		NSV	--		--	
VOCs	Dichlorodifluoromethane(Freon-12)	Freshwater		NSV	--		--	
VOCs	Ethylbenzene	Freshwater	SCV	290	ug/L		USEPA 1996	
VOCs	Isopropylbenzene	Freshwater		2.60	ug/L		USEPA 2006b	
VOCs	m- and p-Xylene	Freshwater		13.0	ug/L		Suter and Tsao 1996	Total xylenes
VOCs	Methyl acetate	Freshwater		NSV	--		--	

TABLE 6-3

Ecological Screening Values (ESVs) for Freshwater

*AOC 7 Expanded Site Inspection Report**Cheatham Annex**Williamsburg, Virginia*

Analytical Group	Chemical	Type	Basis ¹	ESV	Units	Hardness (mg/L)	Reference	Comments
VOCs	Methylcyclohexane	Freshwater		NSV	--		--	
VOCs	Methylene chloride	Freshwater	SCV	2,200	ug/L		Suter and Tsao 1996	
VOCs	Methyl-tert-butyl ether (MTBE)	Freshwater		11,070	ug/L		USEPA 2006b	
VOCs	o-Xylene	Freshwater		13.0	ug/L		Suter and Tsao 1996	Total xylenes
VOCs	Styrene	Freshwater		72.0	ug/L		USEPA 2006b	
VOCs	Tetrachloroethene	Freshwater	SCV	98.0	ug/L		Suter and Tsao 1996	
VOCs	Toluene	Freshwater	SCV	9.80	ug/L		Suter and Tsao 1996	
VOCs	trans-1,2-Dichloroethene	Freshwater	SCV	590	ug/L		Suter and Tsao 1996	
VOCs	trans-1,3-Dichloropropene	Freshwater		24.4	ug/L		USEPA 2001	
VOCs	Trichloroethene	Freshwater	SCV	47.0	ug/L		Suter and Tsao 1996	
VOCs	Trichlorofluoromethane(Freon-11)	Freshwater		NSV	--		--	
VOCs	Vinyl chloride	Freshwater	FCV	930	ug/L		USEPA 2006b	
VOCs	Xylene, total	Freshwater	SCV	13.0	ug/L		Suter and Tsao 1996	

Notes:

NSV - No Screening Value

1 - AWQC: Ambient Water Quality Criterion; FCV: Final Chronic Value; SCV: Secondary Chronic Value

TABLE 6-4

Ecological Screening Statistics - AOC 7 Groundwater

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Chemical	Range of Non-Detect Values	Frequency of Detection	Minimum Concentration Detected	Maximum Concentration Detected	Sample ID of Maximum Detected Concentration	Arithmetic Mean	Standard Deviation of Mean	95% UCL	Ecological Screening Value	Frequency of Exceedance ¹	Maximum Hazard Quotient ²	Step 2 COPC?	Background UTL	Frequency of UTL Exceedance	Maximum Ratio	95% UCL Hazard Quotient	Mean Hazard Quotient	COPC for Risk Evaluation?
Volatiles Organic Compounds (UG/L)																		
1,1,1-Trichloroethane	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	11.0	-- / --	0.09	NO	--	-- / --	--	--	--	NO
1,1,2,2-Tetrachloroethane	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	610	-- / --	0.001	NO	--	-- / --	--	--	--	NO
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon-113)	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
1,1,2-Trichloroethane	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	1,200	-- / --	0.0004	NO	--	-- / --	--	--	--	NO
1,1-Dichloroethane	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	47.0	-- / --	0.02	NO	--	-- / --	--	--	--	NO
1,1-Dichloroethene	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	25.0	-- / --	0.02	NO	--	-- / --	--	--	--	NO
1,2,3-Trichlorobenzene	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	8.00	-- / --	0.13	NO	--	-- / --	--	--	--	NO
1,2,4-Trichlorobenzene	0.25 - 0.25	0 / 5	--	--	--	0.13	0.0	--	110	-- / --	0.002	NO	--	-- / --	--	--	--	NO
1,2-Dibromo-3-chloropropane	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
1,2-Dibromoethane	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
1,2-Dichlorobenzene	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	14.0	-- / --	0.04	NO	--	-- / --	--	--	--	NO
1,2-Dichloroethane	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	910	-- / --	0.001	NO	--	-- / --	--	--	--	NO
1,2-Dichloropropane	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	525	-- / --	0.001	NO	--	-- / --	--	--	--	NO
1,3-Dichlorobenzene	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	71.0	-- / --	0.01	NO	--	-- / --	--	--	--	NO
1,4-Dichlorobenzene	0.25 - 0.25	0 / 5	--	--	--	0.13	0.0	--	15.0	-- / --	0.02	NO	--	-- / --	--	--	--	NO
2-Butanone	2.00 - 2.00	0 / 5	--	--	--	1.00	0.0	--	14,000	-- / --	0.0001	NO	--	-- / --	--	--	--	NO
2-Hexanone	2.00 - 2.00	0 / 5	--	--	--	1.00	0.0	--	99.0	-- / --	0.02	NO	--	-- / --	--	--	--	NO
4-Methyl-2-pentanone	2.00 - 2.00	0 / 5	--	--	--	1.00	0.0	--	170	-- / --	0.01	NO	--	-- / --	--	--	--	NO
Acetone	2.00 - 2.00	0 / 5	--	--	--	1.00	0.0	--	1,500	-- / --	0.001	NO	--	-- / --	--	--	--	NO
Benzene	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	130	-- / --	0.01	NO	--	-- / --	--	--	--	NO
Bromochloromethane	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Bromodichloromethane	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Bromoform	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	320	-- / --	0.003	NO	--	-- / --	--	--	--	NO
Bromomethane	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	110	-- / --	0.01	NO	--	-- / --	--	--	--	NO
Carbon disulfide	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	0.92	-- / --	1.09	YES	--	-- / --	--	--	0.54	NO
Carbon tetrachloride	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	240	-- / --	0.004	NO	--	-- / --	--	--	--	NO
Chlorobenzene	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	64.0	-- / --	0.01	NO	--	-- / --	--	--	--	NO
Chloroethane	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Chloroform	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	28.0	-- / --	0.04	NO	--	-- / --	--	--	--	NO
Chloromethane	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	5,500	-- / --	0.0001	NO	--	-- / --	--	--	--	NO
cis-1,2-Dichloroethene	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	590	-- / --	0.001	NO	--	-- / --	--	--	--	NO
cis-1,3-Dichloropropene	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	24.4	-- / --	0.04	NO	--	-- / --	--	--	--	NO
Cyclohexane	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Dibromochloromethane	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Dichlorodifluoromethane (Freon-12)	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Ethylbenzene	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	290	-- / --	0.003	NO	--	-- / --	--	--	--	NO
Isopropylbenzene	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	2.60	-- / --	0.38	NO	--	-- / --	--	--	--	NO
m- and p-Xylene	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	13.0	-- / --	0.04	NO	--	-- / --	--	--	--	NO
Methyl acetate	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Methylcyclohexane	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Methylene chloride	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	2,200	-- / --	0.0005	NO	--	-- / --	--	--	--	NO
Methyl-tert-butyl ether (MTBE)	0.25 - 0.25	0 / 5	--	--	--	0.13	0.0	--	11,070	-- / --	0.00002	NO	--	-- / --	--	--	--	NO
o-Xylene	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	13.0	-- / --	0.08	NO	--	-- / --	--	--	--	NO
Styrene	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	72.0	-- / --	0.01	NO	--	-- / --	--	--	--	NO
Tetrachloroethene	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	98.0	-- / --	0.01	NO	--	-- / --	--	--	--	NO
Toluene	1.00 - 1.00	1 / 5	0.29	0.29	CAA07-GW02-0114	0.46	0.094	--	9.80	0 / 5	0.03	NO	--	-- / --	--	--	--	NO
trans-1,2-Dichloroethene	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	590	-- / --	0.001	NO	--	-- / --	--	--	--	NO
trans-1,3-Dichloropropene	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	24.4	-- / --	0.02	NO	--	-- / --	--	--	--	NO
Trichloroethene	1.00 - 1.00	0 / 5	--	--	--	0.50	0.0	--	47.0	-- / --	0.02	NO	--	-- / --	--	--	--	NO
Trichlorofluoromethane (Freon-11)	0.25 - 0.25	0 / 5	--	--	--	0.13	0.0	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Vinyl chloride	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	930	-- / --	0.001	NO	--	-- / --	--	--	--	NO
Inorganics (UG/L)																		
Aluminum	31.0 - 50.0	1 / 5	370	370	CAA07-GW02-0114	90.6	156	--	87.0	1 / 5	4.25	YES	2,230	0 / 5	0.17	--	--	NO
Antimony	0.16 - 0.41	0 / 5	--	--	--	0.13	0.047	--	30.0	-- / --	0.01	NO	--	-- / --	--	--	--	NO

TABLE 6-4

Ecological Screening Statistics - AOC 7 Groundwater

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Chemical	Range of Non-Detect Values	Frequency of Detection	Minimum Concentration Detected	Maximum Concentration Detected	Sample ID of Maximum Detected Concentration	Arithmetic Mean	Standard Deviation of Mean	95% UCL	Ecological Screening Value	Frequency of Exceedance ¹	Maximum Hazard Quotient ²	Step 2 COPC?	Background UTL	Frequency of UTL Exceedance	Maximum Ratio	95% UCL Hazard Quotient	Mean Hazard Quotient	COPC for Risk Evaluation?
Arsenic	-- --	5 / 5	0.34	0.58	CAA07-GW04-0114	0.43	0.11	--	150	0 / 5	0.004	NO	--	-- / --	--	--	--	NO
Barium	-- --	5 / 5	16.0	38.0	CAA07-GW01-0114	25.4	8.05	--	4.00	5 / 5	9.50	YES	118	0 / 5	0.32	--	--	NO
Beryllium	0.40 - 0.40	0 / 5	--	--	--	0.20	0.0	--	0.66	-- / --	0.61	NO	--	-- / --	--	--	--	NO
Cadmium	-- --	5 / 5	0.063	0.40	CAA07-GW03-0114	0.17	0.14	--	0.27	1 / 5	1.48	YES	0.605	0 / 5	0.66	--	--	NO
Calcium ³	-- --	5 / 5	130,000	190,000	CAA07-GW03-0114	156,000	24,083	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Chromium	0.87 - 1.10	3 / 5	1.10	1.80	CAA07-GW04-0114	1.12	0.63	--	11.4	0 / 5	0.16	NO	--	-- / --	--	--	--	NO
Cobalt	-- --	5 / 5	0.21	0.38	CAA07-GW03-0114	0.26	0.070	--	23.0	0 / 5	0.02	NO	--	-- / --	--	--	--	NO
Copper	0.33 - 0.42	2 / 5	0.35	0.35	CAA07-GW01-0114	0.26	0.088	--	9.33	0 / 5	0.04	NO	--	-- / --	--	--	--	NO
Iron	-- --	5 / 5	170	960	CAA07-GW02-0114	418	310	--	1,000	0 / 5	0.96	NO	--	-- / --	--	--	--	NO
Lead	0.50 - 0.50	3 / 5	0.15	0.24	CAA07-GW02-0114	0.22	0.044	--	3.18	0 / 5	0.08	NO	--	-- / --	--	--	--	NO
Magnesium ³	-- --	5 / 5	2,100	3,400	CAA07-GW01-0114	2,580	497	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Manganese	-- --	5 / 5	3.50	35.0	CAA07-GW03-0114	10.2	13.9	--	120	0 / 5	0.29	NO	--	-- / --	--	--	--	NO
Mercury	0.10 - 0.10	0 / 5	--	--	--	0.050	0.0	--	0.91	-- / --	0.11	NO	--	-- / --	--	--	--	NO
Nickel	-- --	5 / 5	0.79	1.10	CAA07-GW01-0114	0.91	0.14	--	52.2	0 / 5	0.02	NO	--	-- / --	--	--	--	NO
Potassium ³	-- --	5 / 5	910	2,000	CAA07-GW04-0114	1,362	501	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Selenium	0.39 - 1.10	2 / 5	0.64	0.88	CAA07-GW01-0114	0.53	0.26	--	5.00	0 / 5	0.18	NO	--	-- / --	--	--	--	NO
Silver	0.10 - 0.10	0 / 5	--	--	--	0.050	0.0	--	0.36	-- / --	0.28	NO	--	-- / --	--	--	--	NO
Sodium ³	-- --	5 / 5	5,700	7,700	CAA07-GW01-0114	6,440	841	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Thallium	0.10 - 0.10	1 / 5	0.033	0.033	CAA07-GW01-0114	0.047	0.0076	--	12.0	0 / 5	0.003	NO	--	-- / --	--	--	--	NO
Vanadium	-- --	5 / 5	0.80	2.00	CAA07-GW02-0114	1.23	0.47	--	20.0	0 / 5	0.10	NO	--	-- / --	--	--	--	NO
Zinc	10.0 - 22.0	0 / 5	--	--	--	6.70	2.46	--	120	-- / --	0.18	NO	--	-- / --	--	--	--	NO
Dissolved Metals (UG/L)																		
Aluminum	50.0 - 50.0	0 / 5	--	--	--	25.0	0.0	--	87.0	-- / --	0.57	NO	--	-- / --	--	--	--	NO
Antimony	0.22 - 0.50	0 / 5	--	--	--	0.18	0.067	--	30.0	-- / --	0.02	NO	--	-- / --	--	--	--	NO
Arsenic	0.32 - 0.50	1 / 5	0.22	0.22	CAA07-GW04-0114	0.23	0.039	--	150	0 / 5	0.001	NO	--	-- / --	--	--	--	NO
Barium	-- --	5 / 5	17.0	36.0	CAA07-GW01-0114	24.0	7.18	--	4.00	5 / 5	9.00	YES	127	0 / 5	0.28	--	--	NO
Beryllium	0.40 - 0.40	0 / 5	--	--	--	0.20	0.0	--	0.66	-- / --	0.61	NO	--	-- / --	--	--	--	NO
Cadmium	-- --	5 / 5	0.046	0.34	CAA07-GW03-0114	0.13	0.12	0.25	0.25	1 / 5	1.38	YES	0.177	1 / 5	1.92	1.02	0.55	NO
Calcium ³	-- --	5 / 5	120,000	180,000	CAA07-GW03-0114	152,000	23,875	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Chromium	0.38 - 0.60	1 / 5	1.20	1.20	CAA07-GW04-0114	0.42	0.44	--	11.0	0 / 5	0.11	NO	--	-- / --	--	--	--	NO
Cobalt	-- --	5 / 5	0.12	0.31	CAA07-GW03-0114	0.18	0.074	--	23.0	0 / 5	0.01	NO	--	-- / --	--	--	--	NO
Copper	0.29 - 0.74	1 / 5	0.29	0.29	CAA07-GW02-0114	0.26	0.089	--	8.96	0 / 5	0.03	NO	--	-- / --	--	--	--	NO
Iron	10.0 - 10.0	4 / 5	8.20	21.0	CAA07-GW01-0114	11.2	5.99	--	1,000	0 / 5	0.02	NO	--	-- / --	--	--	--	NO
Lead	0.50 - 0.50	0 / 5	--	--	--	0.25	0.0	--	2.52	-- / --	0.20	NO	--	-- / --	--	--	--	NO
Magnesium ³	-- --	5 / 5	1,900	3,300	CAA07-GW01-0114	2,540	532	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Manganese	-- --	5 / 5	2.30	32.0	CAA07-GW03-0114	9.04	12.9	--	120	0 / 5	0.27	NO	--	-- / --	--	--	--	NO
Mercury	0.10 - 0.10	0 / 5	--	--	--	0.050	0.0	--	0.77	-- / --	0.13	NO	--	-- / --	--	--	--	NO
Nickel	0.78 - 0.78	4 / 5	0.57	1.30	CAA07-GW01-0114	0.80	0.36	--	52.0	0 / 5	0.02	NO	--	-- / --	--	--	--	NO
Potassium ³	-- --	5 / 5	820	2,100	CAA07-GW04-0114	1,322	586	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Selenium	1.00 - 1.00	4 / 5	0.44	0.91	CAA07-GW05-0114	0.66	0.19	--	4.61	0 / 5	0.20	NO	--	-- / --	--	--	--	NO
Silver	0.10 - 0.10	0 / 5	--	--	--	0.050	0.0	--	0.36	-- / --	0.28	NO	--	-- / --	--	--	--	NO
Sodium ³	-- --	5 / 5	5,200	7,600	CAA07-GW01-0114	6,380	1,087	--	NSV	-- / --	NSV	NO	--	-- / --	--	--	--	NO
Thallium	0.028 - 0.10	0 / 5	--	--	--	0.043	0.016	--	12.0	-- / --	0.01	NO	--	-- / --	--	--	--	NO
Vanadium	-- --	5 / 5	0.45	0.66	CAA07-GW02-0114	0.54	0.076	--	20.0	0 / 5	0.03	NO	--	-- / --	--	--	--	NO
Zinc	11.0 - 15.0	0 / 5	--	--	--	6.60	0.89	--	118	-- / --	0.13	NO	--	-- / --	--	--	--	NO

Notes:

NSV - No Screening Value

1 - Count of detected samples exceeding or equaling Screening Value

2 - Shaded cells indicate hazard quotient based on reporting limits

3 - Macronutrient - Not considered to be a COPC

TABLE 6-5

Exceedances - AOC 7 Groundwater
AOC 7 Expanded Site Inspection Report
Cheatham Annex
Williamsburg, Virginia

Chemical	Surface Water ESV	Background UTL	CAA07-MW01		CAA07-MW02	CAA07-MW03	CAA07-MW04	CAA07-MW05
			CAA07-GW01-0114	CAA07-GW01P-0114	CAA07-GW02-0114	CAA07-GW03-0114	CAA07-GW04-0114	CAA07-GW05-0114
			1/16/2014	1/16/2014	1/15/2014	1/15/2014	1/15/2014	1/16/2014
Volatile Organic Compounds (UG/L)								
Toluene	9.80	--	1.00 U	1.00 U	0.29 J	1.00 U	1.00 U	1.00 U
Inorganics (UG/L)								
Aluminum	87.0	2,230	50.0 U	20.0 B	370	31.0 B	35.0 B	50.0 U
Arsenic	150	2.28	0.34 J	0.31 J	0.34 J	0.50 J	0.58 J	0.40 J
Barium	4.00	118	38.0	36.0	26.0	25.0	16.0	22.0
Cadmium	0.27	0.605	0.110 J	0.056 J	0.180 J	0.400	0.084 J	0.063 J
Chromium	11.4	15.1	0.87 B	0.60 B	1.70	1.10	1.80	1.10 B
Cobalt	23.0	20.6	0.22 J	0.23 J	0.25 J	0.38 J	0.22 J	0.21 J
Copper	9.33	12.2	0.35 J	0.35 J	0.40 B	0.33 B	0.42 B	0.35 J
Iron	1,000	894	240	300	960 L	320	340	170
Lead	3.18	21.3	0.50 U	0.50 U	0.24 J	0.15 J	0.19 J	0.50 U
Manganese	120	57.9	5.20	5.00	3.80	35.0	3.50	3.70
Nickel	52.2	11.4	1.10	0.92 J	0.79 J	1.00	0.86 J	0.79 J
Selenium	5.00	--	0.88 J	1.00 U	1.10 B	0.39 B	0.79 B	0.64 J
Thallium	12.0	--	0.033 J	0.100 U	0.100 U	0.100 U	0.100 U	0.100 U
Vanadium	20.0	26.2	0.93 J	0.87 J	2.00	1.20	1.20	0.80 J
Dissolved Metals (UG/L)								
Arsenic	150	1.37	0.50 U	0.50 U	0.50 U	0.50 U	0.22 J	0.32 B
Barium	4.00	127	33.0	36.0	22.0	24.0	17.0	21.0
Cadmium	0.25	0.177	0.046 J	0.041 J	0.150 J	0.340	0.071 J	0.065 J
Chromium	11.0	6.04	0.35 B	0.38 B	0.41 B	0.40 B	1.20	0.60 B
Cobalt	23.0	0.70	0.18 J	0.18 J	0.12 J	0.31 J	0.15 J	0.16 J
Copper	8.96	3.00	0.36 B	0.62 B	0.29 J	0.74 B	0.41 B	0.29 B
Iron	1,000	275	21.0	14.0	11.0	10.0 U	8.20 J	11.0
Manganese	120	49.5	4.70	4.80	2.30	32.0	3.10	3.00
Nickel	52.0	12.2	1.30	0.86 J	0.57 J	1.00	0.74 J	0.78 B
Selenium	4.61	9.10	1.00 U	1.00 U	0.78 J	0.44 J	0.65 J	0.91 J
Vanadium	20.0	4.30	0.45 J	0.40 B	0.66 J	0.53 J	0.56 J	0.52 J

Notes:

Grey highlighting indicates value greater than ESV

Yellow highlighting indicates value equal to ESV

Red highlighting indicates value \geq ESV and \geq background UTL; \geq ESV and no UTL; \geq background UTL and no ESV; or detected and no ESV and UTL

Bold indicates detections

NA - Not analyzed

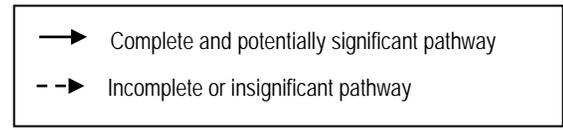
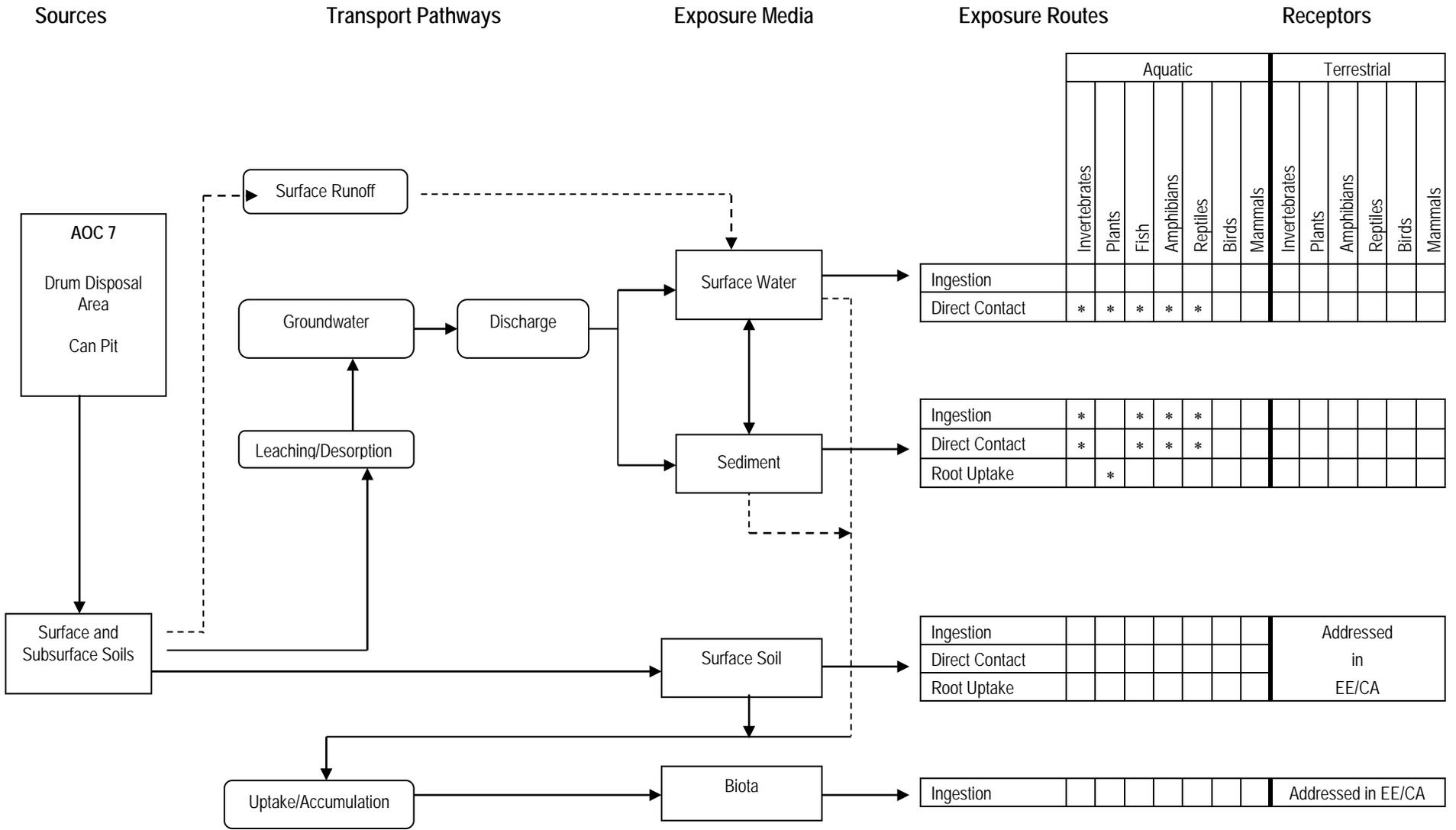


FIGURE 6-1
CONCEPTUAL SITE MODEL FOR THE ERA
AOC 7 EXPANDED SITE INSPECTION REPORT
CHEATHAM ANNEX
WILLIAMSBURG, VIRGINIA

• - Receptor evaluated quantitatively
 * - Receptor evaluated semi-quantitatively

Conclusions and Recommendations

This section summarizes the major conclusions of the ESI for AOC 7 that have been drawn from the findings and results presented and evaluated in earlier sections of this report, and presents and summarizes the overall CSM for AOC 7, which was developed using the compendium of information and data presented in this ESI Report. It also presents a recommended path forward for groundwater at AOC 7.

The ESI field activities described in this report were conducted in January 2014 to characterize potential impacts from contaminant releases, evaluate potential risk to human health or the environment, and determine the need for future investigation or remedial action. The data evaluated in this ESI included all of the newly collected data, and only the newly collected data. The chemical analytical data evaluated in the ESI includes the results from five groundwater samples analyzed for VOCs and metals (total and dissolved).

7.1 Conclusions

The objectives of the ESI have been achieved: the nature and extent of contamination have been sufficiently defined, human health and ecological risks have been assessed, and the CSM has been updated to reflect the data from ESI activities (**Figure 7-1**).

7.1.1 Nature and Extent of Contamination in Groundwater

VOCs were not detected at concentrations exceeding conservative regulatory screening values.

Data generally indicated that metals concentrations were consistent with naturally occurring background conditions. However, select metals were found at concentrations exceeding their respective screening criteria and base background UTLs. These metals include only total thallium and dissolved cadmium, each detected at one location and not in both the total and dissolved fractions. The metals results at AOC 7 did not provide evidence of a release.

7.1.2 Human Health Risk Assessment

The HIs and ELCRs for exposure to groundwater at AOC 7 for all potential human receptors are within USEPA-acceptable levels.

7.1.3 Ecological Risk Assessment

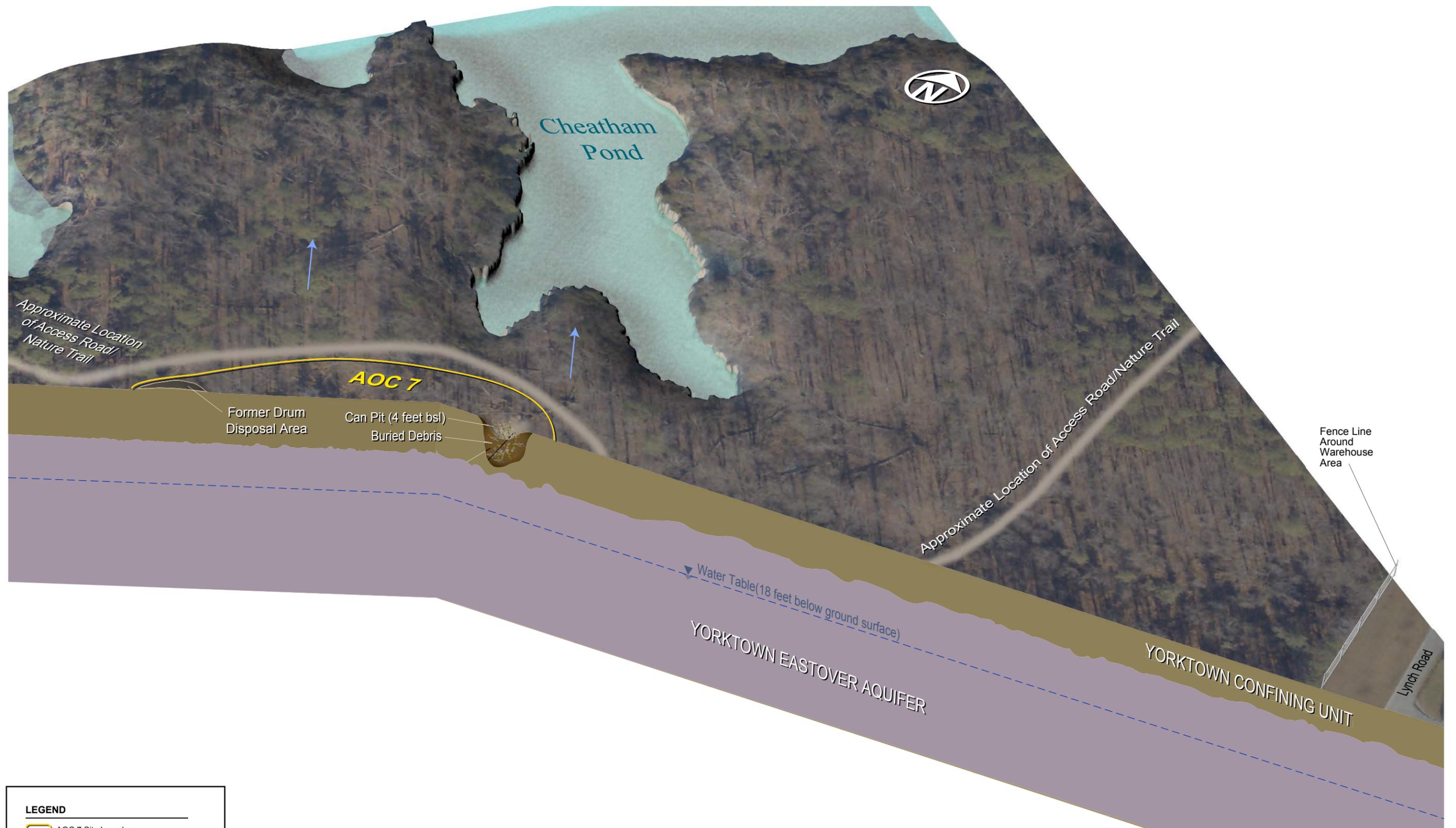
The BERA concluded that site-related constituents in groundwater would not pose a significant risk to aquatic biota.

7.1.4 Conceptual Site Model

The CSM for AOC 7, most recently presented in the AOC 7 SAP (CH2M HILL, 2013), has been updated to reflect the results of the ESI and the risk assessments summarized in **Sections 7.1.2** and **7.1.3**. There are no unacceptable risks to any receptor; therefore, no receptors are shown in the CSM (**Figure 7-1**). In addition, leaching of soil COPCs into groundwater is not included in the CSM, because groundwater concentrations of the soil COPCs are consistent with naturally occurring background conditions. This indicates that leaching from soil to groundwater of any significance has not occurred and is not likely to occur. In any case, an interim removal action is planned to remove subsurface debris and contaminated soil at AOC 7, which will mitigate the potential for future leaching of soil COPCs to groundwater.

7.2 Proposed Actions

It is recommended that no further action be conducted for the groundwater at AOC 7.



LEGEND

- AOC 7 Site boundary
- Yorktown Confining Unit
- Yorktown Eastover Aquifer
- ← Anticipated Surface Water Flow Direction
- ▽ Water Table

* No unacceptable risks were identified due to exposure to groundwater.

FIGURE 7-1
 AOC 7 Conceptual Site Model
 AOC 7 Expanded Site Inspection Report
 Cheatham Annex,
 Williamsburg, Virginia

SECTION 8

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Appendix A
Soil Boring and
Monitoring Well Construction Logs



CH2MHILL

PROJECT NUMBER
423755

BORING NUMBER
MW-01

SOIL BORING LOG

PROJECT : AOC 7 Drum and Can Disposal Area MW Installation LOCATION : Cheatham Annex

ELEVATION : 23.1' DRILLING CONTRACTOR Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Split spoon and 4 1/4" HSA, Track Mounted CME 850 rig

ATD WATER LEVEL : 5.37' bgs Start: 1/9/2014 END : 1/9/2014 LOGGER : K. Coke

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)			STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	USCS	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. DRILLING ACTIONS/DRILLER COMMENTS PID Readings: Breathing Zone: Above Hole:
	RECOVERY (%)	SAMPLE #/TYPE	6"-6"-6"-6" (N)				
4	0-4	100	1	NA	0-10" Topsoil, 10YR 3/2 very dark 10"-2' - soft to medium stiff clayey sand 10YR 4/4 dark yellowish brown 2'-4' - Same as above, hard to very stiff slightly sandy clay	SC SC	0 - 0 - 0 - 19.9 - 0
	4-8	100	2	NA	4'-5.6' - same as above	SM	0 - 0 - 0 - 20.0 - 0
					5.6'-8' fine to medium grained sand, medium stiff 7'-7'4" color 2.5Y 7/1 light gray, everything else dark yellowish brown as above	SM	
	8	8-12	50	3	NA	8-10' no recovery 10'-12' very soft/soft fine grained sand intermittent yellowish brown and light gray color - mixed in	SM
12-16		75	4	NA	12'-13' no recovery 13'-15.4' - saturated very soft sands as above - yellowish brown 15.4'-16' Shell layer cemented with sands ~90% shells	SM	0 - 0 - 0 - 20.2 - 0 Water at 13.5'
16							
20							
24							



CH2MHILL

PROJECT NUMBER

423755

BORING NUMBER

MW-02

SOIL BORING LOG

PROJECT : AOC 7 Drum and Can Disposal Area MW Installation LOCATION : Cheatham Annex

ELEVATION : 16.5 DRILLING CONTRACTOR Parratt Wolff

DRILLING METHC 16.5' Split spoon and 4 1/4" HSA, Track Mounted CME 850 rig

ATD WATER LEVEL : 5.36' bgs Start: 1/8/2014 END : 1/9/2014 LOGGER : K. Coke

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)			STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	SOIL DESCRIPTION SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	USCS	COMMENTS DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. DRILLING ACTIONS/DRILLER COMMENTS PID Readings: Breathing Zone: Above Hole:
	RECOVERY (IN)	SAMPLE #/TYPE					
0-4	75	1	NA	1'-1.3' - non plastic silty topsoil - 10YR 3/2 very dark grayish brown 1.3'-2.7' loose silty sand 10YR 4/4 dark yellowish brown; wet fine to medium grained 2.7'-4' medium plasticity clayey sand, dense, 10YR 5/6 yellowish brown	SM SM SC	0 - 0 - 0 - 20.1 - 0	
4-8	100	2	NA	4'-6' same dense clayey sand as above 6'-8' loose fine grained moist sand, 10YR 6/6 brownish yellow	SC SM	0 - 0 - 0 - 20.2 - 0	
8-12	100	3	NA	8'-9'10" same as above Saturated at 9'10" 9'10"-12' sharp change to shell layer 5Y 6/3 pale olive ~90-95% shell	SM	0 - 0 - 0 - 20.2 - 0 Water at 10'	
12-16	100	4	NA	12'-13' same as above, saturated 13'-13'8" transition to shelly sand very soft- saturated 10YR 5/6 yellowish brown 13'8"-14.8' very soft saturated sand 10YR 5/6 yellowish brown 14.8'-16' dense coarse grained sand 2.5Y 6/6 olive yellow	GM SM SW	0 - 0 - 0 - 20.1 - 0	

24



CH2MHILL

PROJECT NUMBER
423755

BORING NUMBER
MW-03

SOIL BORING LOG

PROJECT : AOC 7 Drum and Can Disposal Area MW Installation LOCATION : Cheatham Annex

ELEVATION : 21.8' DRILLING CONTRACTOR Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Split spoon and 4 1/4" HSA, Track Mounted CME 850 rig

ATD WATER LEVEL : 5.83' bgs Start: 1/7/2014 END : 1/8/2014 LOGGER : K. Coke

DEPTH BELOW SURFACE (FT)				STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	SOIL DESCRIPTION	USCS	COMMENTS
INTERVAL (FT)	RECOVERY (IN)	SAMPLE #/TYPE					
0-4	85	1	NA	0-12" loose topsoil 5YR 2.5/1 black dry 1'-1.5' transition to dense clay 7.5YR 4/4 brown, dry 1.5'-3'3" stiff clay 7.5YR 5/6 strong brown 3'3"-4' loose sand 10YR 5/6 yellowish brown, medium grained	CL CL SP	NR	
4-8	79	2	NA	4'-8' same as above	SP	NR	
8-12	75	3	NA	8-10'8" no recovery 10-8" rubble zone with shells white/gray thin, flaky at 11' 2.5Y 7/4 pale brown	GW	Water at 11' NR	
12-16	35	4	NA	12-16' saturated sand, medium grained	SP	NR	
16-20	81	5	NA	16-20' ~90% seashells, very soft, can rub with finger and some dissolve 19.5'-20' sand, no shells, moist 2.5Y 6/3 light yellowish brown	GW SM	NR	
20-24	100	6	NA	20-24' wet dense medium grained sand 2.5Y 6/3 light yellowish brown	SP	NK	

PID Readings: Breathing Zone: Above Hole:



CH2MHILL

PROJECT NUMBER
423755

BORING NUMBER
MW-04

SOIL BORING LOG

PROJECT : AOC 7 Drum and Can Disposal Area MW Installation LOCATION : Cheatham Annex
 ELEVATION : 22.7' DRILLING CONTRACTOR Parratt Wolff
 DRILLING METHOD AND EQUIPMENT USED : Split spoon and 4 1/4" HSA, Track Mounted CME 850 rig
 ATD WATER LEVEL : 6.79' bgs Start: 1/8/2014 END : 1/8/2014 LOGGER : K. Coke

DEPTH BELOW SURFACE (FT)	INTERVAL (FT)		STANDARD PENETRATION TEST RESULTS 6"-6"-6"-6" (N)	SOIL DESCRIPTION	USCS	COMMENTS		
	RECOVERY (IN)	SAMPLE #/TYPE					SOIL NAME, USCS GROUP SYMBOL, COLOR, MOISTURE CONTENT, RELATIVE DENSITY, OR CONSISTENCY, SOIL STRUCTURE, MINERALOGY.	DEPTH OF CASING, DRILLING RATE, DRILLING FLUID LOSS, TESTS, AND INSTRUMENTATION. DRILLING ACTIONS/DRILLER COMMENTS
0-4	100	1	NA	0-1' 7.5 YR 2.5/2 very dark brown loose topsoil silts 1'-4' high plasticity dense to high density clay 10YR 6/6 brownish yellow impenetrable with finger extremely dense clay @ 2.4'	PT CL	0 - 0 - 0 - 20.6 - 0		
4-8	100	2	NA	4'-5.3' low plasticity clayey sand 10YR 6/6 with ~10% organics throughout 5.3'-8' 10YR 5/8 yellowish brown loose sand fine to med grained moist at 6'10" clay lens at 7.5'-7.8'	OL SC	0 - 0 - 0 - 20.5 - 0		
8-12	90	3	NA	8'-12' same sand as above, soft, moist	SC	0 - 0 - 0 - 20.5 - 0		
12-16	33	4	NA	12'-16' same sand as above, saturated low recovery as a result 15'1" sea shells appear	SC	Water at 14' 0 - 0 - 0 - 20.4 - 0		
16-20	100	5	NA	16'-20' sea shells layer cemented with sand from above, saturated ~80-90% shells	GW	0 - 0 - 0 - 20.4 - 0		
20-24	100	6	NA	20'-21'10" same as above, shell layer saturated 21'10"-24' 5Y 6/2 light olive gray, medium to coarse grained wet sand low/med density	GW SW	0 - 0 - 0 - 20.4 - 0		



CH2MHILL

PROJECT NUMBER
423755

BORING NUMBER
MW-05

SOIL BORING LOG

PROJECT : AOC 7 Drum and Can Disposal Area MW Installation LOCATION : Cheatham Annex

ELEVATION : 21.0' DRILLING CONTRACTOR Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Split spoon and 4 1/4" HSA, Track Mounted CME 850 rig

ATD WATER LEVEL : 5.92' bgs Start: 1/9/2014 END : 1/9/2014 LOGGER : K. Coke

DEPTH BELOW SURFACE (FT)				STANDARD PENETRATION TEST RESULTS	SOIL DESCRIPTION	USCS	COMMENTS
INTERVAL (FT)	RECOVERY (IN)	SAMPLE #/TYPE	6"-6"-6"-6" (N)				
0-4	100	1	NA	0-1' topsoil 10YR 2/2 very dark brown 1'-2.2' low plasticity clayey sand 10YR 5/6 yellowish brown 2.2'-4' same as above, hard	SC SC	0 - 0 - 0 - 20 - 0	
4-8	100	2	NA	4'-8' low plasticity clayey sand 10YR 5/6 yellowish brown, soft to medium stiff to hard throughout	SC	0 - 0 - 0 - 20.1 - 0	
8-12	75	3	NA	8'-12' same as above with color change at 11' to 7.5 YR 4/6 strong brown very soft at 11'	SC	0 - 2 - 0 - 20 - 0 Water at 11.5'	
12-16	50	4	NA	12'-14' no recovery 14'-15' saturated fine to medium grained sand 10YR 5/6 yellowish brown 15'-16' Shell layer ~95% shells	SC GW	0 - 2 - 0 - 20 - 0	

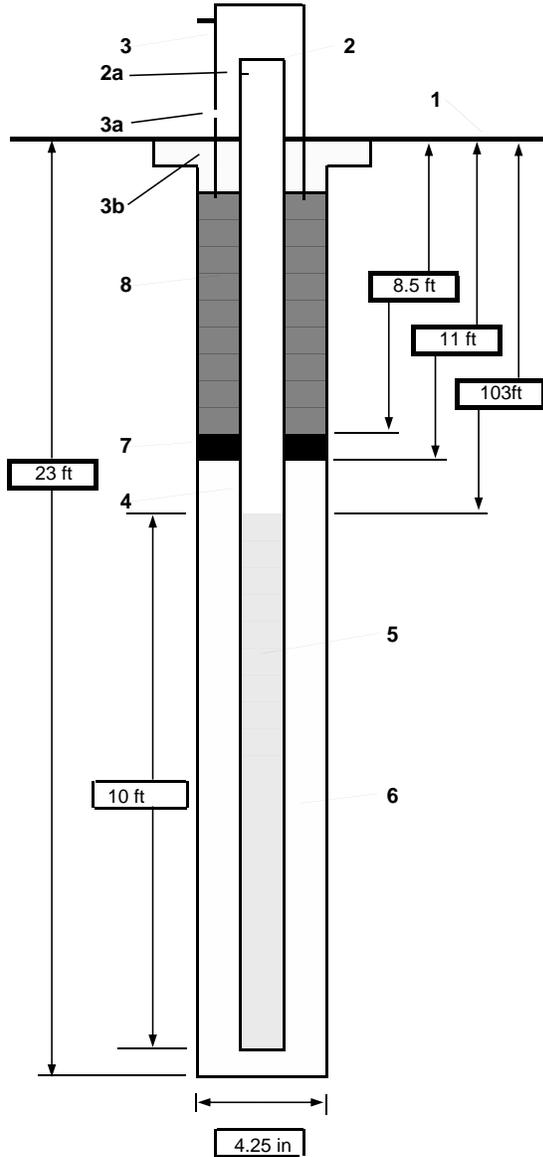
4
8
12
16
20
24



PROJECT NUMBER 423755	WELL NUMBER GW-01	SHEET 1	OF 1
--------------------------	----------------------	---------	------

WELL COMPLETION DIAGRAM

PROJECT : AOC 7 Drum and Can Disposal Area	LOCATION : Cheatham Annex
DRILLING CONTRACTOR : Parratt Wolff	
DRILLING METHOD AND EQUIPMENT USED : Split spoon and 4 1/4" HSA, track mounted CME 850 rig	
WATER LEVELS : 5.37' bgs	START : 1/9/2014 END : 1/09/2014 LOGGER : K. Coke



1- Ground elevation at well	23.1'
2- Top of casing elevation	25.95'
a) vent hole?	Yes
3- Wellhead protection cover type	Steel casing
a) weep hole?	No
b) concrete pad dimensions	2' diameter circle
4- Dia./type of well casing	2" diameter schedule 40 PVC
5- Type/slot size of screen	2" diameter schedule 40 PVC 0.010 slot
6- Type screen filter	#1 sand
a) Quantity used	5 bags
7- Type of seal	Bentonite chips
a) Quantity used	1-50 lb bags
8- Grout	Bentonite-cement grout
a) Grout mix used	Bentonite-cement grout
b) Method of placement	Slow Pour
c) Vol. of well casing grout	80 gallons
Development method	Whale pump
Development time	1 hour
Estimated purge volume	30 gallons
Comments	Used flow through cell



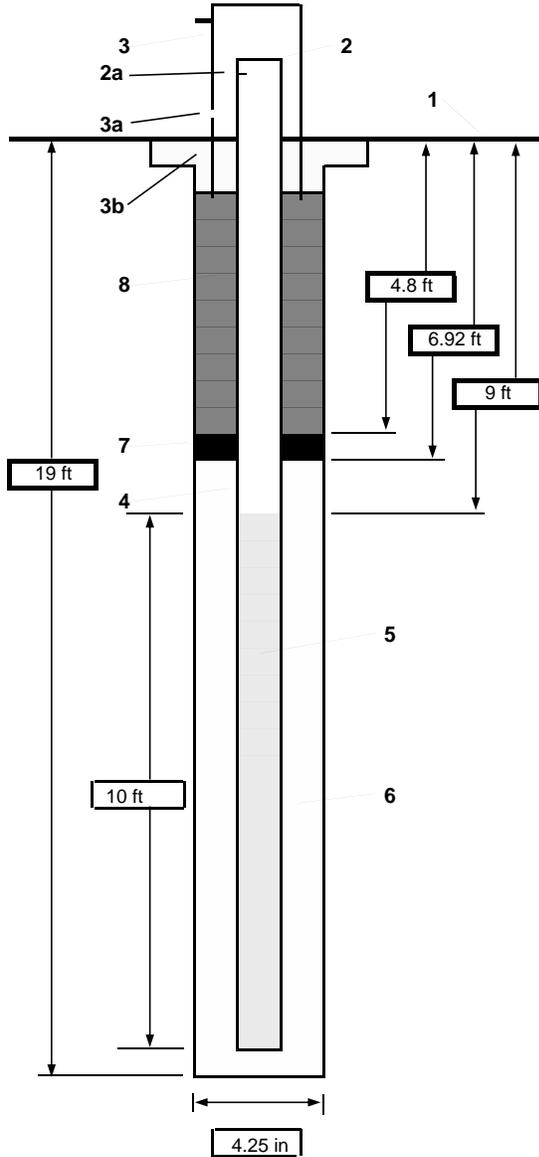
PROJECT NUMBER 423755	WELL NUMBER GW-02
SHEET 1 OF 1	
WELL COMPLETION DIAGRAM	

PROJECT : AOC 7 Drum and Can Disposal Area LOCATION : Cheatham Annex

DRILLING CONTRACTOR : Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Split spoon and 4 1/4" HSA, track mounted CME 850 rig

WATER LEVELS : 5.36' bgs START : 1/8/2014 END : 1/8/2014 LOGGER : K. Coke



1- Ground elevation at well	16.5'
2- Top of casing elevation	19.5'
a) vent hole?	Yes
3- Wellhead protection cover type	Steel casing
a) weep hole?	No
b) concrete pad dimensions	2' diameter circle
4- Dia./type of well casing	2" diameter schedule 40 PVC
5- Type/slot size of screen	2" diameter schedule 40 PVC 0.010 slot
6- Type screen filter	#1 sand
a) Quantity used	6 bags
7- Type of seal	Bentonite chips
a) Quantity used	1-50 lb bags
8- Grout	Bentonite-cement grout
a) Grout mix used	Slow Pour
b) Method of placement	Slow Pour
c) Vol. of well casing grout	80 gallons
Development method	Whale pump
Development time	1 hour
Estimated purge volume	35 gallons
Comments	Used flow through cell



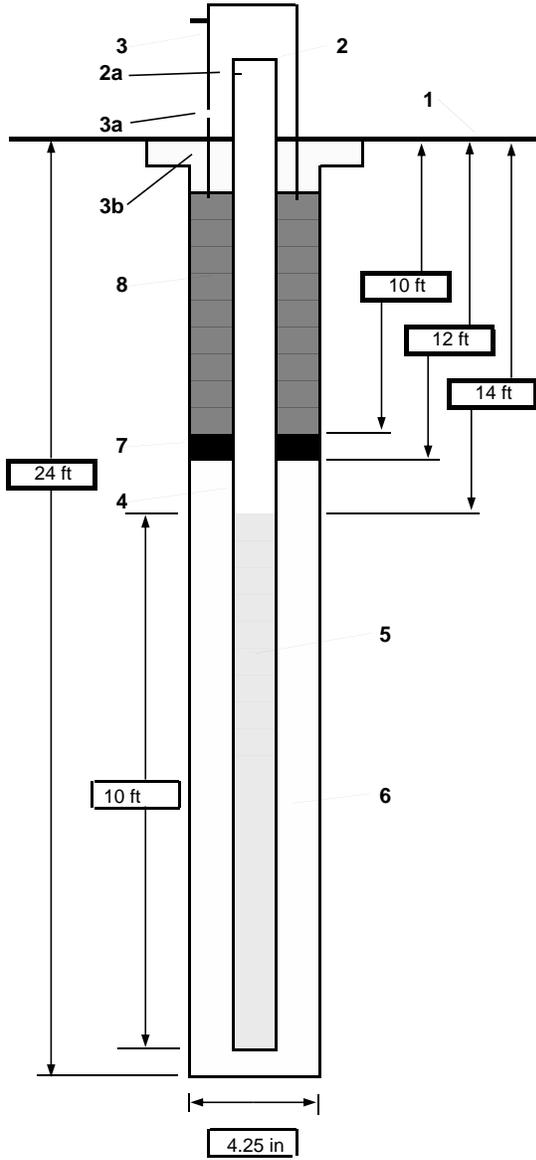
PROJECT NUMBER 423755	WELL NUMBER GW-03
SHEET 1 OF 1	
WELL COMPLETION DIAGRAM	

PROJECT : AOC 7 Drum and Can Disposal Area LOCATION : Cheatham Annex

DRILLING CONTRACTOR : Parratt Wolff

DRILLING METHOD AND EQUIPMENT USED : Split spoon and 4 1/4" HSA, track mounted CME 850 rig

WATER LEVELS : 5.83' bgs START : 1/7/2014 END : 1/7/2014 LOGGER : K. Coke



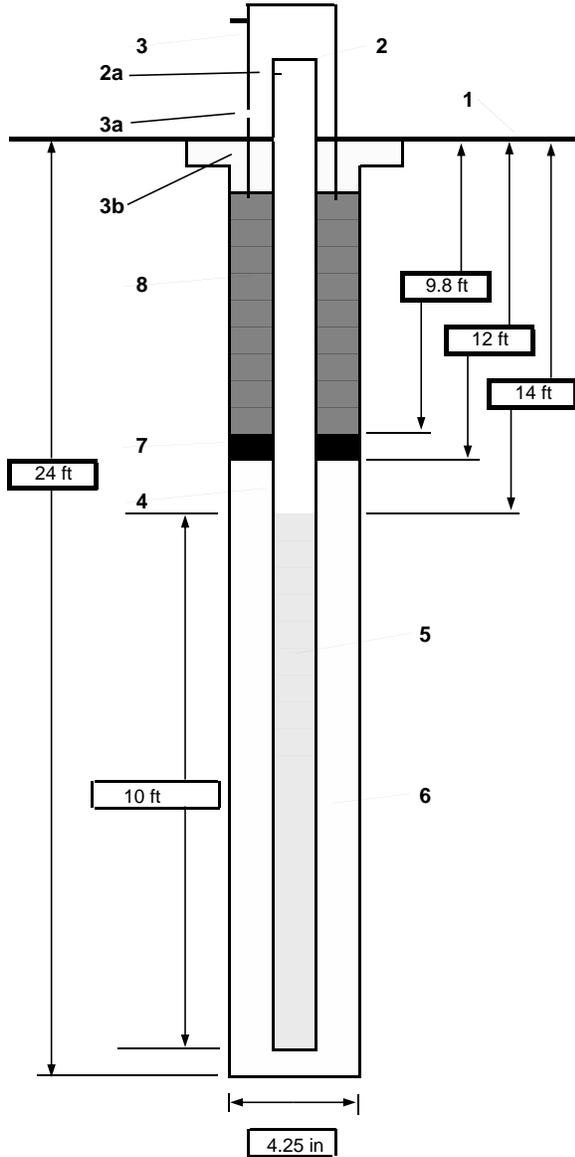
1- Ground elevation at well	21.8'
2- Top of casing elevation	24.76'
a) vent hole?	Yes
3- Wellhead protection cover type	Steel casing
a) weep hole?	No
b) concrete pad dimensions	2' diameter circle
4- Dia./type of well casing	2" diameter schedule 40 PVC
	No
5- Type/slot size of screen	2" diameter schedule 40 PVC
	0.010 slot
6- Type screen filter	#1 sand
a) Quantity used	5.5 bags
7- Type of seal	Bentonite chips
a) Quantity used	3/4 -50 lb bags
8- Grout	Bentonite-cement grout
a) Grout mix used	Bentonite-cement grout
b) Method of placement	Slow Pour
c) Vol. of well casing grout	80 gallons
Development method	Whale pump
Development time	1.5 hours
Estimated purge volume	50 gallons
Comments	_____



PROJECT NUMBER 423755	WELL NUMBER GW-04	SHEET 1	OF 1
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WELL COMPLETION DIAGRAM

PROJECT : AOC 7 Drum and Can Disposal Area LOCATION : Cheatham Annex
 DRILLING CONTRACTOR : Parratt Wolf
 DRILLING METHOD AND EQUIPMENT USED : Split spoon and 4 1/4" HSA, track mounted CME 850 rig
 WATER LEVELS : 6.79' bgs START : 1/8/2014 END : 1/8/2014 LOGGER : K. Coke



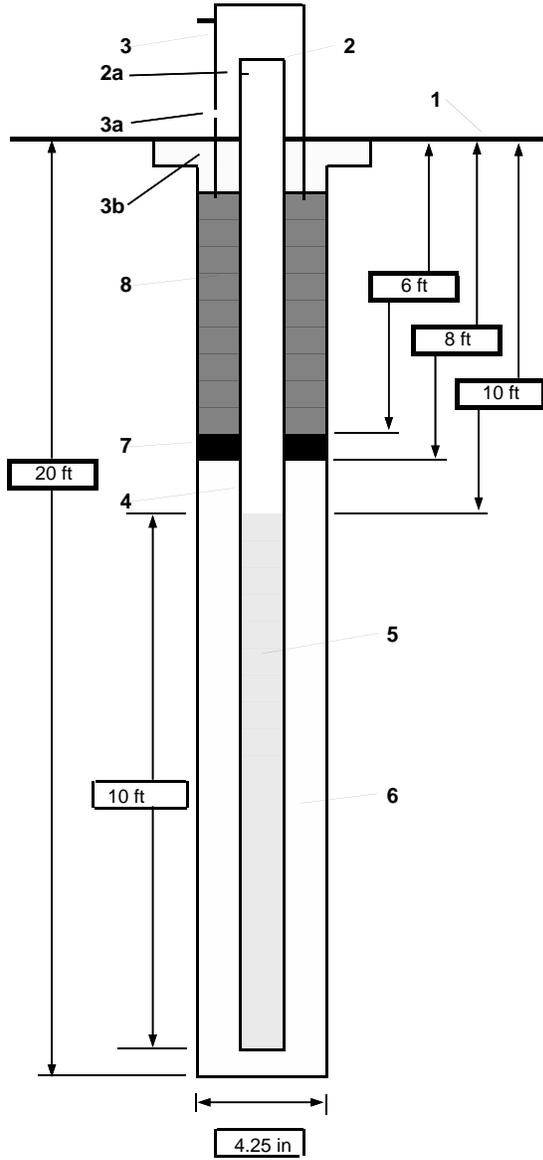
1- Ground elevation at well	22.7'
2- Top of casing elevation	25.56'
a) vent hole?	Yes
3- Wellhead protection cover type	Steel casing
a) weep hole?	No
b) concrete pad dimensions	2' diameter circle
4- Dia./type of well casing	2" diameter schedule 40 PVC
5- Type/slot size of screen	2" diameter schedule 40 PVC 0.010 slot
6- Type screen filter	#1 sand
a) Quantity used	6 bags
7- Type of seal	Bentonite chips
a) Quantity used	1-50 lb bags
8- Grout	Bentonite-cement grout
a) Grout mix used	Slow Pour
b) Method of placement	80 gallons
c) Vol. of well casing grout	
Development method	Whale pump
Development time	1.5 hours
Estimated purge volume	50 gallons
Comments	



PROJECT NUMBER 423755	WELL NUMBER GW-05	SHEET 1	OF 1
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WELL COMPLETION DIAGRAM

PROJECT : AOC 7 Drum and Can Disposal Area LOCATION : Cheatham Annex
 DRILLING CONTRACTOR : Parratt Wolff
 DRILLING METHOD AND EQUIPMENT USED : Split spoon and 4 1/4" HSA, track mounted CME 850 rig
 WATER LEVELS : 5.92' bgs START : 1/9/2014 END : 1/09/2014 LOGGER : K. Coke



1- Ground elevation at well	21.0'
2- Top of casing elevation	24.48'
a) vent hole?	Yes
3- Wellhead protection cover type	Steel casing
a) weep hole?	No
b) concrete pad dimensions	2' diameter circle
4- Dia./type of well casing	2" diameter schedule 40 PVC
5- Type/slot size of screen	2" diameter schedule 40 PVC 0.010 slot
6- Type screen filter	#1 sand
a) Quantity used	6 bags
7- Type of seal	Bentonite chips
a) Quantity used	1-50 lb bags
8- Grout	Bentonite-cement grout
a) Grout mix used	Bentonite-cement grout
b) Method of placement	Slow Pour
c) Vol. of well casing grout	80 gallons
Development method	Whale pump
Development time	55 minutes
Estimated purge volume	35 gallons
Comments	used flow through cell

Appendix B
Survey Report

CH2MHILL - MON WELL LOCATIONS AT SITE AOC 7**PROJECT # 14-001 - DATE: ?**

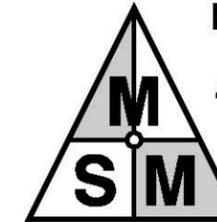
POINT NUMBER	NORTHING	EASTING	ELEVATION	DESCRIPTION
100	3636275.34	12031334.93	25.71	MON WELL AOC 7-1 METAL CASING
101	3636275.23	12031334.92	25.95	MON WELL AOC 7-1 PLASTIC CASING
102	3636273.87	12031335.10	23.07	GROUND AT MON WELL AOC 7-1
103	3636126.91	12031398.67	24.41	MON WELL AOC 7-5 METAL CASING
104	3636126.91	12031398.73	24.48	MON WELL AOC 7-5 PLASTIC CASING
105	3636127.94	12031398.39	21.04	GROUND AT MON WELL AOC 7-5
107	3636015.60	12031722.36	25.39	MON WELL AOC 7-4 METAL CASING
108	3636015.73	12031722.40	25.56	MON WELL AOC 7-4 PLASTIC CASING
109	3636016.98	12031720.88	22.69	GROUND AT MON WELL AOC 7-4
110	3636176.48	12031586.80	24.57	MON WELL AOC 7-3 METAL CASING
111	3636176.63	12031586.93	24.76	MON WELL AOC 7-3 PLASTIC CASING
112	3636175.11	12031585.67	21.83	GROUND AT MON WELL AOC 7-3
113	3636267.58	12031483.49	19.54	MON WELL AOC 7-2 METAL CASING
114	3636267.32	12031483.36	19.50	MON WELL AOC 7-2 PLASTIC CASING
115	3636267.63	12031482.17	16.53	GROUND AT MON WELL AOC 7-2

NOTES:

1. HORIZONTAL COORDINATES ARE REFERRED TO VIRGINIA STATE PLANE COORDINATE SYSTEM SOUTH ZONE NAD 83. ELEVATIONS REFER TO NAVD 88 DATUM. UNITS ARE IN U.S. SURVEY FEET.

2. THIS TOPOGRAPHIC SURVEY WAS COMPLETED UNDER THE DIRECT AND RESPONSIBLE CHARGE OF, PAUL W. MICHAEL, JR. FROM AND ACTUAL GROUND OR AIRBORNE SURVEY MADE UNDER MY SUPERVISION; THAT THE IMAGERY AND/OR ORIGINAL DATA WAS OBTAINED IN APRIL 17, 2014; AND THAT THIS PLAT, MAP, OR DIGITAL GEOSPATIAL DATA INCLUDING METADATA MEETS MINIMUM ACCURACY STANDARDS UNLESS OTHERWISE NOTED.

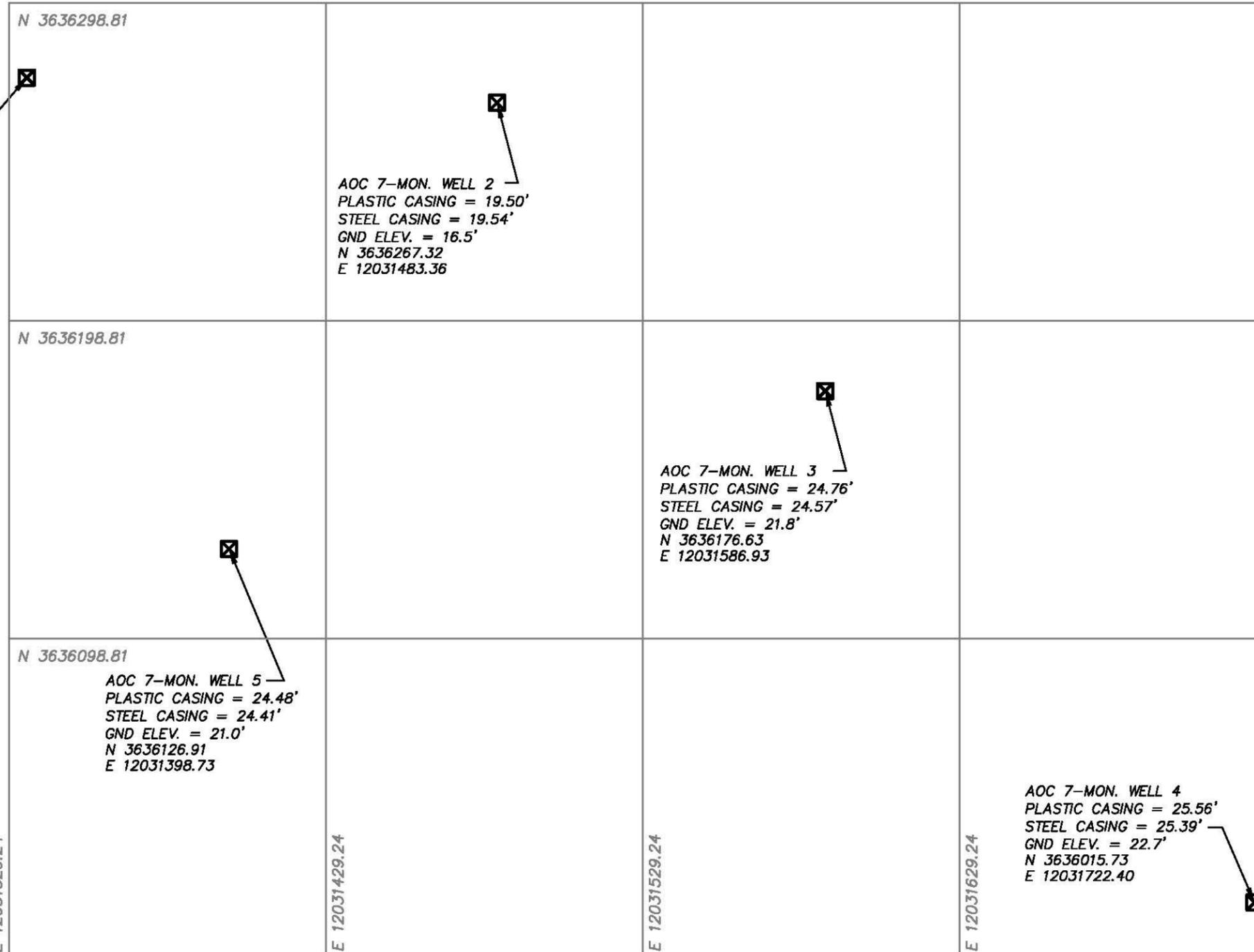
LOCATION OF MONITORING WELLS
 SITE AOC 7
 CHEATHAM ANNEX
 FOR: CH2MHILL
 PROJ. #14-001
 SCALE: 1"=40' - DATE: 4/17/14



**MICHAEL SURVEYING
 & MAPPING, P.C.**
 41 OLD OYSTER POINT ROAD
 SUITE B
 NEWPORT NEWS, VA. 23602
 TEL 757.873.1762
 FAX 757.873.1772



AOC 7-MON. WELL 1
 PLASTIC CASING = 25.95'
 STEEL CASING = 25.71'
 GND ELEV. = 23.1'
 N 3636275.23
 E 12031334.92



LEGEND

DENOTES MON. WELL

GRAPHIC SCALE



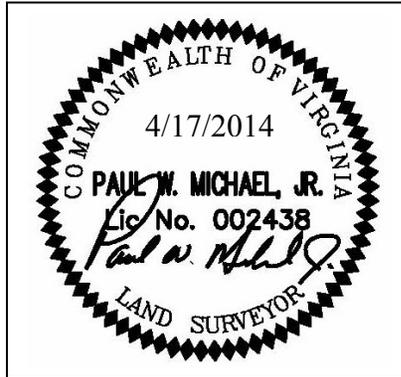
SCALE: 1" = 40'

REPORT OF SURVEY

Surveying of Monitoring Well Locations Areas of Concern 1, 6 & 7 Cheatham Annex, Williamsburg, VA

INTRODUCTION

The project consisted of staking out the locations of 15 monitoring wells and surveying the locations of 20 new monitoring wells at Cheatham Annex, Williamsburg, Virginia. The survey was completed by Michael Surveying & Mapping, PC of Newport News, VA., 41 Old Oyster Point Road, Suite B, Newport News, VA 23606, Tel. (757) 873-1762. The person in charge of this project is Paul W. Michael Jr. L.S., email: pmichael@msmva.com. Paul W. Michael, Jr. L.S. certifies that the work was completed in compliance with the specifications stated below.



This report details the work accomplished during this collaboration to establish horizontal and vertical control information on the items outlined in the statement of work. The project consisted of using Global Positioning System (GPS) RTK observations to establish 4 temporary control points and conventional survey techniques for the locations DGM Grid Points.

Standard surveying techniques were used and all horizontal control work complies with Third Order Class I (1:10,000) specifications as outlined in the **FGDC Geospatial Positioning Accuracy Standards, Part 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management**. RTK GPS techniques were used to establish survey control points at all three sites. The shortest GPS vector length was 151,935 feet. We then performed short conventional survey observations used to close and check the control points, our closures exceed the minimum closure of 1:10,000. 0.08 was our maximum horizontal misclosure ($151,935/0.08=1:1,899,187$)

Vertical Control work will comply with Third Order ($0.05\sqrt{\text{miles}}$) or better – As outlined in the **FGDC Geospatial Positioning Accuracy Standards, Part 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management**. RTK GPS techniques were used to establish elevations on the survey control points at all three sites. The shortest GPS vector length was 151,935 feet. We then performed short conventional survey observations used to close and check the control points, our worst elevation closure was 0.06', exceeding the minimum required $0.27' \cdot (0.05\sqrt{28.77})$

Point location results are located in the accompanying excel file. Horizontal coordinate values are based on the Virginia State Plane Coordinate System, South Zone. Elevations are referenced the NAVD 88 datum. Units are the U.S. Survey foot.

DATES OF FIELD OPERATIONS

Primary Field operations took place during the beginning of 2014 as follows:

1/2/14 GPS/Conventional survey observations & Well Stake Out
4/17/14 Conventional survey observations for well locations

CONTROL POINTS SET

As required by the statement of work, a minimum of three control points were set on the exterior of the site. 5/8" iron rods were set at each site.

GPS OBSERVATIONS

One Trimble 5700 RTK Rover was used with a Trimble Zephyr antenna (P/N 39105). Fixed height rods were used, and all antenna heights were 2.000 m to the bottom of the antenna mount. Our RTK system utilizes the Keystone precision VRS system.

TERRESTRIAL OBSERVATIONS

Standard survey operations were performed in wooded areas after the temporary control points were set using a Trimble VX Spatial total station. Both terrestrial and GPS observations were used for the well locations.

POINT DERIVATIONS

The following is a point derivation report showing the GPS observations and errors.

Coordinate System

Name:	US State Plane 1983
Datum:	Datum from Data Collector
Zone:	Virginia South 4502
Geoid:	GEOID12A (Conus)
Vertical datum:	NAVD 88

Resultant Coordinates for point:[1](#)

Northing		Easting		Elevation		Height	
3635789.145 ft 📏		12030402.900 ft 📏		23.955 ft 📏		-92.213 ft 📏	
Data	Used to calc.	Status	Δ North (US survey foot)	Δ East (US survey foot)	Distance (Horiz) (US survey foot)	Δ Elevation (US survey foot)	Δ Height (US survey foot)
 Global (14001GPSCNTRL.dc)	NEeh	Enabled	0.000 ft 📏	0.000 ft 📏	0.000 ft 📏	0.000 ft 📏	0.000 ft 📏
 JRE1 → 1		Enabled	0.026 ft 📏	-0.021 ft 📏	0.033 ft 📏	-0.016 ft 📏	-0.016 ft 📏

Survey Data used to calculate point:1

Precision Confidence Level: 95%

GNSS vectors

JRE1 → 1	Length (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
Mean:	158937.507 ft	90527.083 ft	92828.400 ft	91917.716 ft
σ:		0.028 ft	0.065 ft	0.053 ft

Residuals	Horiz. (US survey foot)	Vert. (US survey foot)	3D (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
 JRE1-1 (V4)	0.010 ft	0.125 ft	0.125 ft	-0.018 ft	0.103 ft	-0.070 ft
 JRE1-1 (V6)	0.060 ft	0.086 ft	0.105 ft	0.053 ft	-0.090 ft	0.011 ft

Data	H. Prec. (US survey foot)	V. Prec. (US survey foot)	Length (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
 JRE1-1 (V4)	0.033 ft	0.043 ft	158937.498 ft	90527.101 ft	92828.297 ft	91917.786 ft
 JRE1-1 (V6)	0.029 ft	0.026 ft	158937.523 ft	90527.030 ft	92828.490 ft	91917.705 ft

Coordinates

Source	Northing (US survey foot)	Easting (US survey foot)	Elevation (US survey foot)	Height (US survey foot)
 Global (14001GPSCNTRL.dc)	3635789.145 ft 	12030402.900 ft 	23.955 ft 	-92.213 ft 

Resultant Coordinates for point:[2](#)

Northing

3635474.812 ft 📏

Easting

12030768.221 ft 📏

Elevation

28.595 ft 📏

Height

-87.588 ft 📏

Data	Used to calc.	Status	ΔNorth (US survey foot)	ΔEast (US survey foot)	Distance (Horiz) (US survey foot)	ΔElevation (US survey foot)	ΔHeight (US survey foot)
📍 JRE1 → 2	NEeh	Enabled	0.000 ft 📏	0.000 ft 📏	0.000 ft 📏	0.000 ft 📏	0.000 ft 📏

Survey Data used to calculate point:[2](#)

Precision Confidence Level: 95%

GNSS vectors

JRE1 → 2	H. Prec. (US survey foot)	V. Prec. (US survey foot)	Length (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
📍 JRE1-2 (V5)	0.050 ft	0.052 ft	158952.740 ft	90922.254 ft	92718.390 ft	91664.702 ft

Resultant Coordinates for point:[6](#)

Northing

3630463.416 ft 📏

Easting

12026461.524 ft 📏

Elevation

80.019 ft 📏

Height

-36.159 ft 📏

Data	Used to calc.	Status	ΔNorth (US survey foot)	ΔEast (US survey foot)	Distance (Horiz) (US survey foot)	ΔElevation (US survey foot)	ΔHeight (US survey foot)
📍 Global (14001GPSCNTRL.dc)	NEeh	Enabled	0.000 ft 📏	0.000 ft 📏	0.000 ft 📏	0.000 ft 📏	0.000 ft 📏
📍 PRS686197981554 → 6		Enabled	0.000 ft 📏	0.001 ft 📏	0.001 ft 📏	-0.004 ft 📏	-0.004 ft 📏

Survey Data used to calculate point:6

Precision Confidence Level: 95%

GNSS vectors

PRS686197981554 → 6	Length (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
Mean:	152348.825 ft	87335.797 ft	88756.758 ft	87777.337 ft
σ:		0.020 ft	0.024 ft	0.016 ft

Residuals	Horiz. (US survey foot)	Vert. (US survey foot)	3D (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
PRS686197981554-6 (V7)	0.068 ft	0.043 ft	0.081 ft	-0.057 ft	-0.054 ft	0.020 ft
PRS686197981554-6 (V9)	0.009 ft	0.002 ft	0.009 ft	0.008 ft	0.004 ft	0.000 ft

Data	H. Prec. (US survey foot)	V. Prec. (US survey foot)	Length (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
PRS686197981554-6 (V7)	0.062 ft	0.045 ft	152348.877 ft	87335.854 ft	88756.811 ft	87777.317 ft
PRS686197981554-6 (V9)	0.024 ft	0.018 ft	152348.818 ft	87335.789 ft	88756.753 ft	87777.338 ft

Coordinates

Source	Northing (US survey foot)	Easting (US survey foot)	Elevation (US survey foot)	Height (US survey foot)
Global (14001GPSCNTRL.dc)	3630463.416 ft	12026461.524 ft	80.019 ft	-36.159 ft

Resultant Coordinates for point:7

Northing: 3630125.097 ft
 Easting: 12026218.145 ft
 Elevation: 79.261 ft
 Height: -36.918 ft

Data	Used to calc.	Status	ΔNorth (US survey foot)	ΔEast (US survey foot)	Distance (Horiz) (US survey foot)	ΔElevation (US survey foot)	ΔHeight (US survey foot)
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PRS686197981554 → 7	NEeh	Enabled	0.000 ft				
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Survey Data used to calculate point:[7](#)

Precision Confidence Level: 95%

GNSS vectors

PRS686197981554 → 7	H. Prec. (US survey foot)	V. Prec. (US survey foot)	Length (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
PRS686197981554-7 (V8)	0.030 ft	0.019 ft	151935.118 ft	87139.091 ft	88503.042 ft	87511.544 ft

Resultant Coordinates for point:[10](#)

Northing	Easting	Elevation	Height
3630615.720 ft	12036500.653 ft	24.725 ft	-91.696 ft

Data	Used to calc.	Status	ΔNorth (US survey foot)	ΔEast (US survey foot)	Distance (Horiz) (US survey foot)	ΔElevation (US survey foot)	ΔHeight (US survey foot)
Global (14001GPSCNTRL.dc)	NEeh	Enabled	0.000 ft	0.000 ft	0.000 ft	0.000 ft	0.000 ft
PRS686197981554 → 10		Enabled	-0.004 ft	0.000 ft	0.004 ft	-0.001 ft	-0.001 ft

Survey Data used to calculate point:[10](#)

Precision Confidence Level: 95%

GNSS vectors

PRS686197981554 → 10	Length (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
Mean:	159433.751 ft	97100.242 ft	91095.778 ft	87705.322 ft
σ:		0.011 ft	0.011 ft	0.009 ft

Residuals	Horiz. (US survey foot)	Vert. (US survey foot)	3D (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
PRS686197981554-10 (V10)	0.007 ft	0.010 ft	0.013 ft	-0.007 ft	0.010 ft	-0.003 ft
PRS686197981554-10 (V12)	0.023 ft	0.043 ft	0.048 ft	0.031 ft	-0.028 ft	0.025 ft

Data	H. Prec. (US survey foot)	V. Prec. (US survey foot)	Length (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
PRS686197981554-10 (V10)	0.025 ft	0.017 ft	159433.752 ft	97100.249 ft	91095.768 ft	87705.324 ft
PRS686197981554-10 (V12)	0.047 ft	0.036 ft	159433.735 ft	97100.211 ft	91095.806 ft	87705.297 ft

Coordinates

Source	Northing (US survey foot)	Easting (US survey foot)	Elevation (US survey foot)	Height (US survey foot)
Global (14001GPSCNTRL.de)	3630615.720 ft	12036500.653 ft	24.725 ft	-91.696 ft

Resultant Coordinates for point:[11](#)

Northing
 3630857.511 ft

Easting
 12036691.459 ft

Elevation
 26.280 ft

Height
 -90.141 ft

Data	Used to calc.	Status	Δ North (US survey)	Δ East (US survey)	Distance (Horiz)	Δ Elevation (US survey)	Δ Height (US survey)
------	---------------	--------	-------------------------------	------------------------------	---------------------	-----------------------------------	--------------------------------

			foot)	foot)	(US survey foot)	foot)	foot)
Global (14001GPSCNTRL.de)	NEeh	Enabled	0.000 ft	0.000 ft	0.000 ft	0.000 ft	0.000 ft
PRS686197981554 → 11		Enabled	0.005 ft	0.003 ft	0.006 ft	-0.025 ft	-0.025 ft

Survey Data used to calculate point:[11](#)

Precision Confidence Level: 95%

GNSS vectors

PRS686197981554 → 11	Length (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
Mean:	159739.462 ft	97257.450 ft	91280.076 ft	87895.573 ft
σ:		0.049 ft	0.058 ft	0.050 ft

Residuals	Horiz. (US survey foot)	Vert. (US survey foot)	3D (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
PRS686197981554-11 (V11)	0.100 ft	0.058 ft	0.116 ft	0.022 ft	-0.105 ft	-0.044 ft
PRS686197981554-11 (V13)	0.059 ft	0.011 ft	0.060 ft	-0.013 ft	0.042 ft	0.040 ft

Data	H. Prec. (US survey foot)	V. Prec. (US survey foot)	Length (US survey foot)	ΔX (US survey foot)	ΔY (US survey foot)	ΔZ (US survey foot)
PRS686197981554-11 (V11)	0.028 ft	0.023 ft	159739.533 ft	97257.429 ft	91280.181 ft	87895.617 ft
PRS686197981554-11 (V13)	0.025 ft	0.024 ft	159739.423 ft	97257.463 ft	91280.034 ft	87895.533 ft

Coordinates

Source	Northing (US survey foot)	Easting (US survey foot)	Elevation (US survey foot)	Height (US survey foot)
Global (14001GPSCNTRL.de)	3630857.511 ft	12036691.459 ft	26.280 ft	-90.141 ft

Appendix C
IDW Profiles and Disposal Manifests



Clearfield MMG

Post Office Box 1444
Chesapeake, VA 23327
(757) 549-8448
FAX: (757) 549-6668

NON-HAZARDOUS SHIPPING MANIFEST

MANIFEST NO. _____

GENERATOR

NAME **NAVFAC Mid-Atlantic** TELEPHONE **757-341-0481**

ADDRESS **9742 Maryland Ave. Bldg N-26** CITY **Norfolk** STATE **VA**

SHIPMENT ORIGIN **Cheatham Annex, Site 9, AOC 1, 2, & 6** CITY **Williamsburg** STATE **VA**

AUTHORIZED AGENT **c/o CH2M Hill, Inc.** FIRM _____

ADDRESS _____ OTHER **CTO WE02
CH2M HILL Project # 423755**

MATERIAL CHARACTERIZATION

ACTIVITY GENERATING THIS MATERIAL: UST/AST REMOVAL _____ OTHER **Monitoring Well Activities**

PETROLEUM TYPE (S): **None** VIRGIN PRODUCT _____ NON-VIRGIN PRODUCT _____

PHYSICAL STATE: STOCKPILED _____ EXCAVATING _____ DRUMS **25** OTHER _____
(Groundwater)

HANDLING INSTRUCTIONS: **Transport To Facility Designated Below**

FIRE OR SPILL INSTRUCTIONS: **Non-Flammable / Non-Hazardous**

DESTINATION: **Chesapeake Facility, 416 Dominion Blvd. North**

I hereby certify, to the best of my knowledge, the material characterized above is non-hazardous as defined by the Virginia Hazardous Waste Management Regulations, Federal Regulations under Subtitle C - RCRA, U.S. Department of Transportation, or local / state of origin regulations.

Rhonda Mickelborough
Signature of Generator / Agent
RHONDA MICKELBOROUGH
TREYDRE MANNING 4 APR 14
Printed Name / Date

TRANSPORTER

TRANSPORTER NAME **Clearfield MMG, Inc.** TELEPHONE **757-549-8448** TRUCK NO. **14**

I certify that the materials described above were received by me for shipment and delivered to the designated facility.

[Signature]
Transporter Signature / Date **4-4-14**

FACILITY

I certify that the materials described above were delivered to the facility and received by me.

ACCEPTED BY *[Signature]* DATE **4-4-14**

REASONS FOR REJECTION _____

Gross Weight	
Tare Weight	
Net Weight	
Tons	

GENERATOR



Clearfield MMG

Post Office Box 1444
Chesapeake, VA 23327
(757) 549-8448
FAX: (757) 549-6668

NON-HAZARDOUS SHIPPING MANIFEST

MANIFEST NO. 4-002

GENERATOR

NAME **NAVFAC Mid-Atlantic** TELEPHONE **757-341-0481**

ADDRESS **9742 Maryland Ave. Bldg N-26** CITY **Norfolk** STATE **VA**

SHIPMENT ORIGIN **Cheatham Annex, Site 9, AOC 1, 2, & 6** CITY **Williamsburg** STATE **VA**

AUTHORIZED AGENT **c/o CH2M Hill, Inc.** FIRM

ADDRESS OTHER **CTO WE02
CH2M HILL Project # 423755**

MATERIAL CHARACTERIZATION

ACTIVITY GENERATING THIS MATERIAL: UST/AST REMOVAL _____ OTHER Monitoring Well Activities

PETROLEUM TYPE (S): **None** VIRGIN PRODUCT _____ NON-VIRGIN PRODUCT _____

PHYSICAL STATE: STOCKPILED _____ EXCAVATING _____ DRUMS 7 OTHER _____
(Groundwater)

HANDLING INSTRUCTIONS: **Transport To Facility Designated Below**

FIRE OR SPILL INSTRUCTIONS: **Non-Flammable / Non-Hazardous**

DESTINATION: **Chesapeake Facility, 416 Dominion Blvd. North**

I hereby certify, to the best of my knowledge, the material characterized above is non-hazardous as defined by the Virginia Hazardous Waste Management Regulations, Federal Regulations under Subtitle C - RCRA, U.S. Department of Transportation, or local / state of origin regulations.

Rhonda Mickelberry for
Signature of Generator / Agent

TREVOR MANNING 4-4-14
Printed Name / Date

TRANSPORTER

TRANSPORTER NAME Clearfield MMG, Inc. TELEPHONE 757-549-8448 TRUCK NO. 14

I certify that the materials described above were received by me for shipment and delivered to the designated facility.

[Signature] 4-4-14
Transporter Signature / Date

FACILITY

I certify that the materials described above were delivered to the facility and received by me.

ACCEPTED BY [Signature] DATE 4-4-14

REASONS FOR REJECTION _____

Gross Weight	
Tare Weight	
Net Weight	
Tons	

GENERATOR



Clearfield MMG

Post Office Box 1444
Chesapeake, VA 23327
(757) 549-8448
FAX: (757) 549-6668

NON-HAZARDOUS SHIPPING MANIFEST

MANIFEST NO. 4-001

GENERATOR

NAME **NAVFAC Mid-Atlantic** TELEPHONE **757-341-0481**

ADDRESS **9742 Maryland Ave. Bldg N-26** CITY **Norfolk** STATE **VA**

SHIPMENT ORIGIN **Cheatham Annex, Site 9, AOC 1, 2, & 6** CITY **Williamsburg** STATE **VA**

AUTHORIZED AGENT **c/o CH2M Hill, Inc.** FIRM

ADDRESS OTHER **CTO WE02
CH2M HILL Project # 423755**

MATERIAL CHARACTERIZATION

ACTIVITY GENERATING THIS MATERIAL: UST/AST REMOVAL _____ OTHER Monitoring Well Installation

PETROLEUM TYPE (S): **None** VIRGIN PRODUCT _____ NON-VIRGIN PRODUCT _____

PHYSICAL STATE: STOCKPILED _____ EXCAVATING _____ DRUMS 14 OTHER _____
(Soil)

HANDLING INSTRUCTIONS: **Transport To Facility Designated Below**

FIRE OR SPILL INSTRUCTIONS: **Non-Flammable / Non-Hazardous**

DESTINATION: **Chesapeake Facility, 416 Dominion Blvd. North**

I hereby certify, to the best of my knowledge, the material characterized above is non-hazardous as defined by the Virginia Hazardous Waste Management Regulations, Federal Regulations under Subtitle C - RCRA, U.S. Department of Transportation, or local / state of origin regulations.

Rhonda Mickerborough
Signature of Generator / Agent
RHONDA MICKERBOROUGH
TREVOR MANNING APR 4 2014
Printed Name / Date

TRANSPORTER

TRANSPORTER NAME Clearfield MMG, Inc. TELEPHONE 757-549-8448 TRUCK NO. 14

I certify that the materials described above were received by me for shipment and delivered to the designated facility.

[Signature] 4-4-14
Transporter Signature / Date

FACILITY

I certify that the materials described above were delivered to the facility and received by me.

ACCEPTED BY [Signature] DATE 4-4-14

REASONS FOR REJECTION _____

Gross Weight	
Tare Weight	
Net Weight	
Tons	

GENERATOR



Clearfield MMG

Post Office Box 1444
Chesapeake, VA 23327
(757) 549-8448
FAX: (757) 549-6668

NON-HAZARDOUS SHIPPING MANIFEST

MANIFEST NO. _____

GENERATOR

NAME **NAVFAC Mid-Atlantic** TELEPHONE **757-341-0481**

ADDRESS **9742 Maryland Ave. Bldg N-26** CITY **Norfolk** STATE **VA**

SHIPMENT ORIGIN **Cheatham Annex, Site 9, AOC 1, 2, & 6** CITY **Williamsburg** STATE **VA**

AUTHORIZED AGENT **c/o CH2M Hill, Inc.** FIRM _____

ADDRESS _____ OTHER **CTO WE02
CH2M HILL Project # 423755**

MATERIAL CHARACTERIZATION

ACTIVITY GENERATING THIS MATERIAL: UST/AST REMOVAL _____ OTHER **Monitoring Well Installation**

PETROLEUM TYPE (S): **None** VIRGIN PRODUCT _____ NON-VIRGIN PRODUCT _____

PHYSICAL STATE: STOCKPILED _____ EXCAVATING _____ DRUMS **25** OTHER _____
(Soil)

HANDLING INSTRUCTIONS: **Transport To Facility Designated Below**

FIRE OR SPILL INSTRUCTIONS: **Non-Flammable / Non-Hazardous**

DESTINATION: **Chesapeake Facility, 416 Dominion Blvd. North**

I hereby certify, to the best of my knowledge, the material characterized above is non-hazardous as defined by the Virginia Hazardous Waste Management Regulations, Federal Regulations under Subtitle C - RCRA, U.S. Department of Transportation, or local / state of origin regulations.

Rhonda Mickelberry
Signature of Generator / Agent

*RHONDA MICKELBERRY
TREVOR MANNING 4 APR 14*
Printed Name / Date

TRANSPORTER

TRANSPORTER NAME **Clearfield MMG, Inc.** TELEPHONE **757-549-8448** TRUCK NO. **14**

I certify that the materials described above were received by me for shipment and delivered to the designated facility.

[Signature]
Transporter Signature / Date

FACILITY

I certify that the materials described above were delivered to the facility and received by me.

ACCEPTED BY *[Signature]* DATE **4-4-14**

REASONS FOR REJECTION _____

Gross Weight	
Tare Weight	
Net Weight	
Tons	

GENERATOR

Appendix D
Data Quality Evaluation

Data Quality Report for Cheatham Annex AOC 7 Expanded Site Inspection

July 2014

CH2MHILL®

5701 Cleveland Street, Suite 200
Virginia Beach, Virginia 23462

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Data Quality Evaluation Process

This data quality evaluation assesses the effect of the overall analytical process on the availability of the analytical data. “Availability” in this context refers to whether results can be used by the project team, and is based on the analytical soundness of the results, as determined in the evaluation process. If a result is analytically sound, it is available for use in evaluating the potential release, nature, and extent of contamination, and estimating potentially associated human health and ecological risks. Though results are available, the data user may consider a particular result or group of results to be not usable for one or more purposes if other conditions apply. In order to avoid confusion of terms, this data quality evaluation differentiates the “availability” of results from “usability” of results.

Three major categories of data evaluation are considered: laboratory performance, field collection performance, and matrix interference. Evaluation of laboratory performance is a check of the laboratory’s compliance with the method and client-specified requirements. Evaluation of field collection performance is a review of field quality control (QC) samples such as equipment blanks and field duplicates. Evaluation of potential matrix interference involves the review of supporting data such as surrogate recoveries and matrix spike (MS) recoveries.

Data evaluation is a multi-tiered approach, as outlined in Table 13 of the Cheatham Annex *Tier II Sampling and Analysis Plan for Expanded Site Inspection – Site 9, AOC 1, Ammonia Settling Pits Subarea of AOC 6, and AOC 7 (AOC 7 SAP)* (CH2M HILL, 2013). The process begins with an internal review by the laboratory, continues with validation, and ends with an overall review by the CH2M HILL project chemistry team and the production of this report. While only the data validator applies final qualifiers to the data, the tiered-approach allows for data quality to be evaluated thoroughly and provides a medium for essential communication among the laboratory, validator, and project team.

1.1 Laboratory Internal Quality Control Review

During analysis and prior to releasing the analytical data, the laboratory reviewed both the client sample and laboratory QC sample data to verify sample identity, instrument calibration, quantitation limits, dilution factors, numerical computations, transcription accuracy, and chemical identification. The QC data were tabulated and the results reviewed to determine whether they were within the limits for accuracy and precision. Corrective action was taken and any non-conforming data was discussed in the data package cover letter and case narrative.

To identify the need for corrective action, the laboratory referred to their in-house Standard Operating Procedures (SOPs) and the specifications of the Sampling and Analysis Plan(s) (SAPs) specific to this project. Laboratory SOPs were based on the analytical method, Department of Defense requirements, and accumulated laboratory experience; the AOC 7 SAP was referenced (CH2M HILL, 2013).

1.2 Data Validation

Validation was performed by CH2M HILL. The validator reviewed all definitive data packages, qualified data, and reduced the dataset to present only one result per analyte, per sample. For each sample, and each analyte, the validator retained the result with the highest data quality and excluded any other results (from re-extraction, re-analysis, or multiple dilutions) to avoid redundancy.

During this review and determination of the need for qualification, the validator evaluated analytical results against the quality assurance (QA)/QC criteria of the SAP, analytical methods, and laboratory SOPs, respectively. The data qualifiers applied are those presented in *Region III Modifications to the National Functional Guidelines for Organic Data Review (September 1994)* and *Region III Modifications to National Functional Guidelines for Inorganic Data Review (April 1993)*. National Functional Guidelines may have also been used during validation if criteria did not contradict criteria in the SAPs.

The data validation was focused on the laboratory's performance and the sample matrix and their effects on the analytical results. Areas of review consisted of holding time compliance, surrogate recovery accuracy, blank contamination (trip, equipment, and method blanks), initial and continuing calibration accuracy and precision, laboratory control sample (LCS) accuracy, internal standard response and retention time accuracy, instrument tune criteria accuracy, matrix spike and matrix spike duplicate (MS/MSD) recovery and duplicate sample precision (laboratory and field duplicates). Additionally, the analytical spectrum and raw data output were reviewed and 10% of the laboratory results were recalculated from the raw data to verify final laboratory identification and quantitation.

1.3 Precision, Accuracy, Representativeness, Completeness, Comparability (PARCC)

Throughout the data evaluation process, data quality is evaluated by the precision, accuracy, representativeness, completeness, and comparability (PARCC) of the data. For reference, PARCC is defined as:

1.3.1 Precision

Precision is defined as the agreement between duplicate results, and was characterized by comparing the relative percent differences (RPDs) of MS/MSD, laboratory control sample (LCS) and its duplicate, serial dilutions, laboratory replicates, and/or field duplicate sample results. Although results may have been qualified due to QC exceedances that may suggest an impact on precision, there is no actual significant negative impact on precision unless a data point is deemed unavailable (rejected) due to precision exceedances.

1.3.2 Accuracy/Bias

Accuracy/bias is a measure of the agreement between an analytical determination and the true value of the parameter being measured. For organic analyses, each sample was spiked with surrogate compounds; and for both organic and inorganic analyses, an MS/MSD and LCS were spiked with a known analyte concentration before preparation. Internal standards, surrogates and MS/MSDs provide a measure of the matrix effects on the analytical accuracy. The LCS demonstrates accuracy of the method and the laboratory's ability to meet the method criteria. Accuracy/bias is also assessed by calibration recoveries. Although results may have been qualified due to QC exceedances which may suggest an impact on accuracy/bias, there is no actual significant negative impact on accuracy unless a data point is deemed unusable (rejected) due to accuracy exceedances.

1.3.3 Representativeness

Representativeness is a qualitative measure of the degree to which sample data accurately and precisely represent a characteristic environmental condition (in this case, the nature and extent of contamination). Representativeness is a subjective parameter and is used to evaluate the efficacy of the sample planning design. In terms of data quality, representativeness is assured by the sampling team by following approved standard operating procedures (SOPs) for sample collection and handling, and the laboratory following approved SOPs for sample handling, preparation, and analysis.

1.3.4 Completeness

Completeness is calculated as the number of analytically-sound results that are available for use compared to the total number of measurements made. All results except those R-qualified as "rejected" are available for use as analytically-sound results. The R-qualifier is the only qualifier that negatively affects a data point's availability. The completeness of the dataset will be compared to a completeness goal identified in the UFP-SAP, or a goal of 95% if no goal was identified in the SAP.

1.3.6 Comparability

Comparability is a qualitative measure designed to express the confidence with which one data set may be compared to another. Factors that affect comparability are sample collection and handling techniques, sample matrix, and analytical methods. If SOPs are followed, then with the exception of data that has been rejected due to quality exceedances, precision and accuracy are said to be acceptable and the data user may be confident that this data set is comparable to others of high data quality.

Qualifiers and Reasons

2.1 Availability of Qualified Data

The qualifiers applied during validation affect the availability of the results and may affect their usability for certain purposes. The qualifiers in **Table 2-1** were applied to the 2014 AOC 7 dataset during the data quality evaluation process. Final qualifiers were issued by the validator. Qualifiers are discussed in greater detail in **Sections 2.1.1 through 2.1.5**, and reasons for applying these qualifiers are discussed in **Section 2.2**.

TABLE 2-1
Final Qualifiers Applied to Cheatham Annex AOC 7 ESI Data

Qualifier	Meaning	Percent of Data Qualified	Count
U	Nondetect at the reported concentration	64.43%	375
[NONE]	Detected	16.32%	95
J	Detected, concentration estimated	10.31%	60
B	Attributed to blank contamination	8.25%	48
UJ	Nondetect, estimated quantitation limit	0.52%	3
L	Detected, concentration biased low	0.17%	1
Totals:		100.00%	582

2.1.1 R-Qualified Results

In certain cases, a result is rejected and deemed to be unavailable. “Unavailable” in this instance is defined as a result that is not analytically sound and is not considered available for use by the project team. The R-qualifier is the only qualifier that may have an adverse effect on the availability of data. There are rejected data points in this data set.

2.1.2 Results with No Qualification

The absence of a qualifier indicates that the analyte was detected at the reported concentration and no qualification was warranted.

2.1.3 J-, UJ-, and U-Qualified Results

The J-qualification, UJ-qualification, and U-qualification of results are common occurrences and have no adverse effect on the availability of that result to the project team for making decisions. J-qualified results are available for use as detects at the reported result as long as they are considered “estimated” by the project team. Human health risk assessment guidance suggests that these qualifiers “indicate uncertainty in the reported concentration of the chemical, but not in its assigned identity. Therefore, these data can be used just as positive data with no qualifiers or codes.” In addition, one is to use “J-qualified concentrations the same way as positive data that do not have this qualifier” (*Risk Assessment Guidance for Superfund: Volume I - Human Health Evaluation Manual*. (Part A) EPA/540/1-89/002. Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C. 1989). U-qualified and UJ-qualified results are available for use as nondetects at the reported quantitation limit as long as they are considered “nondetect,” or “nondetect, estimated quantitation limit,” as appropriate.

2.1.4 B-Qualified Results

The B-qualification indicates that the results may be attributable to field or laboratory blank contamination, and that the analyte was detected in an associated blank as well as in the sample. If the B-qualifier is applied to definitive data, the results are usable as nondetects as long as they are considered “not detected at significantly greater concentration than that in an associated blank.” If the B-qualifier is applied to screening data, the results are usable as detects as qualified.

2.1.5 K-, L-, and UL-Qualified Results

The K-qualification, L-qualification, and UL-qualification indicate the data is affected by an undeterminable degree of positive or negative bias. This may indicate the presence of a QC problem, but not a problem severe enough to warrant rejection of data. K-qualified results are usable as detects as long as they are considered “estimated and biased high.” L-qualified results are available for use as detects and UL-qualified results are usable as nondetects as long as L- and UL-qualified results are considered “estimated and biased low.”

2.2 Reasons for Data Qualification

When qualifying data the validator associates a reason code to explain why the qualification was made. Examining reasons for qualifying data provides insight into whether QC issues were encountered due to laboratory performance, field collection performance, or matrix interference. **Table 2-2** provides a list of the combinations of qualifiers and reason codes applied to the AOC 7 ESI dataset, explains them, and identifies the impact of these qualifications on data quality. Whenever data is available for use as reported or as qualified, there is no impact on the availability of data for use by the project team.

TABLE 2-2
Reasons for Data Qualification

Qualifier	Reason Code	Count	Percent	Explanation	Impact on PARCC
<i>Data Available as Reported</i>					
U	[NONE]	375	64.43%	Constituent was analyzed for but not detected. Further qualification was not necessary as there were no QA/QC exceedances. The result is available as a nondetect at the reported quantitation limit.	none
[NONE]	[NONE]	95	16.32%	Constituent was detected and further qualification was not necessary as there were no QA/QC exceedances. The result is available as a detect as reported.	none
J	[NONE]	60	10.31%	Constituent was detected at a concentration less than the quantitation limit and was thus qualified as estimated by the laboratory. Further qualification was not necessary as there were no QA/QC exceedances. The result is available as a detect as reported.	none
<i>Data Available as Qualified</i>					
B	EBL	23	3.95%	Constituent was detected. The result was B-qualified due to equipment blank contamination. The result is available as a nondetect as qualified.	none
B	CCBL	15	2.58%	Constituent was detected. The result was B-qualified due to continuing calibration blank contamination. The result is available as a nondetect as qualified.	none
B	MBL	10	1.72%	Constituent was detected. The result is B-qualified due to method blank contamination. The result is available as a nondetect as qualified.	none
UJ	CCL	3	0.52%	Constituent was analyzed for but not detected. Result is UJ-qualified due to low recovery in a continuing calibration verification. The QA/QC exceedance (potential low bias) was not severe enough to warrant rejection. The result is available as a nondetect as qualified.	none
L	MSL	1	0.17%	Constituent was detected. The result was L-qualified due to low recovery in a matrix spike and/or matrix spike duplicate. The QA/QC exceedance (potential low bias) was not severe enough to warrant rejection. The result is available as a detect as qualified.	none
Totals:		582	100.00%		

100.00% not R-flagged and available for use

SECTION 3

Evaluation of Data against Project Action Limits

When nondetect results are reported at a value greater than project action limits (PALs), the results are available for use as nondetects, but their use may add uncertainty to the conclusions drawn. This is a relatively common occurrence, and there are a variety of potentially unavoidable reasons why the value at which nondetects are reported may exceed PALs, but the following is the most common for aqueous samples:

- Current technology may not be able to achieve an LOD or DL less than the PAL, in such cases the PAL is considered unreasonably low

When drafting the UFP-SAPs for AOC 7 ESI, it was anticipated that some PALs would not be met. This is detailed in the Reference Limits and Evaluation Tables of the SAP (CH2M HILL, 2013) with shading of the PALs that would not be met.

As part of the data quality evaluation, nondetected results, their associated nondetect value (the LOD), and the detection limit (DL) are compared to the minimum PAL (or to the background value if one exists). Such a comparison identifies instances where there is uncertainty regarding whether the analyte is present above the PAL (or background) due to the detection limits of the method and instrument. Since any concentration greater than the DL would be reported as a detection, uncertainty only exists when the DL is greater than the PAL. The different permutations for the PAL, LOD, and DL are summarized in **Table 3-1**, along with their impact on certainty of absence.

TABLE 3-1
Possible Arrangements for PAL, LOD, and DL, and Impact on Certainty of Absence

PAL relative to limits	Impact on Certainty of Absence
<u>PAL</u> > LOD > DL	barring other qualifications, there is certainty that the analyte is not present above the PAL, this is apparent on data tables
LOD > <u>PAL</u> > DL	barring other qualifications, there is certainty that the analyte is not present above the PAL, however this may not be apparent from data tables
LOD > DL > <u>PAL</u>	though the data is qualified as nondetect, there is uncertainty regarding whether the analyte is present at a concentration exceeding the PAL; this may not be apparent from data tables

PAL (project action limit) – the comparison criteria

LOD (limit of detection) – the value at which nondetects are reported in data tables

DL (detection limit) – the lowest concentration the instrument can detect; any response greater than this is reported as a detection

Lists of all data for which the lowest PAL (or to the background value if one exists) is lower than the LOD or the DL is are included in **Tables 3-2 and 3-4**. Data for which PAL is lower than the DL is discussed in Section 4, as appropriate.

Comparison Criteria

The comparison criteria considered in **Tables 3-2 and 3-4** were as follows; note that in cases where a background value exists, the results and their DLs are compared to the background value instead of the minimum PAL.

- Groundwater: Federal Maximum Contaminant Levels (MCLs), Adjusted USEPA Regional Screening Levels (RSLs) for Tapwater from November 2013, and Cheatham Annex Yorktown-Eastover Aquifer background

TABLE 3-2

Nondetect Results Reported at Value Greater than Comparison Criteria

Organics in AOC 7 Groundwater

DL meets Action Limit?	Sample ID	Analysis Group	Analyte	CAS #	Result	Units	Qualifier	Reason Code	DL	LOD	LOQ	Minimum PAL or Background
No	CAA07-GW01-0114	VOA	1,1,2,2-Tetrachloroethane	79-34-5	0.50	UG L	U		0.22	0.50	1.0	0.066
No	CAA07-GW01-0114	VOA	1,1,2-Trichloroethane	79-00-5	0.50	UG L	U		0.22	0.50	1.0	0.041
No	CAA07-GW01-0114	VOA	1,2-Dibromo-3-chloropropane	96-12-8	1.0	UG L	U		0.64	1.0	1.0	0.00032
No	CAA07-GW01-0114	VOA	1,2-Dibromoethane	106-93-4	1.0	UG L	U		0.23	1.0	1.0	0.0065
No	CAA07-GW01-0114	VOA	1,2-Dichloroethane	107-06-2	0.50	UG L	U		0.15	0.50	1.0	0.15
No	CAA07-GW01-0114	VOA	Bromodichloromethane	75-27-4	0.50	UG L	U		0.12	0.50	1.0	0.12
No	CAA07-GW01-0114	VOA	Chloroform	67-66-3	1.0	UG L	U		0.26	1.0	1.0	0.19
No	CAA07-GW01-0114	VOA	cis-1,3-Dichloropropene	10061-01-5	1.0	UG L	U		0.28	1.0	1.0	0.055
No	CAA07-GW01-0114	VOA	trans-1,3-Dichloropropene	10061-02-6	0.50	UG L	U		0.14	0.50	1.0	0.055
No	CAA07-GW01-0114	VOA	Vinyl chloride	75-01-4	0.50	UG L	U		0.14	0.50	1.0	0.015
No	CAA07-GW01P-0114	VOA	1,1,2,2-Tetrachloroethane	79-34-5	0.50	UG L	U		0.22	0.50	1.0	0.066
No	CAA07-GW01P-0114	VOA	1,1,2-Trichloroethane	79-00-5	0.50	UG L	U		0.22	0.50	1.0	0.041
No	CAA07-GW01P-0114	VOA	1,2-Dibromo-3-chloropropane	96-12-8	1.0	UG L	U		0.64	1.0	1.0	0.00032
No	CAA07-GW01P-0114	VOA	1,2-Dibromoethane	106-93-4	1.0	UG L	U		0.23	1.0	1.0	0.0065
No	CAA07-GW01P-0114	VOA	1,2-Dichloroethane	107-06-2	0.50	UG L	U		0.15	0.50	1.0	0.15
No	CAA07-GW01P-0114	VOA	Bromodichloromethane	75-27-4	0.50	UG L	U		0.12	0.50	1.0	0.12
No	CAA07-GW01P-0114	VOA	Chloroform	67-66-3	1.0	UG L	U		0.26	1.0	1.0	0.19
No	CAA07-GW01P-0114	VOA	cis-1,3-Dichloropropene	10061-01-5	1.0	UG L	U		0.28	1.0	1.0	0.055
No	CAA07-GW01P-0114	VOA	trans-1,3-Dichloropropene	10061-02-6	0.50	UG L	U		0.14	0.50	1.0	0.055
No	CAA07-GW01P-0114	VOA	Vinyl chloride	75-01-4	0.50	UG L	U		0.14	0.50	1.0	0.015
No	CAA07-GW02-0114	VOA	1,1,2,2-Tetrachloroethane	79-34-5	0.50	UG L	U		0.22	0.50	1.0	0.066
No	CAA07-GW02-0114	VOA	1,1,2-Trichloroethane	79-00-5	0.50	UG L	U		0.22	0.50	1.0	0.041
No	CAA07-GW02-0114	VOA	1,2-Dibromo-3-chloropropane	96-12-8	1.0	UG L	U		0.64	1.0	1.0	0.00032
No	CAA07-GW02-0114	VOA	1,2-Dibromoethane	106-93-4	1.0	UG L	U		0.23	1.0	1.0	0.0065
No	CAA07-GW02-0114	VOA	1,2-Dichloroethane	107-06-2	0.50	UG L	U		0.15	0.50	1.0	0.15
No	CAA07-GW02-0114	VOA	Bromodichloromethane	75-27-4	0.50	UG L	U		0.12	0.50	1.0	0.12
No	CAA07-GW02-0114	VOA	Chloroform	67-66-3	1.0	UG L	U		0.26	1.0	1.0	0.19
No	CAA07-GW02-0114	VOA	cis-1,3-Dichloropropene	10061-01-5	1.0	UG L	U		0.28	1.0	1.0	0.055
No	CAA07-GW02-0114	VOA	trans-1,3-Dichloropropene	10061-02-6	0.50	UG L	U		0.14	0.50	1.0	0.055
No	CAA07-GW02-0114	VOA	Vinyl chloride	75-01-4	0.50	UG L	U		0.14	0.50	1.0	0.015
No	CAA07-GW03-0114	VOA	1,1,2,2-Tetrachloroethane	79-34-5	0.50	UG L	U		0.22	0.50	1.0	0.066
No	CAA07-GW03-0114	VOA	1,1,2-Trichloroethane	79-00-5	0.50	UG L	U		0.22	0.50	1.0	0.041
No	CAA07-GW03-0114	VOA	1,2-Dibromo-3-chloropropane	96-12-8	1.0	UG L	U		0.64	1.0	1.0	0.00032
No	CAA07-GW03-0114	VOA	1,2-Dibromoethane	106-93-4	1.0	UG L	U		0.23	1.0	1.0	0.0065
No	CAA07-GW03-0114	VOA	1,2-Dichloroethane	107-06-2	0.50	UG L	U		0.15	0.50	1.0	0.15
No	CAA07-GW03-0114	VOA	Bromodichloromethane	75-27-4	0.50	UG L	U		0.12	0.50	1.0	0.12
No	CAA07-GW03-0114	VOA	Chloroform	67-66-3	1.0	UG L	U		0.26	1.0	1.0	0.19
No	CAA07-GW03-0114	VOA	cis-1,3-Dichloropropene	10061-01-5	1.0	UG L	U		0.28	1.0	1.0	0.055
No	CAA07-GW03-0114	VOA	trans-1,3-Dichloropropene	10061-02-6	0.50	UG L	U		0.14	0.50	1.0	0.055
No	CAA07-GW03-0114	VOA	Vinyl chloride	75-01-4	0.50	UG L	U		0.14	0.50	1.0	0.015
No	CAA07-GW04-0114	VOA	1,1,2,2-Tetrachloroethane	79-34-5	0.50	UG L	U		0.22	0.50	1.0	0.066
No	CAA07-GW04-0114	VOA	1,1,2-Trichloroethane	79-00-5	0.50	UG L	U		0.22	0.50	1.0	0.041
No	CAA07-GW04-0114	VOA	1,2-Dibromo-3-chloropropane	96-12-8	1.0	UG L	U		0.64	1.0	1.0	0.00032
No	CAA07-GW04-0114	VOA	1,2-Dibromoethane	106-93-4	1.0	UG L	U		0.23	1.0	1.0	0.0065
No	CAA07-GW04-0114	VOA	1,2-Dichloroethane	107-06-2	0.50	UG L	U		0.15	0.50	1.0	0.15
No	CAA07-GW04-0114	VOA	Bromodichloromethane	75-27-4	0.50	UG L	U		0.12	0.50	1.0	0.12
No	CAA07-GW04-0114	VOA	Chloroform	67-66-3	1.0	UG L	U		0.26	1.0	1.0	0.19
No	CAA07-GW04-0114	VOA	cis-1,3-Dichloropropene	10061-01-5	1.0	UG L	U		0.28	1.0	1.0	0.055
No	CAA07-GW04-0114	VOA	trans-1,3-Dichloropropene	10061-02-6	0.50	UG L	U		0.14	0.50	1.0	0.055
No	CAA07-GW04-0114	VOA	Vinyl chloride	75-01-4	0.50	UG L	U		0.14	0.50	1.0	0.015
No	CAA07-GW05-0114	VOA	1,1,2,2-Tetrachloroethane	79-34-5	0.50	UG L	U		0.22	0.50	1.0	0.066
No	CAA07-GW05-0114	VOA	1,1,2-Trichloroethane	79-00-5	0.50	UG L	U		0.22	0.50	1.0	0.041
No	CAA07-GW05-0114	VOA	1,2-Dibromo-3-chloropropane	96-12-8	1.0	UG L	U		0.64	1.0	1.0	0.00032
No	CAA07-GW05-0114	VOA	1,2-Dibromoethane	106-93-4	1.0	UG L	U		0.23	1.0	1.0	0.0065
No	CAA07-GW05-0114	VOA	1,2-Dichloroethane	107-06-2	0.50	UG L	U		0.15	0.50	1.0	0.15
No	CAA07-GW05-0114	VOA	Bromodichloromethane	75-27-4	0.50	UG L	U		0.12	0.50	1.0	0.12
No	CAA07-GW05-0114	VOA	Chloroform	67-66-3	1.0	UG L	U		0.26	1.0	1.0	0.19
No	CAA07-GW05-0114	VOA	cis-1,3-Dichloropropene	10061-01-5	1.0	UG L	U		0.28	1.0	1.0	0.055
No	CAA07-GW05-0114	VOA	trans-1,3-Dichloropropene	10061-02-6	0.50	UG L	U		0.14	0.50	1.0	0.055
No	CAA07-GW05-0114	VOA	Vinyl chloride	75-01-4	0.50	UG L	U		0.14	0.50	1.0	0.015
Yes	CAA07-GW01-0114	VOA	1,2,3-Trichlorobenzene	87-61-6	1.0	UG L	U		0.23	1.0	2.0	0.52
Yes	CAA07-GW01-0114	VOA	1,2-Dichloropropane	78-87-5	0.50	UG L	U		0.18	0.50	1.0	0.38
Yes	CAA07-GW01-0114	VOA	Benzene	71-43-2	1.0	UG L	U		0.32	1.0	1.0	0.39
Yes	CAA07-GW01-0114	VOA	Bromomethane	74-83-9	1.0	UG L	U		0.23	1.0	1.0	0.7
Yes	CAA07-GW01-0114	VOA	Carbon disulfide	75-15-0	1.0	UG L	U		0.28	1.0	5.0	0.92
Yes	CAA07-GW01-0114	VOA	Carbon tetrachloride	56-23-5	1.0	UG L	U		0.23	1.0	1.0	0.39
Yes	CAA07-GW01-0114	VOA	Dibromochloromethane	124-48-1	0.50	UG L	U		0.14	0.50	1.0	0.15
Yes	CAA07-GW01-0114	VOA	Trichloroethene	79-01-6	1.0	UG L	U		0.24	1.0	1.0	0.26
Yes	CAA07-GW01P-0114	VOA	1,2,3-Trichlorobenzene	87-61-6	1.0	UG L	U		0.23	1.0	2.0	0.52
Yes	CAA07-GW01P-0114	VOA	1,2-Dichloropropane	78-87-5	0.50	UG L	U		0.18	0.50	1.0	0.38
Yes	CAA07-GW01P-0114	VOA	Benzene	71-43-2	1.0	UG L	U		0.32	1.0	1.0	0.39
Yes	CAA07-GW01P-0114	VOA	Bromomethane	74-83-9	1.0	UG L	U		0.23	1.0	1.0	0.7
Yes	CAA07-GW01P-0114	VOA	Carbon disulfide	75-15-0	1.0	UG L	U		0.28	1.0	5.0	0.92
Yes	CAA07-GW01P-0114	VOA	Carbon tetrachloride	56-23-5	1.0	UG L	U		0.23	1.0	1.0	0.39
Yes	CAA07-GW01P-0114	VOA	Dibromochloromethane	124-48-1	0.50	UG L	U		0.14	0.50	1.0	0.15
Yes	CAA07-GW01P-0114	VOA	Trichloroethene	79-01-6	1.0	UG L	U		0.24	1.0	1.0	0.26

TABLE 3-2

Nondetect Results Reported at Value Greater than Comparison Criteria

Organics in AOC 7 Groundwater

DL meets Action Limit?	Sample ID	Analysis Group	Analyte	CAS #	Result	Units	Qualifier	Reason Code	DL	LOD	LOQ	Minimum PAL or Background
Yes	CAA07-GW02-0114	VOA	1,2,3-Trichlorobenzene	87-61-6	1.0	UG L	U		0.23	1.0	2.0	0.52
Yes	CAA07-GW02-0114	VOA	1,2-Dichloropropane	78-87-5	0.50	UG L	U		0.18	0.50	1.0	0.38
Yes	CAA07-GW02-0114	VOA	Benzene	71-43-2	1.0	UG L	U		0.32	1.0	1.0	0.39
Yes	CAA07-GW02-0114	VOA	Bromomethane	74-83-9	1.0	UG L	UJ	CCL	0.23	1.0	1.0	0.7
Yes	CAA07-GW02-0114	VOA	Carbon disulfide	75-15-0	1.0	UG L	U		0.28	1.0	5.0	0.92
Yes	CAA07-GW02-0114	VOA	Carbon tetrachloride	56-23-5	1.0	UG L	U		0.23	1.0	1.0	0.39
Yes	CAA07-GW02-0114	VOA	Dibromochloromethane	124-48-1	0.50	UG L	U		0.14	0.50	1.0	0.15
Yes	CAA07-GW02-0114	VOA	Trichloroethene	79-01-6	1.0	UG L	U		0.24	1.0	1.0	0.26
Yes	CAA07-GW03-0114	VOA	1,2,3-Trichlorobenzene	87-61-6	1.0	UG L	U		0.23	1.0	2.0	0.52
Yes	CAA07-GW03-0114	VOA	1,2-Dichloropropane	78-87-5	0.50	UG L	U		0.18	0.50	1.0	0.38
Yes	CAA07-GW03-0114	VOA	Benzene	71-43-2	1.0	UG L	U		0.32	1.0	1.0	0.39
Yes	CAA07-GW03-0114	VOA	Bromomethane	74-83-9	1.0	UG L	UJ	CCL	0.23	1.0	1.0	0.7
Yes	CAA07-GW03-0114	VOA	Carbon disulfide	75-15-0	1.0	UG L	U		0.28	1.0	5.0	0.92
Yes	CAA07-GW03-0114	VOA	Carbon tetrachloride	56-23-5	1.0	UG L	U		0.23	1.0	1.0	0.39
Yes	CAA07-GW03-0114	VOA	Dibromochloromethane	124-48-1	0.50	UG L	U		0.14	0.50	1.0	0.15
Yes	CAA07-GW03-0114	VOA	Trichloroethene	79-01-6	1.0	UG L	U		0.24	1.0	1.0	0.26
Yes	CAA07-GW03-0114	VOA	1,2,3-Trichlorobenzene	87-61-6	1.0	UG L	U		0.23	1.0	2.0	0.52
Yes	CAA07-GW04-0114	VOA	1,2-Dichloropropane	78-87-5	0.50	UG L	U		0.18	0.50	1.0	0.38
Yes	CAA07-GW04-0114	VOA	Benzene	71-43-2	1.0	UG L	U		0.32	1.0	1.0	0.39
Yes	CAA07-GW04-0114	VOA	Bromomethane	74-83-9	1.0	UG L	UJ	CCL	0.23	1.0	1.0	0.7
Yes	CAA07-GW04-0114	VOA	Carbon disulfide	75-15-0	1.0	UG L	U		0.28	1.0	5.0	0.92
Yes	CAA07-GW04-0114	VOA	Carbon tetrachloride	56-23-5	1.0	UG L	U		0.23	1.0	1.0	0.39
Yes	CAA07-GW04-0114	VOA	Dibromochloromethane	124-48-1	0.50	UG L	U		0.14	0.50	1.0	0.15
Yes	CAA07-GW04-0114	VOA	Trichloroethene	79-01-6	1.0	UG L	U		0.24	1.0	1.0	0.26
Yes	CAA07-GW05-0114	VOA	1,2,3-Trichlorobenzene	87-61-6	1.0	UG L	U		0.23	1.0	2.0	0.52
Yes	CAA07-GW05-0114	VOA	1,2-Dichloropropane	78-87-5	0.50	UG L	U		0.18	0.50	1.0	0.38
Yes	CAA07-GW05-0114	VOA	Benzene	71-43-2	1.0	UG L	U		0.32	1.0	1.0	0.39
Yes	CAA07-GW05-0114	VOA	Bromomethane	74-83-9	1.0	UG L	U		0.23	1.0	1.0	0.7
Yes	CAA07-GW05-0114	VOA	Carbon disulfide	75-15-0	1.0	UG L	U		0.28	1.0	5.0	0.92
Yes	CAA07-GW05-0114	VOA	Carbon tetrachloride	56-23-5	1.0	UG L	U		0.23	1.0	1.0	0.39
Yes	CAA07-GW05-0114	VOA	Dibromochloromethane	124-48-1	0.50	UG L	U		0.14	0.50	1.0	0.15
Yes	CAA07-GW05-0114	VOA	Trichloroethene	79-01-6	1.0	UG L	U		0.24	1.0	1.0	0.26

TABLE 3-3

*Nondetect Results Reported at Value Greater than Comparison Criteria**Total Metals in AOC 7 Groundwater*

DL meets Action Limit?	Sample ID	Analysis Group	Analyte	CAS #	Result	Units	Qualifier	Reason Code	DL	LOD	LOQ	Minimum PAL or Background
NA	CAA07-GW01-0114	METAL	Zinc	7440-66-6	9.9	UG_L	B	EBL	1.5	4.0	10	4.52
NA	CAA07-GW01P-0114	METAL	Zinc	7440-66-6	22	UG_L	B	EBL	1.5	4.0	10	4.52
NA	CAA07-GW02-0114	METAL	Zinc	7440-66-6	11	UG_L	B	EBL	1.5	4.0	10	4.52
NA	CAA07-GW03-0114	METAL	Zinc	7440-66-6	13	UG_L	B	EBL	1.5	4.0	10	4.52
NA	CAA07-GW04-0114	METAL	Zinc	7440-66-6	10	UG_L	B	EBL	1.5	4.0	10	4.52
NA	CAA07-GW05-0114	METAL	Zinc	7440-66-6	11	UG_L	B	EBL	1.5	4.0	10	4.52
No	CAA07-GW01-0114	METAL	Mercury	7439-97-6	0.10	UG_L	U		0.055	0.10	0.20	0.026
No	CAA07-GW01P-0114	METAL	Mercury	7439-97-6	0.10	UG_L	U		0.055	0.10	0.20	0.026
No	CAA07-GW01P-0114	METAL	Thallium	7440-28-0	0.10	UG_L	U		0.027	0.10	1.0	0.016
No	CAA07-GW02-0114	METAL	Mercury	7439-97-6	0.10	UG_L	U		0.055	0.10	0.20	0.026
No	CAA07-GW02-0114	METAL	Thallium	7440-28-0	0.10	UG_L	U		0.027	0.10	1.0	0.016
No	CAA07-GW03-0114	METAL	Mercury	7439-97-6	0.10	UG_L	U		0.055	0.10	0.20	0.026
No	CAA07-GW03-0114	METAL	Thallium	7440-28-0	0.10	UG_L	U		0.027	0.10	1.0	0.016
No	CAA07-GW04-0114	METAL	Mercury	7439-97-6	0.10	UG_L	U		0.055	0.10	0.20	0.026
No	CAA07-GW04-0114	METAL	Thallium	7440-28-0	0.10	UG_L	U		0.027	0.10	1.0	0.016
No	CAA07-GW05-0114	METAL	Mercury	7439-97-6	0.10	UG_L	U		0.055	0.10	0.20	0.026
No	CAA07-GW05-0114	METAL	Thallium	7440-28-0	0.10	UG_L	U		0.027	0.10	1.0	0.016

TABLE 3-4

*Nondetect Results Reported at Value Greater than Comparison Criteria**Dissolved Metals in AOC 7 Groundwater*

DL meets Action Limit?	Sample ID	Analysis Group	Analyte	CAS #	Result	Units	Qualifier	Reason Code	DL	LOD	LOQ	Minimum PAL or Background
NA	CAA07-GW04-0114	FMETAL	Thallium	7440-28-0	0.028	UG_L	B	EBL	0.027	0.10	1.0	0.016
No	CAA07-GW01-0114	FMETAL	Thallium	7440-28-0	0.10	UG_L	U		0.027	0.10	1.0	0.016
No	CAA07-GW01P-0114	FMETAL	Thallium	7440-28-0	0.10	UG_L	U		0.027	0.10	1.0	0.016
No	CAA07-GW02-0114	FMETAL	Thallium	7440-28-0	0.10	UG_L	U		0.027	0.10	1.0	0.016
No	CAA07-GW03-0114	FMETAL	Thallium	7440-28-0	0.10	UG_L	U		0.027	0.10	1.0	0.016
No	CAA07-GW05-0114	FMETAL	Thallium	7440-28-0	0.10	UG_L	U		0.027	0.10	1.0	0.016

SECTION 4

Data Quality Evaluation

In this section data qualifiers and the reason for their use are presented by for organic constituents, total metals, and filtered metals. Qualifiers and the reason codes are defined in **Section 2**.

Each subsection includes a summary table of qualifications. The table shows the qualifiers and the reason for their use in order of decreasing frequency, and each qualifier is identified as being either available as reported by the laboratory, available as qualified by the validator, or not available. The impact on Precision, Accuracy, Representativeness, Completeness and Comparability (PARCC) is identified. Statistics are also included: a count and percentage of the number of instances of each type of qualification is shown. Note that the statistics in these tables consider only parent and field duplicate results; data for quality control samples such as MS/MSD and blanks are not counted. The last row of the table shows the statistics totals.

A discussion is included if data that was deemed unusable or if there are other quality issues that should be considered during data use. In many cases the data is 100% usable and the need for qualification was sporadic and unremarkable; therefore the table is presented with no discussion, which implies that the data is of excellent quality.

All samples for the AOC 7 ESI were collected in the month of January 2014 and analysis performed by TriMatrix Laboratories in Grand Rapids, Michigan.

4.1 Organics

Volatile Organic Compounds (VOCs) were analyzed by SW-846 8260B as specified in the AOC 7 SAP. The validation process issued the qualifiers shown in the following table.

Qualifier	Reason Code	Count	Percent	Available as Reported	Available as Qualified	Impact on PARCC
U	[NONE]	302	98.69%	X		none
UJ	CCL	3	0.98%		X	none
J	[NONE]	1	0.33%	X		none
		306	100.00%	99.02%	0.98%	

100.00% not R-flagged and available for use

All data is of sufficient quality to evaluate whether action limits were met, with the exception of data for which the DL was greater than the comparison criteria. Affected nondetect data are listed in **Table 3-2** and include data for 10 VOCs: 1,1,2,2-tetrachloroethane, 1,1,2-trichloroethane, 1,2-dibromo-3-chloropropane, 1,2-dibromoethane, 1,2-dichloroethane, bromodichloromethane, chloroform, cis-1,3-dichloropropene, trans-1,3-dichloropropene, and vinyl chloride. These results are available for use as nondetects, but their use may add uncertainty to the conclusions drawn.

4.2 Total Metals

Total metals were analyzed by either SW-846 6010C, 6020A, or 7470A as applicable and as specified in the AOC 7 SAP. The validation process issued the qualifiers shown in the following table.

Qualifier	Reason Code	Count	Percent	Available as Reported	Available as Qualified	Impact on PARCC
[NONE]	[NONE]	51	36.96%	X		none
J	[NONE]	33	23.91%	X		none

Qualifier	Reason Code	Count	Percent	Available as Reported	Available as Qualified	Impact on PARCC
U	[NONE]	29	21.01%	X		none
B	EBL	12	8.70%		X	none
B	CCBL	9	6.52%		X	none
B	MBL	3	2.17%		X	none
L	MSL	1	0.72%		X	none
		138	100.00%	81.88%	18.12%	

100.00% not R-flagged and available for use

All data is of sufficient quality to evaluate whether action limits were met, with the exception of data for which the DL was greater than the comparison criteria. Affected nondetect data are listed in **Table 3-3** and include data for two metals: mercury and thallium. These results are available for use as nondetects, but their use may add uncertainty to the conclusions drawn.

Additionally, some metals results were attributed to blank contamination, including aluminum, chromium, copper selenium and zinc. These B-qualified results are available as non-detects at the concentration reported. The concentrations reported for B-qualified results were below the background values, or the minimum PAL, with the exception of zinc. These results are available for use as nondetects, but their use may add uncertainty to the conclusions drawn.

4.3 Dissolved Metals

Dissolved metals were analyzed by either SW-846 6010C, 6020A, or 7470A as applicable and as specified in the AOC 7 SAP. The validation process issued the qualifiers shown in the following table.

Qualifier	Reason Code	Count	Percent	Available as Reported	Available as Qualified	Impact on PARCC
U	[NONE]	44	31.88%	X		none
[NONE]	[NONE]	44	31.88%	X		none
J	[NONE]	26	18.84%	X		none
B	EBL	11	7.97%		X	none
B	MBL	7	5.07%		X	none
B	CCBL	6	4.35%		X	none
		138	100.00%	82.61%	17.39%	

100.00% not R-flagged and available for use

All data is of sufficient quality to evaluate whether action limits were met, with the exception of data for which the DL was greater than the comparison criteria. Affected nondetect data are listed in **Table 3-4** and include data for one metal: thallium. These results are available for use as nondetects, but their use may add uncertainty to the conclusions drawn.

Additionally, some metals results were attributed to blank contamination, including antimony, arsenic, chromium, copper, nickel, thallium, vanadium, and zinc. The concentrations reported for B-qualified results were below the background values, or the minimum PAL, with the exception of thallium. These results are available for use as nondetects, but their use may add uncertainty to the conclusions drawn.

SECTION 5

Conclusions

The data user may express confidence in the fact that the data for Cheatham Annex AOC 7 ESI is comparable to others of acceptable data quality because approved SOPs were used for sample collection and handling, common sample matrices were evaluated, and EPA methods were utilized.

Precision, accuracy, representativeness, and completeness were demonstrated to be acceptable and the data user may be confident that this data set is comparable to others of high data quality. All data is available for use, none was rejected for quality issues, and the dataset is 100% complete. This far exceeds the typical 95% completeness goal.

Appendix E
Groundwater Analytical Laboratory Results

TABLE 6

Groundwater Analytical Laboratory Results - January 2014

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Station ID	CAA07-MW01		CAA07-MW02	CAA07-MW03	CAA07-MW04	CAA07-MW05
Sample ID	CAA07-GW01-0114	CAA07-GW01P-0114	CAA07-GW02-0114	CAA07-GW03-0114	CAA07-GW04-0114	CAA07-GW05-0114
Sample Date	01/16/14	01/16/14	01/15/14	01/15/14	01/15/14	01/16/14
Chemical Name						
Volatile Organic Compounds (µg/l)						
1,1,1-Trichloroethane	1 U	1 U	1 U	1 U	1 U	1 U
1,1,2,2-Tetrachloroethane	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2-Trichloro-1,2,2-trifluoroethane (Freon-113)	1 U	1 U	1 U	1 U	1 U	1 U
1,1,2-Trichloroethane	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethane	1 U	1 U	1 U	1 U	1 U	1 U
1,1-Dichloroethene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2,3-Trichlorobenzene	1 U	1 U	1 U	1 U	1 U	1 U
1,2,4-Trichlorobenzene	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
1,2-Dibromo-3-chloropropane	1 U	1 U	1 U	1 U	1 U	1 U
1,2-Dibromoethane	1 U	1 U	1 U	1 U	1 U	1 U
1,2-Dichlorobenzene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloroethane	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloropropane	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,3-Dichlorobenzene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,4-Dichlorobenzene	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
2-Butanone	2 U	2 U	2 U	2 U	2 U	2 U
2-Hexanone	2 U	2 U	2 U	2 U	2 U	2 U
4-Methyl-2-pentanone	2 U	2 U	2 U	2 U	2 U	2 U
Acetone	2 U	2 U	2 U	2 U	2 U	2 U
Benzene	1 U	1 U	1 U	1 U	1 U	1 U
Bromochloromethane	1 U	1 U	1 U	1 U	1 U	1 U
Bromodichloromethane	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromoform	1 U	1 U	1 U	1 U	1 U	1 U
Bromomethane	1 U	1 U	1 U	1 U	1 U	1 U
Carbon disulfide	1 U	1 U	1 U	1 U	1 U	1 U
Carbon tetrachloride	1 U	1 U	1 U	1 U	1 U	1 U
Chlorobenzene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroethane	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroform	1 U	1 U	1 U	1 U	1 U	1 U
Chloromethane	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,2-Dichloroethene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,3-Dichloropropene	1 U	1 U	1 U	1 U	1 U	1 U
Cyclohexane	1 U	1 U	1 U	1 U	1 U	1 U
Dibromochloromethane	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Dichlorodifluoromethane (Freon-12)	1 U	1 U	1 U	1 U	1 U	1 U
Ethylbenzene	1 U	1 U	1 U	1 U	1 U	1 U
Isopropylbenzene	1 U	1 U	1 U	1 U	1 U	1 U
m- and p-Xylene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl acetate	1 U	1 U	1 U	1 U	1 U	1 U
Methylcyclohexane	1 U	1 U	1 U	1 U	1 U	1 U
Methylene chloride	1 U	1 U	1 U	1 U	1 U	1 U
Methyl-tert-butyl ether (MTBE)	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
o-Xylene	1 U	1 U	1 U	1 U	1 U	1 U
Styrene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tetrachloroethene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Toluene	1 U	1 U	0.29 J	1 U	1 U	1 U
trans-1,2-Dichloroethene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
trans-1,3-Dichloropropene	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Trichloroethene	1 U	1 U	1 U	1 U	1 U	1 U
Trichlorofluoromethane (Freon-11)	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U	0.25 U
Vinyl chloride	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Total Metals (µg/l)						
Aluminum	50 U	20 B	370	31 B	35 B	50 U
Antimony	0.18 B	0.21 B	0.25 B	0.28 B	0.41 B	0.16 B
Arsenic	0.34 J	0.31 J	0.34 J	0.5 J	0.58 J	0.4 J
Barium	38	36	26	25	16	22
Beryllium	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
Cadmium	0.11 J	0.056 J	0.18 J	0.4	0.084 J	0.063 J
Calcium	150,000	140,000	130,000	190,000	140,000	170,000
Chromium	0.87 B	0.6 B	1.7	1.1	1.8	1.1 B
Cobalt	0.22 J	0.23 J	0.25 J	0.38 J	0.22 J	0.21 J
Copper	0.35 J	0.35 J	0.4 B	0.33 B	0.42 B	0.35 J
Iron	240	300	960 L	320	340	170
Lead	0.5 U	0.5 U	0.24 J	0.15 J	0.19 J	0.5 U
Magnesium	3,400	3,300	2,100	2,600	2,500	2,300
Manganese	5.2	5	3.8	35	3.5	3.7
Mercury	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Nickel	1.1	0.92 J	0.79 J	1	0.86 J	0.79 J
Potassium	1,800	1,800	1,000	1,100	2,000	910
Selenium	0.88 J	1 U	1.1 B	0.39 B	0.79 B	0.64 J
Silver	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U

TABLE 6

Groundwater Analytical Laboratory Results - January 2014

AOC 7 Expanded Site Inspection Report

Cheatham Annex

Williamsburg, Virginia

Station ID	CAA07-MW01		CAA07-MW02	CAA07-MW03	CAA07-MW04	CAA07-MW05
Sample ID	CAA07-GW01-0114	CAA07-GW01P-0114	CAA07-GW02-0114	CAA07-GW03-0114	CAA07-GW04-0114	CAA07-GW05-0114
Sample Date	01/16/14	01/16/14	01/15/14	01/15/14	01/15/14	01/16/14
Chemical Name						
Sodium	7,700	7,400	5,700	6,300	6,800	5,700
Thallium	0.033 J	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Vanadium	0.93 J	0.87 J	2	1.2	1.2	0.8 J
Zinc	9.9 B	22 B	11 B	13 B	10 B	11 B
Dissolved Metals (µg/l)						
Aluminum, Dissolved	50 U	50 U	50 U	50 U	50 U	50 U
Antimony, Dissolved	0.16 B	0.5 U	0.22 B	0.25 B	0.34 B	0.5 U
Arsenic, Dissolved	0.5 U	0.5 U	0.5 U	0.5 U	0.22 J	0.32 B
Barium, Dissolved	33	36	22	24	17	21
Beryllium, Dissolved	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U	0.4 U
Cadmium, Dissolved	0.046 J	0.041 J	0.15 J	0.34	0.071 J	0.065 J
Calcium, Dissolved	140,000	140,000	120,000	180,000	150,000	170,000
Chromium, Dissolved	0.35 B	0.38 B	0.41 B	0.4 B	1.2	0.6 B
Cobalt, Dissolved	0.18 J	0.18 J	0.12 J	0.31 J	0.15 J	0.16 J
Copper, Dissolved	0.36 B	0.62 B	0.29 J	0.74 B	0.41 B	0.29 B
Iron, Dissolved	21	14	11	10 U	8.2 J	11
Lead, Dissolved	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Magnesium, Dissolved	3,100	3,300	1,900	2,600	2,700	2,200
Manganese, Dissolved	4.7	4.8	2.3	32	3.1	3
Mercury, Dissolved	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Nickel, Dissolved	1.3	0.86 J	0.57 J	1	0.74 J	0.78 B
Potassium, Dissolved	1,700	1,800	820	980	2,100	910
Selenium, Dissolved	1 U	1 U	0.78 J	0.44 J	0.65 J	0.91 J
Silver, Dissolved	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U	0.1 U
Sodium, Dissolved	7,200	7,600	5,200	6,200	7,400	5,500
Thallium, Dissolved	0.1 U	0.1 U	0.1 U	0.1 U	0.028 B	0.1 U
Vanadium, Dissolved	0.45 J	0.4 B	0.66 J	0.53 J	0.56 J	0.52 J
Zinc, Dissolved	11 B	9.7 B	15 B	15 B	13 B	12 B

\\VBOFFP01\Proj\CLEANII\BASES\CAX\AOC 7\Expanded SI Report\Pre-Draft\Appendices\Appendix E-AnalyticalData\Raw Data Table.xlsx, Dean, Juliana/VBO, 06/12/2014

Notes:

Shading indicates detections

B - Analyte not detected significantly above the level reported in an associated blank

J - Analyte present, value may or may not be accurate or precise

L - Analyte present, value may be biased low, actual value may be higher

U - The material was analyzed for, but not detected

UJ - Analyte not detected, quantitation limit may be inaccurate

µg/l - Micrograms per liter

Appendix F
Human Health Risk Assessment
Supporting Information

Table 1
 SELECTION OF EXPOSURE PATHWAYS
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	On-Site/ Off-Site	Type of Analysis	Rationale for Selection or Exclusion of Exposure Pathway
Future	Groundwater	Groundwater	Tap Water	Industrial Worker	Adult	Dermal	On-site	None	Industrial workers assumed not to shower/bath at work.
						Ingestion	On-site	Quant	Groundwater is not currently used on-site as a water supply; however, although unlikely, future industrial potable use of the groundwater is possible.
				Resident*	Adult	Dermal Absorption	On-site	Quant	Groundwater is not currently used on-site as a water supply and the site is not expected to be developed for residential use; however, the residential scenario is included for a conservative evaluation of unrestricted land use.
						Ingestion	On-site	Quant	
			Child		Dermal Absorption	On-site	Quant		
			Child/Adult	Dermal Absorption	On-site	Quant			
				Ingestion	On-site	Quant			
			Water in Excavation Trench	Construction Worker	Adult	Dermal	On-site	Quant	Workers could be exposed to shallow groundwater during excavation activities.
		Ingestion				On-site	None	Incidental ingestion of groundwater by construction workers would be minimal during construction or excavation activities.	
		Air	Water Vapors at Showerhead	Industrial Worker	Adult	Inhalation	On-site	None	Industrial worker not expected to shower while at work.
						Resident*	Adult	Inhalation	On-site
				Child	Inhalation			On-site	None
							Child/Adult		
				Water Vapors at Excavation Trench	Construction Worker	Adult	Inhalation	On-site	Quant

* Noncarcinogenic hazard evaluated separately for adult and child receptors, combined lifetime carcinogenic risk evaluated on an age-adjusted basis for residential scenario.
 Quant: will be quantitatively evaluated.

Table 2.1
 OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
 Medium: Groundwater
 Exposure Medium: Groundwater

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Tap Water and Water in Excavation Trench	108-88-3	Toluene	2.9E-01 J	2.9E-01 J	UG/L	CAA07-GW02-0114	1/5	1.0E-03 - 1.0E-03	2.9E-01	N/A	8.6E+01 N	1.0E+03	MCL	NO	BSL
	7429-90-5	Aluminum	3.7E+02	3.7E+02	UG/L	CAA07-GW02-0114	1/5	1.0E+02 - 1.0E+02	3.7E+02	2.2E+03	1.6E+03 N	50 - 200	SMCL	NO	BSL
	7440-38-2	Arsenic	3.4E-01 J	5.8E-01 J	UG/L	CAA07-GW04-0114	5/5	1.0E+00 - 1.0E+00	5.8E-01	2.3E+00	4.5E-02 C	1.0E+03	MCL	YES	ASL
	7440-39-3	Barium	1.6E+01	3.8E+01	UG/L	CAA07-GW01-0114	5/5	1.0E+01 - 1.0E+01	3.8E+01	1.2E+02	2.9E+02 N	2.0E+03	MCL	NO	BSL
	7440-43-9	Cadmium	6.3E-02 J	4.0E-01	UG/L	CAA07-GW03-0114	5/5	2.0E-01 - 2.0E-01	4.0E-01	6.1E-01	6.9E-01 N	5.0E+00	MCL	NO	BSL
	7440-70-2	Calcium	1.3E+05	1.9E+05	UG/L	CAA07-GW03-0114	5/5	5.0E+02 - 5.0E+02	1.9E+05	1.7E+05	N/A	N/A		NO	NUT
	7440-47-3	Chromium	1.1E+00	1.8E+00	UG/L	CAA07-GW04-0114	3/5	1.0E+00 - 1.0E+00	1.8E+00	1.5E+01	3.1E-02 C	1.0E+02	MCL	YES	ASL
	7440-48-4	Cobalt	2.1E-01 J	3.8E-01 J	UG/L	CAA07-GW03-0114	5/5	1.0E+00 - 1.0E+00	3.8E-01	2.1E+01	4.7E-01 N	N/A		NO	BSL
	7440-50-8	Copper	3.5E-01 J	3.5E-01 J	UG/L	CAA07-GW05-0114	2/5	1.0E+00 - 1.0E+00	3.5E-01	1.2E+01	6.2E+01 N	1.3E+03	MCL	NO	BSL
	7439-89-6	Iron	1.7E+02	9.6E+02 L	UG/L	CAA07-GW02-0114	5/5	1.0E+01 - 1.0E+01	9.6E+02	8.9E+02	1.1E+03 N	3.0E+02	SMCL	NO	BSL
	7439-92-1	Lead	1.5E-01 J	2.4E-01 J	UG/L	CAA07-GW02-0114	3/5	1.0E+00 - 1.0E+00	2.4E-01	2.1E+01	1.5E+01	1.5E+01	MCL	NO	BSL
	7439-95-4	Magnesium	2.1E+03	3.4E+03	UG/L	CAA07-GW01-0114	5/5	5.0E+02 - 5.0E+02	3.4E+03	1.2E+04	N/A	N/A		NO	NUT
	7439-96-5	Manganese	3.5E+00	3.5E+01	UG/L	CAA07-GW03-0114	5/5	1.0E+00 - 1.0E+00	3.5E+01	5.8E+01	3.2E+01 N	5.0E+01	SMCL	YES	ASL
	7440-02-0	Nickel	7.9E-01 J	1.1E+00	UG/L	CAA07-GW01-0114	5/5	1.0E+00 - 1.0E+00	1.1E+00	1.1E+01	3.0E+01 N	N/A		NO	BSL
	7440-09-7	Potassium	9.1E+02	2.0E+03	UG/L	CAA07-GW04-0114	5/5	1.0E+02 - 1.0E+02	2.0E+03	1.3E+04	N/A	N/A		NO	NUT
	7782-49-2	Selenium	6.4E-01 J	8.8E-01 J	UG/L	CAA07-GW01-0114	2/5	1.0E+00 - 1.0E+00	8.8E-01	N/A	7.8E+00 N	5.0E+01	MCL	NO	BSL
	7440-23-5	Sodium	5.7E+03	7.7E+03	UG/L	CAA07-GW01-0114	5/5	5.0E+02 - 5.0E+02	7.7E+03	6.5E+04	N/A	N/A		NO	NUT
	7440-28-0	Thallium	3.3E-02 J	3.3E-02 J	UG/L	CAA07-GW01-0114	1/5	1.0E+00 - 1.0E+00	3.3E-02	N/A	1.6E-02 N	2.0E+00	MCL	YES	ASL
	7440-62-2	Vanadium	8.0E-01 J	2.0E+00	UG/L	CAA07-GW02-0114	5/5	1.0E+00 - 1.0E+00	2.0E+00	2.6E+01	6.3E+00 N	N/A		NO	BSL

[1] Minimum/Maximum detected concentration. Unfiltered results for metals since in general no significant difference between filtered and unfiltered results of aluminum, iron, and manganese in any of the monitoring wells.

[2] Maximum concentration is used for screening.

[3] Background values are Yorktown/Eastover Aquifer, 95% UTL, from Final Background Study Report, Naval Weapons Station Yorktown, Yorktown, Virginia and Cheatham Annex, Williamsburg, Virginia.

[4] Oak Ridge National Laboratory (ORNL). November, 2013. Regional Screening Levels for Chemical Contaminants at Superfund Sites. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/whatsnew.html. Tap water RSLs. RSLs based on non-carcinogenic effects based on hazard quotient of 0.1. RSL value for chromium (VI) used as surrogate for chromium. The screening value of 15 ug/L for lead is the action level provided in the Drinking Water Regulations and Health Advisories.

[5] Rationale Codes
 Selection Reason: Above Screening Levels (ASL)
 Deletion Reason: No Toxicity Information (NTX)
 Essential Nutrient (NUT)

COPC = Chemical of Potential Concern
 ARAR/TBC = Applicable or Relevant and Appropriate Requirement/
 To Be Considered
 J = Estimated Value
 L = Biased Low
 C = Carcinogenic
 N = Noncarcinogenic
 N/A= Not available or not applicable
 UG/L = micrograms per liter
 MCL = Maximum Contaminant Level
 SMCL = Maximum Contaminant Level, Secondary Drinking Water Standards

Table 2.2
 OCCURRENCE, DISTRIBUTION AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Air

Exposure Point	CAS Number	Chemical	Minimum [1] Concentration Qualifier	Maximum [1] Concentration Qualifier	Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration [2] Used for Screening	Background [3] Value	Screening [4] Toxicity Value	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag	Rationale for [5] Contaminant Deletion or Selection
Water Vapors at at Showerhead and at Excavation Trench	108-88-3	Toluene	2.9E-01 J	2.9E-01 J	UG/L	CAA07-GW02-0114	1/5	1.0E-03 - 1.0E-03	2.9E-01	N/A	8.6E+01 N	1.0E+03	MCL	NO	BSL

[1] Minimum/Maximum detected concentration.

[2] Maximum concentration is used for screening.

[3] No background values for VOCs.

[4] Oak Ridge National Laboratory (ORNL), November, 2013. Regional Screening Levels for Chemical Contaminants at Superfund Sites. http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/whatsnew.html. Tap water RSLs. RSLs based on non-carcinogenic effects based on hazard quotient of 0.1

[5] Rationale Codes

Selection Reason:	Above Screening Levels (ASL)
Deletion Reason:	No Toxicity Information (NTX)
	Essential Nutrient (NUT)
	Below Screening Level (BSL)

COPC = Chemical of Potential Concern

ARAR/TBC = Applicable or Relevant and Appropriate Requirement/ To Be Considered

J = Estimated Value

N = Noncarcinogenic

N/A= Not available or not applicable

UG/L = micrograms per liter

MCL = Maximum Contaminant Level

Table 3.1
MEDIUM-SPECIFIC EXPOSURE POINT CONCENTRATION SUMMARY
Cheatham Annex AOC 7/Expanded Site Investigation Report
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Point	Chemical of Potential Concern	Units	Arithmetic Mean	95% UCL (Distribution)		Maximum Concentration (Qualifier)		Exposure Point Concentration			
								Value	Units	Statistic	Rationale
Tap Water and Water in Excavation Trench	Arsenic	UG/L	4.3E-01	5.3E-01	N	5.8E-01	J	5.3E-01	UG/L	95% Stud-t	1, 2, 3
	Chromium	UG/L	1.3E+00	1.7E+00	NP	1.8E+00		1.7E+00	UG/L	95% KM-t	1, 2
	Manganese	UG/L	1.0E+01	3.7E+01	NP	3.5E+01		3.5E+01	UG/L	Max	1, 6
	Thallium	UG/L	N/A	N/A		3.3E-02	J	3.3E-02	UG/L	Max	5

ProUCL, Version 5.0.00 used to calculate exposure point concentration, following recommendations in users guide (USEPA, September 2013. Prepared by Lockheed Martin Environmental Services).
Options: 95% Student's-t UCL (95% Stud-t); 95% Kaplan-Meier (t) UCL (95% KM-t); Maximum Detected Value (Max)

- UCL Rationale:
- (1) Shapiro-Wilk W Test indicates data are log-normally distributed.
 - (2) Shapiro-Wilk W Test indicates data are normally distributed.
 - (3) Data fit gamma distribution.
 - (4) Data do not fit lognormal, normal, or gamma distribution.
 - (5) Maximum concentration used because EPC data set contains only 1 detected concentration.
 - (6) Maximum value used because calculated UCL exceeds maximum concentration.

UG/L = micrograms per liter
N = normal
N/A = Not Applicable
NP = non-parametric

TABLE 4.1.RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
Cheatham Annex AOC 7/Expanded Site Investigation Report
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future Medium: Groundwater Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference	Intake Equation/Model Name
Ingestion	Industrial Worker	Adult	Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1 EPA, 2014 (1) EPA, 2014 EPA, 1991 -- EPA, 2014 EPA, 1989 EPA, 1989	CDI (mg/kg-day) = CW x IR-W x EF x ED x CF x 1/BW x 1/AT
				IR-W	Ingestion Rate of Water	1.25	liters/day		
				EF	Exposure Frequency	250	days/year		
				ED	Exposure Duration	25	years		
				CF	Conversion Factor 1	0.001	mg/µg		
				BW	Body Weight	80	kg		
	AT-C	Averaging Time (Cancer)	25,550	days					
	AT-N	Averaging Time (Non-Cancer)	9,125	days					
	Resident	Adult	Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1 EPA, 2014 EPA, 2014 EPA, 2014 -- EPA, 2014 EPA, 1989 EPA, 2014	Chronic Daily Intake (CDI) (mg/kg-day) = CW x IR-W x EF x ED x CF1 x 1/BW x 1/AT
				IR-W	Ingestion Rate of Water	2.5	liters/day		
				EF	Exposure Frequency	350	days/year		
				ED	Exposure Duration	20	years		
CF1				Conversion Factor 1	0.001	mg/µg			
BW				Body Weight	80	kg			
AT-C	Averaging Time (Cancer)	25,550	days						
AT-N	Averaging Time (Non-Cancer)	7,300	days						
Child	Child	Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1 EPA, 2014 EPA, 2014 EPA, 2014 -- EPA, 2014 EPA, 1989 EPA, 1989	CDI (mg/kg-day) = CW x IR-W x EF x ED x CF1 x 1/BW x 1/AT	
			IR-W	Ingestion Rate of Water	0.78	liters/day			
			EF	Exposure Frequency	350	days/year			
			ED	Exposure Duration	6	years			
			CF1	Conversion Factor 1	0.001	mg/µg			
			BW	Body Weight	15	kg			
AT-C	Averaging Time (Cancer)	25,550	days						
AT-N	Averaging Time (Non-Cancer)	2,190	days						
Child/Adult	Child/Adult	Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1 EPA, 2014 EPA, 2014 calculated EPA, 2014 EPA, 2014 EPA, 2014 -- EPA, 2014 EPA, 2014 EPA, 2014	CDI (mg/kg-day) = CW x IR-W-Adj x EF x CF1 x 1/AT IR-W-Adj (liter-year/kg-day) = (ED-C x IR-W-C / BW-C) + (ED-A x IR-W-A / BW-A)	
			IR-W-A	Ingestion Rate of Water, Adult	2.5	liters/day			
			IR-W-C	Ingestion Rate of Water, Child	0.78	liters/day			
			IR-W-Adj	Ingestion Rate of Water, Age-adjusted	0.94	liter-year/kg-day			
			EF	Exposure Frequency	350	days/year			
			ED-A	Exposure Duration, Adult	20	years			
			ED-C	Exposure Duration, Child	6	years			
			CF1	Conversion Factor 1	0.001	mg/µg			
			BW-A	Body Weight, Adult	80	kg			
			BW-C	Body Weight, Child	15	kg			
AT-C	Averaging Time (Cancer)	25,550	days						

TABLE 4.1.RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
Cheatham Annex AOC 7/Expanded Site Investigation Report
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference	Intake Equation/Model Name
Dermal	Resident	Adult	Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	$CDI \text{ (mg/kg-day)} = DA_{event} \times SA \times EV \times EF \times ED \times 1/BW \times 1/AT$ $Inorganics: DA_{event} \text{ (mg/cm}^2\text{-event)} = K_p \times CW \times t_{event} \times CF1 \times CF2$ $Organics:$ $t_{event} < t^*: DA_{event} \text{ (mg/cm}^2\text{-event)} = 2 \times FA \times K_p \times CW \times (\sqrt{6 \times \tau \times t_{event}/\pi}) \times CF1 \times CF2$ $t_{event} > t^*: DA_{event} \text{ (mg/cm}^2\text{-event)} = FA \times K_p \times CW \times (t_{event}/(1+B) + 2 \times \tau \times ((1 + 3B + 3B^2)/(1+B)^2)) \times CF1 \times CF2$
		DAevent	Dermally Absorbed Dose per Event	Calculated	mg/cm ² -event	calculated			
FA	Fraction absorbed water	Chemical-specific	dimensionless	EPA, 2004					
K _p	Permeability Coefficient	Chemical-specific	cm/hr	EPA, 2004					
τ	Lag Time	Chemical-specific	hr/event	EPA, 2004					
t*	Time to Reach Steady-state	Chemical-specific	hours	EPA, 2004					
B	Ratio of Permeability of Stratum Corneum to Epidermis	Chemical-specific	dimensionless	EPA, 2004					
t _{event}	Event Time	0.71	hr/event	EPA, 2014					
SA	Skin Surface Area Available for Contact	20,900	cm ²	EPA, 2014					
EV	Event Frequency	1	events/day	EPA, 2004					
EF	Exposure Frequency	350	days/year	EPA, 2014					
ED	Exposure Duration	20	years	EPA, 2014					
BW	Body Weight	80	kg	EPA, 2014					
AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989					
AT-N	Averaging Time (Non-Cancer)	7,300	days	EPA, 2014					
CF1	Conversion Factor 1	0.001	mg/µg	--					
CF2	Conversion Factor 2	0.001	l/cm ³	--					
Dermal	Resident	Child	Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	$CDI \text{ (mg/kg-day)} = DA_{event} \times SA \times EV \times EF \times ED \times 1/BW \times 1/AT$ $Inorganics: DA_{event} \text{ (mg/cm}^2\text{-event)} = K_p \times CW \times t_{event} \times CF1 \times CF2$ $Organics:$ $t_{event} < t^*: DA_{event} \text{ (mg/cm}^2\text{-event)} = 2 \times FA \times K_p \times CW \times (\sqrt{6 \times \tau \times t_{event}/\pi}) \times CF1 \times CF2$ $t_{event} > t^*: DA_{event} \text{ (mg/cm}^2\text{-event)} = FA \times K_p \times CW \times (t_{event}/(1+B) + 2 \times \tau \times ((1 + 3B + 3B^2)/(1+B)^2)) \times CF1 \times CF2$
		DAevent	Dermally Absorbed Dose per Event	Calculated	mg/cm ² -event	calculated			
FA	Fraction absorbed water	Chemical-specific	dimensionless	EPA, 2004					
K _p	Permeability Coefficient	Chemical-specific	cm/hr	EPA, 2004					
τ	Lag Time	Chemical-specific	hr/event	EPA, 2004					
t*	Time to Reach Steady-state	Chemical-specific	hours	EPA, 2004					
B	Ratio of Permeability of Stratum Corneum to Epidermis	Chemical-specific	dimensionless	EPA, 2004					
t _{event}	Event Time	0.54	hr/event	EPA, 2014					
SA	Skin Surface Area Available for Contact	6,378	cm ²	EPA, 2014					
EV	Event Frequency	1	events/day	EPA, 2004					
EF	Exposure Frequency	350	days/year	EPA, 2014					
ED	Exposure Duration	6	years	EPA, 2014					
BW	Body Weight	15	kg	EPA, 2014					
AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989					
AT-N	Averaging Time (Non-Cancer)	2,190	days	EPA, 1989					
CF1	Conversion Factor 1	0.001	mg/µg	--					
CF2	Conversion Factor 2	0.001	l/cm ³	--					

TABLE 4.1.RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
Cheatham Annex AOC 7/Expanded Site Investigation Report
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future
Medium: Groundwater
Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/Reference	Intake Equation/Model Name
Dermal (cont'd)	Resident	Child/Adult	Tap Water	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	$CDI (mg/kg\text{-}day) = DA\text{-}Adj \times EF \times 1/AT$ $DA\text{-}Adj = (DAevent\text{-}A \times SA\text{-}A \times ED\text{-}A \times 1/BW\text{-}A) + (DAevent\text{-}C \times SA\text{-}C \times ED\text{-}C \times 1/BW\text{-}C)$ Inorganics: $DAevent (mg/cm^2\text{-}event) = Kp \times CW \times t_{event} \times CF1 \times CF2$ Organics : $t_{event} < t^*$: $DAevent (mg/cm^2\text{-}event) = 2 \times FA \times Kp \times CW \times (\sqrt{(6 \times \tau \times t_{event})/\pi}) \times CF1 \times CF2$ $t_{event} > t^*$: $DAevent (mg/cm^2\text{-}event) = FA \times Kp \times CW \times (t_{event}/(1+B) + 2 \times \tau \times ((1 + 3B + 3B^2)/(1+B)^2)) \times CF1 \times CF2$
				DAevent-A	Dermally Absorbed Dose per Event, Adult	Calculated	mg/cm ² -event	calculated	
				DAevent-C	Dermally Absorbed Dose per Event, Child	Calculated	mg/cm ² -event	calculated	
				DA-Adj	Dermally Absorbed Dose, Age-adjusted	Calculated	mg-year/event-kg	calculated	
				FA	Fraction absorbed water	Chemical-specific	dimensionless	EPA, 2004	
				K _p	Permeability Coefficient	Chemical-specific	cm/hr	EPA, 2004	
				τ	Lag Time	Chemical-specific	hr/event	EPA, 2004	
				t*	Time to Reach Steady-state	Chemical-specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	Chemical-specific	dimensionless	EPA, 2004	
				t _{event} -A	Event Time, Adult	0.71	hr/event	EPA, 2014	
				t _{event} -C	Event Time, Child	0.54	hr/event	EPA, 2014	
				SA-A	Skin Surface Area, Adult	20,900	cm ²	EPA, 2014	
				SA-C	Skin Surface Area, Child	6,378	cm ²	EPA, 2014	
				EV	Event Frequency	1	events/day	EPA, 2004	
				EF	Exposure Frequency	350	days/year	EPA, 2014	
				ED-A	Exposure Duration, Adult	20	years	EPA, 2014	
				ED-C	Exposure Duration, Child	6	years	EPA, 2014	
				BW-A	Body Weight, Adult	80	kg	EPA, 2014	
				BW-C	Body Weight, Child	15	kg	EPA, 2014	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				CF1	Conversion Factor 1	0.001	mg/µg	--	
CF2	Conversion Factor 2	0.001	l/cm ³	--					
	Construction Worker	Adult	Water in Excavation Trench	CW	Chemical Concentration in Water	See Table 3.1	µg/l	See Table 3.1	$CDI (mg/kg\text{-}day) = DAevent \times SA \times EV \times EF \times ED \times 1/BW \times 1/AT$ Inorganics: $DAevent (mg/cm^2\text{-}event) = Kp \times CW \times t_{event} \times CF2 \times CF3$ Organics : $t_{event} < t^*$: $DAevent (mg/cm^2\text{-}event) = 2 \times FA \times Kp \times CW \times (\sqrt{(6 \times \tau \times t_{event})/\pi}) \times CF2 \times CF3$ $t_{event} > t^*$: $DAevent (mg/cm^2\text{-}event) = FA \times Kp \times CW \times (t_{event}/(1+B) + 2 \times \tau \times ((1 + 3B + 3B^2)/(1+B)^2)) \times CF2 \times CF3$
				DAevent	Dermally Absorbed Dose per Event	calculated	mg/cm ² -event	calculated	
				FA	Fraction absorbed water	chemical specific	dimensionless	EPA, 2004	
				K _p	Permeability Coefficient	chemical specific	cm/hr	EPA, 2004	
				τ	Lag Time	chemical specific	hr/event	EPA, 2004	
				t*	Time to Reach Steady-state	chemical specific	hours	EPA, 2004	
				B	Ratio of Permeability of Stratum Corneum to Epidermis	chemical specific	dimensionless	EPA, 2004	
				t _{event}	Event Time	8	hr/day	(2)	
				SA	Skin Surface Area Available for Contact	6,032	cm ²	EPA, 2014 (3)	
				EV	Event Frequency	1	events/day	EPA, 2004	
				EF	Exposure Frequency	125	days/year	VDEQ, 2003	
				ED	Exposure Duration	1	years	EPA, 1991	
				BW	Body Weight	80	kg	EPA, 2014	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA, 1989	
				AT-N	Averaging Time (Non-Cancer)	365	days	EPA, 1989	
				CF2	Conversion Factor 2	0.001	mg/µg	--	
				CF3	Conversion Factor 3	0.001	l/cm ³	--	

TABLE 4.1.RME
VALUES USED FOR DAILY INTAKE CALCULATIONS
REASONABLE MAXIMUM EXPOSURE
Cheatham Annex AOC 7/Expanded Site Investigation Report
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Scenario Timeframe: Future Medium: Groundwater Exposure Medium: Groundwater

Exposure Route	Receptor Population	Receptor Age	Exposure Point	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
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- (1) Based on EPA 1991 using 1/2 of residential water ingestion rate.
- (2) Professional judgment based on construction activities that would occur 8 hrs per day for the RME.
- (3) Surface area for adult resident exposed to soil from EPA, 2014, and includes weighted average of mean values for head, hands, forearms, lower legs, and feet .

Sources:

EPA, 1989: Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual, Part A. OERR. EPA/540/1-89/002.
EPA, 1991: Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual - Supplemental Guidance, Standard Default Exposure Factors. Interim Final. OSWER Directive 9285.6-03.
EPA, 2004 . Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment (Final). EPA/540/R/99/005. July 2004.
EPA, 2014: Human Health Evaluation Manual, Supplemental Guidance: Update of Standard Default Exposure Factors, OSWER Directive 9200.1-120, February 6, 2014.
VADEQ, 2013 . Virginia Voluntary Remediation Program Risk Assessment Guidance, May 2013.
<http://www.deq.virginia.gov/Programs/LandProtectionRevitalization/RemediationProgram/VoluntaryRemediationProgram/VRPRiskAssessmentGuidance/Guidance.aspx>

TABLE 5.1
 NON-CANCER TOXICITY DATA -- ORAL/DERMAL
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Chronic/ Subchronic	Oral RfD Value	Oral RfD Units	Oral to Dermal Adjustment Factor (1)	Adjusted Dermal RfD (2)	Units	Primary Target Organ	Combined Uncertainty/Modifying Factors	Sources of RfD: Target Organ	Dates of RfD: Target Organ (MM/DD/YY)
Arsenic	Chronic	3.0E-04	mg/kg-day	95%	3.0E-04	mg/kg-day	Skin, Vascular	3/1	IRIS	4/22/2014
	Subchronic	3.0E-04	mg/kg-day	95%	3.0E-04	mg/kg-day	Skin, Vascular	3	HEAST	7/1/1997
Chromium (hexavalent)	Chronic	3.0E-03	mg/kg-day	2.5%	7.5E-05	mg/kg-day	NOE	300/1	IRIS	4/22/2014
	Subchronic	5.0E-03	mg/kg-day	2.5%	1.3E-04	mg/kg-day	Blood	100	ATSDR	9/1/2008
Manganese (non-diet)	Chronic	2.4E-02	mg/kg-day	4%	9.6E-04	mg/kg-day	CNS	1/1	IRIS	4/22/2014
	Subchronic	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thallium	Chronic	1.0E-05	mg/kg-day	100%	1.0E-05	mg/kg-day	Hair	3000	PPRTV	10/8/2010
	Subchronic	4.0E-05	mg/kg-day	100%	4.0E-05	mg/kg-day	Hair	1000	PPRTV	10/8/2010

Notes:

- (1) Source: Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final Section 4.2 and Exhibit 4-1. USEPA recommends that the oral RfD should not be adjusted to estimate the absorbed dose for compounds when the absorption efficiency is greater than 50%. Constituents that do not have oral to dermal adjustment factors reported on this table were assumed to have an oral absorption efficiency of 100%.
- (2) Adjusted based on RAGS Part E. (dermal RfD = Oral RfD x oral to dermal adjustment factor)

- Definitions: CNS = Central Nervous System
 HEAST = Health Effects Assessment Summary Tables
 IRIS = Integrated Risk Information System
 N/A = Not Available
 NOE = No Observed Effects
 PPRTV = Provisional Peer-Reviewed Toxicity Value
 ATSDR = Agency for Toxic Substances and Disease Registry

TABLE 6.1
 CANCER TOXICITY DATA -- ORAL/DERMAL
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Oral Cancer Slope Factor	Oral to Dermal Adjustment Factor (1)	Adjusted Dermal Cancer Slope Factor (2)	Units	EPA Carcinogen Group	Source	Date (MM/DD/YY)
Arsenic	1.5E+00	95%	1.5E+00	(mg/kg-day) ⁻¹	A	IRIS	4/22/2014
Chromium (hexavalent) (3)	5.0E-01	2.5%	2.0E+01	(mg/kg-day) ⁻¹	D	NJ DEP	4/8/2009
Manganese	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Thallium	N/A	N/A	N/A	N/A	N/A	N/A	N/A

(1) Source: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment) Final. Section 4.2 and Exhibit 4-1. USEPA recommends that the oral slope factor should not be adjusted to estimate the absorbed dose for compounds when the absorption efficiency is greater than 50%. Constituents that do not have oral to dermal adjustment factors reported on this table were assumed to have an oral absorption efficiency of 100%.

Definitions: IRIS = Integrated Risk Information System
 N/A = Not Available
 NJ DEP = New Jersey Department of Environmental Protection

(2) Adjusted based on RAGS Part E. (dermal CSF = Oral CSF / oral to dermal adjustment factor)

(3) This chemical operates with a mutagenic mode of action.

Chemical-specific data are not available; therefore, default age-dependant adjustment factors (ADAF) will be applied to the slope factor as applicable for each age range. The ADAFs are used with the intake calculations and exposure durations for the appropriate age ranges, as shown in Table 7.4.RME Supplement A.

AGE	Exposure Duration	AGE ADAF
0-<2	2	10
2-<6	4	3
6-<16	10	3
16-<26	10	1

Weight of Evidence definitions:

Group A chemicals (known human carcinogens) are agents for which there is sufficient evidence to support the causal association between exposure to the agents in humans and cancer.

Group D chemicals (not classifiable as to human carcinogenicity) are agents with inadequate human and animal evidence of carcinogenicity or for which no data are available.

TABLE 7.1.RME
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 REASONABLE MAXIMUM EXPOSURE
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Tap Water	Ingestion	Arsenic	5.3E-01	ug/L	2.0E-06	mg/kg/day	1.5E+00	1/mg/kg-day	3.1E-06	5.7E-06	mg/kg/day	3.0E-04	mg/kg/day	1.9E-02
				Chromium	1.7E+00	ug/L	6.6E-06	mg/kg/day	5.0E-01	1/mg/kg-day	3.3E-06	1.9E-05	mg/kg/day	3.0E-03	mg/kg/day	6.2E-03
				Manganese	3.5E+01	ug/L	1.3E-04	mg/kg/day	N/A		N/A	3.7E-04	mg/kg/day	2.4E-02	mg/kg/day	1.6E-02
				Thallium	3.3E-02	ug/L	1.3E-07	mg/kg/day	N/A		N/A	3.5E-07	mg/kg/day	1.0E-05	mg/kg/day	3.5E-02
			Exp. Route Total							6.4E-06					7.6E-02	
			Exposure Medium Total							6.4E-06					7.6E-02	
			Groundwater Total							6.4E-06					7.6E-02	
										Total of Receptor Risk	6.4E-06			Total of Receptor Hazard	7.6E-02	

Notes-
 N/A = Not applicable.

TABLE 7.2.RME
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 REASONABLE MAXIMUM EXPOSURE
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations					
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient	
							Value	Units	Value	Units		Value	Units	Value	Units		
Groundwater	Groundwater	Tap Water	Ingestion	Arsenic	5.3E-01	ug/L	N/A		N/A		N/A	1.6E-05	mg/kg/day	3.0E-04	mg/kg/day	5.3E-02	
				Chromium	1.7E+00	ug/L	N/A		N/A		N/A	5.2E-05	mg/kg/day	3.0E-03	mg/kg/day	1.7E-02	
				Manganese	3.5E+01	ug/L	N/A		N/A		N/A	1.0E-03	mg/kg/day	2.4E-02	mg/kg/day	4.4E-02	
				Thallium	3.3E-02	ug/L	N/A		N/A		N/A	9.9E-07	mg/kg/day	1.0E-05	mg/kg/day	9.9E-02	
				Exp. Route Total							N/A						2.1E-01
			Dermal	Arsenic	5.3E-01	ug/L	N/A		N/A		N/A	9.5E-08	mg/kg/day	3.0E-04	mg/kg/day	3.2E-04	
				Chromium	1.7E+00	ug/L	N/A		N/A		N/A	6.2E-07	mg/kg/day	7.5E-05	mg/kg/day	8.2E-03	
				Manganese	3.5E+01	ug/L	N/A		N/A		N/A	6.2E-06	mg/kg/day	9.6E-04	mg/kg/day	6.5E-03	
				Thallium	3.3E-02	ug/L	N/A		N/A		N/A	5.9E-09	mg/kg/day	1.0E-05	mg/kg/day	5.9E-04	
				Exp. Route Total							N/A						1.6E-02
	Exposure Medium Total							N/A						2.3E-01			
Groundwater Total															2.3E-01		
							Total of Receptor Risk		N/A	Total of Receptor Hazard					2.3E-01		

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

Table 7.2.RME Supplement A
 Calculation of DAevent for Groundwater
 Adult Resident
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Water Concentration (CW) (µg/L)	Permeability Coefficient (Kp) (cm/hr)	B (dimensionless)	Lag Time (τ_{event}) (hr)	t* (hr)	Fraction Absorbed Water (FA) (dimensionless)	Duration of Event (tevent) (hr)	DAevent (mg/cm ² -event)	Eq
Arsenic	5.3E-01	1.0E-03	N/A	N/A	N/A	N/A	0.71	3.8E-10	1
Chromium	1.7E+00	2.0E-03	N/A	N/A	N/A	N/A	0.71	2.5E-09	1
Manganese	3.5E+01	1.0E-03	N/A	N/A	N/A	N/A	0.71	2.5E-08	1
Thallium	3.3E-02	1.0E-03	N/A	N/A	N/A	N/A	0.71	2.3E-11	1

Notes:

N/A - Not applicable

Permeability constants from EPA 2004, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment - Final)*. EPA/540/R/99/005. The default value of 0.001 was assigned to inorganics not listed in this document.

B - Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless).

t* - Time to reach steady-state

Inorganics: DAevent (mg/cm²-event) =

$$Kp \times CW \times t_{event} \times 0.001 \text{ mg/ug} \times 0.001 \text{ l/cm}^3 \text{ (eq 1)}$$

TABLE 7.3.RME
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 REASONABLE MAXIMUM EXPOSURE
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations					
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient	
							Value	Units	Value	Units		Value	Units	Value	Units		
Groundwater	Groundwater	Tap Water	Ingestion	Arsenic	5.3E-01	ug/L	N/A		N/A		N/A	2.7E-05	mg/kg/day	3.0E-04	mg/kg/day	8.9E-02	
				Chromium	1.7E+00	ug/L	N/A		N/A		N/A	8.7E-05	mg/kg/day	3.0E-03	mg/kg/day	2.9E-02	
				Manganese	3.5E+01	ug/L	N/A		N/A		N/A	1.7E-03	mg/kg/day	2.4E-02	mg/kg/day	7.3E-02	
				Thallium	3.3E-02	ug/L	N/A		N/A		N/A	1.6E-06	mg/kg/day	1.0E-05	mg/kg/day	1.6E-01	
				Exp. Route Total							N/A						3.5E-01
			Dermal	Arsenic	5.3E-01	ug/L	N/A		N/A		N/A	1.2E-07	mg/kg/day	3.0E-04	mg/kg/day	3.9E-04	
				Chromium	1.7E+00	ug/L	N/A		N/A		N/A	7.7E-07	mg/kg/day	7.5E-05	mg/kg/day	1.0E-02	
				Manganese	3.5E+01	ug/L	N/A		N/A		N/A	7.7E-06	mg/kg/day	9.6E-04	mg/kg/day	8.0E-03	
				Thallium	3.3E-02	ug/L	N/A		N/A		N/A	7.3E-09	mg/kg/day	1.0E-05	mg/kg/day	7.3E-04	
				Exp. Route Total							N/A						1.9E-02
	Exposure Medium Total							N/A						3.7E-01			
Groundwater Total															3.7E-01		
							Total of Receptor Risk				N/A	Total of Receptor Hazard				3.7E-01	

Notes-
 DAevent for exposure to groundwater calculated on Table 7.3.RME Supplement A.
 N/A = Not applicable.

Table 7.3.RME Supplement A
 Calculation of DAevent for Groundwater
 Child Resident
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Water Concentration (CW) (µg/L)	Permeability Coefficient (Kp) (cm/hr)	B (dimensionless)	Lag Time (τ_{event}) (hr)	t* (hr)	Fraction Absorbed Water (FA) (dimensionless)	Duration of Event (tevent) (hr)	DAevent (mg/cm ² -event)	Eq
Arsenic	5.3E-01	1.0E-03	N/A	N/A	N/A	N/A	0.54	2.9E-10	1
Chromium	1.7E+00	2.0E-03	N/A	N/A	N/A	N/A	0.54	1.9E-09	1
Manganese	3.5E+01	1.0E-03	N/A	N/A	N/A	N/A	0.54	1.9E-08	1
Thallium	3.3E-02	1.0E-03	N/A	N/A	N/A	N/A	0.54	1.8E-11	1

Notes:

N/A - Not applicable

Permeability constants from EPA 2004, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment - Final)*. EPA/540/R/99/005. The default value of 0.001 was assigned to inorganics not listed in this document.

B - Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless).

t* - Time to reach steady-state

Inorganics: DAevent (mg/cm²-event) =

$$Kp \times CW \times t_{event} \times 0.001 \text{ mg/ug} \times 0.001 \text{ l/cm}^3 \text{ (eq 1)}$$

TABLE 7.4.RME
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 REASONABLE MAXIMUM EXPOSURE
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Tap Water	Ingestion	Arsenic	5.3E-01	ug/L	6.9E-06	mg/kg/day	1.5E+00	1/mg/kg-day	1.0E-05	N/A		N/A		N/A
				Chromium ¹	1.7E+00	ug/L			5.0E-01	1/mg/kg-day	3.5E-05	N/A		N/A		N/A
				Manganese	3.5E+01	ug/L	4.5E-04	mg/kg/day				N/A		N/A		N/A
				Thallium	3.3E-02	ug/L	4.2E-07	mg/kg/day				N/A		N/A		N/A
			Exp. Route Total								4.5E-05					N/A
			Dermal	Arsenic	5.3E-01	ug/L	3.7E-08	mg/kg/day	1.5E+00	1/mg/kg-day	5.6E-08	N/A		N/A		N/A
				Chromium ¹	1.7E+00	ug/L			2.0E+01	1/mg/kg-day	1.4E-05	N/A		N/A		N/A
				Manganese	3.5E+01	ug/L	2.4E-06	mg/kg/day				N/A		N/A		N/A
				Thallium	3.3E-02	ug/L	2.3E-09	mg/kg/day				N/A		N/A		N/A
			Exp. Route Total								1.4E-05					N/A
Exposure Medium Total									5.9E-05					N/A		
Groundwater Total									5.9E-05					N/A		
										Total of Receptor Risk	5.9E-05	Total of Receptor Hazard				N/A

Notes-

DAevent for exposure to groundwater calculated on Tables 7.2.RME Supplement A and 7.3.RME Supplement A.

¹ See Table 7.4.RME Supplement A for calculation of intake and cancer risk following MMOA method.

TABLE 7.4.RME Supplement A
 CALCULATION OF CHEMICAL CANCER RISKS FOR COPC WITH MUTAGENIC MODE OF ACTION
 REASONABLE MAXIMUM EXPOSURE
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations										
					Value	Units	Intake				Units	CSF/Unit Risk				Cancer Risk	
							Value					Units	Value				
							0-2 yrs	2-6 yrs	6-16 years	16-26 yrs			0-2 yrs (ADAF=10)	2-6 yrs (ADAF=3)	6-16 yrs (ADAF=3)		16-26 yrs (ADAF=1)
Groundwater	Groundwater	Tap Water	Ingestion	Chromium	1.7E+00	ug/L	2.5E-06	5.0E-06	7.4E-06	7.4E-06	mg/kg/day	5.0E+00	1.5E+00	1.5E+00	5.0E-01	1/(mg/kg-day)	3.5E-05
			Dermal	Chromium	1.7E+00	ug/L	2.2E-08	4.4E-08	8.8E-08	8.8E-08	mg/kg/day	2.0E+02	6.0E+01	6.0E+01	2.0E+01	1/(mg/kg-day)	1.4E-05

Cancer risk = (Intake₀₋₂ x CSF₀₋₂) + (Intake₂₋₆ x CSF₂₋₆) + (Intake₆₋₁₆ x CSF₆₋₁₆) + (Intake₁₆₋₂₆ x CSF₁₆₋₂₆)

TABLE 7.5.RME
 CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS
 REASONABLE MAXIMUM EXPOSURE
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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

Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	EPC		Cancer Risk Calculations					Non-Cancer Hazard Calculations				
					Value	Units	Intake/Exposure Concentration		CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Hazard Quotient
							Value	Units	Value	Units		Value	Units	Value	Units	
Groundwater	Groundwater	Water in Excavation Trench	Dermal	Arsenic	5.3E-01	ug/L	1.6E-09	mg/kg/day	1.5E+00	1/mg/kg-day	2.4E-09	1.1E-07	mg/kg/day	3.0E-04	mg/kg/day	3.7E-04
				Chromium	1.7E+00	ug/L	1.0E-08	mg/kg/day	2.0E+01	1/mg/kg-day	2.1E-07	7.2E-07	mg/kg/day	1.3E-04	mg/kg/day	5.5E-03
				Manganese	3.5E+01	ug/L	1.0E-07	mg/kg/day	N/A		N/A	7.2E-06	mg/kg/day	9.6E-04	mg/kg/day	7.5E-03
				Thallium	3.3E-02	ug/L	9.7E-11	mg/kg/day	N/A		N/A	6.8E-09	mg/kg/day	4.0E-05	mg/kg/day	1.7E-04
				Exp. Route Total								2.1E-07				
Exposure Medium Total										2.1E-07					1.4E-02	
Groundwater Total										2.1E-07					1.4E-02	
										Total of Receptor Risk	2.1E-07	Total of Receptor Hazard				1.4E-02

Notes-
 N/A = Not applicable.
 DAevent for exposure to groundwater calculated on Table 7.5.RME Supplement A.

Table 7.5.RME Supplement A
 Calculation of DAevent for Groundwater
 Adult Construction Worker
 Cheatham Annex AOC 7/Expanded Site Investigation Report
 Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

Chemical of Potential Concern	Water Concentration (CW) (µg/L)	Permeability Coefficient (Kp) (cm/hr)	B (dimensionless)	Lag Time (τ _{event}) (hr)	t* (hr)	Fraction Absorbed Water (FA) (dimensionless)	Duration of Event (tevent) (hr)	DAevent (mg/cm ² -event)	Eq
Arsenic	5.3E-01	1.0E-03	N/A	N/A	N/A	N/A	8	4.3E-09	1
Chromium	1.7E+00	2.0E-03	N/A	N/A	N/A	N/A	8	2.8E-08	1
Manganese	3.5E+01	1.0E-03	N/A	N/A	N/A	N/A	8	2.8E-07	1
Thallium	3.3E-02	1.0E-03	N/A	N/A	N/A	N/A	8	2.6E-10	1

Notes:

NA - Not applicable

Permeability constants from EPA 2004, *Risk Assessment Guidance for Superfund Volume I: Human Health Evaluation Manual (Part E, Supplemental Guidance for Dermal Risk Assessment - Final)*. EPA/540/R/99/005. The default value of 0.001 was assigned to inorganics not listed in this document.

B - Dimensionless ratio of the permeability coefficient of a compound through the stratum corneum relative to its permeability coefficient across the viable epidermis (dimensionless).

t* - Time to reach steady-state

Inorganics: DAevent (mg/cm²-event) =

$$Kp \times CW \times tevent \times 0.001 \text{ mg/ug} \times 0.001 \text{ l/cm}^3 \text{ (eq 1)}$$

TABLE 9.1.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
Cheatham Annex AOC 7/Expanded Site Investigation Report
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient					
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
Groundwater	Groundwater	Tap Water	Arsenic	3E-06	N/A	N/A	3E-06	Skin, Vascular	2E-02	N/A	N/A	2E-02	
			Chromium	3E-06	N/A	N/A	3E-06		NOE	6E-03	N/A	N/A	6E-03
			Manganese	N/A	N/A	N/A	N/A		CNS	2E-02	N/A	N/A	2E-02
			Thallium	N/A	N/A	N/A	N/A		Hair	4E-02	N/A	N/A	4E-02
		Chemical Total	6E-06	N/A	N/A	6E-06		8E-02	N/A	N/A	8E-02		
		Exposure Point Total				6E-06					8E-02		
		Exposure Medium Total				6E-06					8E-02		
Groundwater Total						6E-06					8E-02		
Receptor Total						6E-06				Receptor HI Total	8E-02		

Notes:
N/A = Not applicable
HI = Hazard Index
CNS = Central Nervous System
NOE = No Observed Effects

Total Skin HI Across All Media =	2E-02
Total Vascular HI Across All Media =	2E-02
Total Neurological HI Across All Media =	2E-02
Total Hair HI Across All Media =	4E-02

TABLE 9.2.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
Cheatham Annex AOC 7/Expanded Site Investigation Report
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Tap Water	Arsenic	N/A	N/A	N/A	N/A	Skin, Vascular	5E-02	N/A	3E-04	5E-02
			Chromium	N/A	N/A	N/A	N/A	NOE	2E-02	N/A	8E-03	3E-02
			Manganese	N/A	N/A	N/A	N/A	CNS	4E-02	N/A	6E-03	5E-02
			Thallium	N/A	N/A	N/A	N/A	Hair	1E-01	N/A	6E-04	1E-01
			Chemical Total	N/A	N/A	N/A	N/A		2E-01	N/A	2E-02	2E-01
		Exposure Point Total				N/A					2E-01	
	Exposure Medium Total						N/A				2E-01	
Groundwater Total							N/A				2E-01	
Receptor Total							N/A			Receptor HI Total	2E-01	

Notes:
N/A = Not applicable
HI = Hazard Index
CNS = Central Nervous System
NOE = No Observed Effects

Total Skin HI Across All Media =	5E-02
Total Vascular HI Across All Media =	5E-02
Total Neurological HI Across All Media =	5E-02
Total Hair HI Across All Media =	1E-01

TABLE 9.3.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
Cheatham Annex AOC 7/Expanded Site Investigation Report
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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

Chromium

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient								
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total				
Groundwater	Groundwater	Tap Water	Arsenic	N/A	N/A	N/A	N/A	Skin, Vascular NOE CNS Hair	9E-02 3E-02 7E-02 2E-01	N/A N/A N/A N/A	4E-04 1E-02 8E-03 7E-04	9E-02 4E-02 8E-02 2E-01				
			Chromium	N/A	N/A	N/A	N/A									
			Manganese	N/A	N/A	N/A	N/A									
			Thallium	N/A	N/A	N/A	N/A									
			Chemical Total	N/A	N/A	N/A	N/A						4E-01	N/A	2E-02	4E-01
			Exposure Point Total				N/A									4E-01
Exposure Medium Total						N/A				4E-01						
Groundwater Total							N/A				4E-01					
Receptor Total							N/A	Receptor HI Total			4E-01					

Notes:

N/A = Not applicable
HI = Hazard Index
CNS = Central Nervous System
NOE = No Observed Effects

Total Skin HI Across All Media =	9E-02
Total Vascular HI Across All Media =	9E-02
Total Neurological HI Across All Media =	8E-02
Total Hair HI Across All Media =	2E-01

TABLE 9.4.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
Cheatham Annex AOC 7/Expanded Site Investigation Report
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
Groundwater	Groundwater	Tap Water	Arsenic	1E-05	N/A	6E-08	1E-05		N/A	N/A	N/A	N/A
			Chromium	3E-05	N/A	1E-05	5E-05		N/A	N/A	N/A	N/A
			Manganese	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A
			Thallium	N/A	N/A	N/A	N/A		N/A	N/A	N/A	N/A
		Chemical Total	5E-05	N/A	1E-05	6E-05	N/A	N/A	N/A	N/A		
		Exposure Point Total				6E-05					N/A	
		Exposure Medium Total				6E-05					N/A	
Groundwater Total						6E-05					N/A	
Receptor Total						6E-05				Receptor HI Total	N/A	

Notes:
N/A = Not applicable
HI = Hazard Index

TABLE 9.5.RME
SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs
REASONABLE MAXIMUM EXPOSURE
Cheatham Annex AOC 7/Expanded Site Investigation Report
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia

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

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk				Non-Carcinogenic Hazard Quotient					
				Ingestion	Inhalation	Dermal	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
Groundwater	Groundwater	Water in Excavation Trench	Arsenic	N/A	N/A	2E-09	2E-09	Skin, Vascular	N/A	N/A	4E-04	4E-04	
			Chromium	N/A	N/A	2E-07	2E-07		Blood	N/A	N/A	6E-03	6E-03
			Manganese	N/A	N/A	N/A	N/A		CNS	N/A	N/A	8E-03	8E-03
			Thallium	N/A	N/A	N/A	N/A		Hair	N/A	N/A	2E-04	2E-04
			Chemical Total	N/A	N/A	2E-07	2E-07		N/A	N/A	1E-02	1E-02	
		Exposure Point Total				2E-07					1E-02		
		Exposure Medium Total				2E-07					1E-02		
Groundwater Total						2E-07					1E-02		
Receptor Total						2E-07					Receptor HI Total = 1E-02		

Notes:
N/A = Not applicable
HI = Hazard Index
CNS = Central Nervous System

Total Skin HI Across All Media =	4E-04
Total Vascular HI Across All Media =	4E-04
Total Blood HI Across All Media =	6E-03
Total Neurological HI Across All Media =	8E-03
Total Hair HI Across All Media =	2E-04

Regulatory Acceptance



COMMONWEALTH of VIRGINIA

DEPARTMENT OF ENVIRONMENTAL QUALITY

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Molly Joseph Ward
Secretary of Natural Resources

David K. Paylor
Director

(804) 698-4000
1-800-592-5482

November 20, 2014

Mr. Scott Park
NAVFAC MIDLANT, Building N-26
Hampton Roads Restoration Product Line, Code OPHREV4
9742 Maryland Avenue
Norfolk, VA 23511-3095

**RE: Area of Concern 7 Expanded Site Inspection Report
Naval Weapons Station Yorktown Cheatham Annex, Williamsburg, Virginia**

Dear Mr. Park:

The Virginia Department of Environmental Quality (DEQ) has received the *Draft Area of Concern 7 Expanded Site Inspection Report* (SI Report) for Cheatham Annex (CAX). The SI Report, prepared by CH2M HILL, was received by the DEQ on September 15, 2014.

Thank you for providing the DEQ's Office of Remediation Programs the opportunity to review the above-referenced SI Report. Subsequent to DEQ's internal review and per discussions conducted during CAX Partnering Meetings, this office has no comments, and recommends preparation of the *Final Area of Concern 7 Expanded Site Inspection Report*.

Please contact me at (804) 698-4125 or wade.smith@deq.virginia.gov with any additional questions.

Sincerely,

A handwritten signature in blue ink, appearing to read 'Wade M. Smith'.

Wade M. Smith
Remediation Project Manager
Office of Remediation Programs

cc: Jerry Hoover, EPA



**UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION III
1650 Arch Street
Philadelphia, Pennsylvania 19103-2029**

November 10, 2014

Mr. Scott Park
NAVFAC MIDLANT, Building N-26, Room 3208
Attention: Code OPHE3, Mr. Scott Park
9742 Maryland Avenue
Norfolk, VA 23511-3095

Subject: Area of Concern 7 Expanded Site Inspection Report, Naval Weapons Station Yorktown
Cheatham Annex, Williamsburg, Virginia, September 2014

Mr. Park:

Thank you for the opportunity to review the subject document. EPA has no comments on the document. Please submit a final copy of the subject document for our records. If you have any questions, please contact me at 215-814-2077.

Sincerely,

A handwritten signature in blue ink that reads "Gerald F. Hoover". The signature is written in a cursive style with a large, sweeping initial "G".

Gerald F. Hoover, RPM
NPL/BRAC Federal Facilities Branch

cc: Wade Smith, VDEQ