THIRD FIVE-YEAR REVIEW REPORT FOR BUCKINGHAM COUNTY LANDFILL SUPERFUND SITE BUCKINGHAM COUNTY, VIRGINIA

ORIGINAL

August 2013

Prepared by

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8/26/2013

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LIST OF ABBREVIATIONS

ARARs	Applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COCs	Contaminant of Concern
EPA	Environmental Protection Agency
FS	Feasibility Study
GPRA	Government Performance and Results Act
HWDA	Hazardous Waste Disposal Area
HDPE	High Density Polyethylene
ISVE	In-Situ Soil Vapor Extraction
LTGWMP	Long-Term Groundwater Monitoring Program
MCL	Maximum Contaminant Level
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPL	National Priorities List
O&M	Operation and Maintenance
PCOR	Preliminary Close-Out Report
POC	point-of-compliance
RA	Remedial Action
RAO	Remedial Action Objective
RBC	Risk-Based Concentration
RD	Remedial Design
RI	Remedial Investigation
ROD	Record of Decision
RP	Responsible Party
RPM	Remedial Project Manager
SI	Site Investigation
SVOC	Semivolatile Organic Compound
SWRAU	Site-wide Ready for Anticipated Use
TS	Treatability Study
UAO	Unilateral Administrative Order
VDEQ	Virginia Department of Environmental Quality
VOC	Volatile Organic Compound
VSBH	Virginia State Board of Health

Executive Summary

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The remedy for the Buckingham County Landfill Superfund Site (the Site) in Dillwyn, Buckingham County, Virginia consists of re-grading and capping of a landfill, institutional controls, and quarterly groundwater monitoring. The quarterly groundwater monitoring involves collection of samples from the nearest down-gradient residential wells and monitoring wells surrounding the landfill. The monitoring wells surrounding the landfill are located no farther than 150 feet from the edge of the landfill cap and were designated the "point-of-compliance" (POC) wells for purposes of determining if a contingency remedy was needed by determining if contamination has migrated beyond the landfill perimeter at unacceptable concentrations.

The trigger for the first Five-Year Review (FYR) in 2003 was the start of the implementation (also referred to as construction) of the Long-Term Groundwater Monitoring Program (LTGWMP) in April 1998. The second FYR was completed in 2008 and this third FYR is a follow-up review to the Site actions conducted since 2008.

This third FYR finds that the remedy was constructed in accordance with the requirements of the Record of Decision (ROD), dated September 30, 1994. The quarterly groundwater monitoring is also in accordance with the ROD. However, groundwater sampling has highlighted problems with the remedy. None of the contingency remedies (off-site incineration, in-situ soil vapor extraction, or groundwater pump and treatment) identified in the ROD have been implemented. Contingency remedies were identified in the ROD to address the source area and groundwater contamination in the event contamination was detected at the POC wells at levels exceeding Maximum Contamination Levels (MCLs) or Risk-Based Concentrations (RBCs) for site related contaminants identified in the ROD. The responsible parties (RPs) are evaluating other technologies as an alternative to the ROD contingency remedies. Currently, additional groundwater delineation work is being performed as part of a Focused Feasibility Study (FFS) and a field treatability study (TS) is being developed to evaluate in-situ chemical oxidation for use in addressing the source area and groundwater contamination.

The remedy is not functioning as intended nor as called for in the ROD. However, the remedy is currently protective of human health and the environment in the short term. Several Site-related contaminants have migrated beyond POC wells where they have been detected in groundwater samples at levels exceeding screening levels (MCLs or health-based contaminant levels) identified in the ROD. Site-related contaminants including 1,4-dioxane, chlorinated volatile organic compounds (VOCs) and metals, have also migrated into Cooper Creek, which is a stream located approximately 1,200 feet from the landfill. Groundwater to surface water discharge in the stream has been confirmed. Two additional semi-volatile organic compound (SVOC) contaminants which are not currently considered Site-related contaminants, bis(2-ethylhexyl) phthalate and diethyl phthalate, were also detected in the stream. Groundwater and surface water sample analytical results indicate the contamination is not fully delineated.

Based upon available data, no human or environmental receptors are known to be exposed to Site-related contaminants above screening levels (MCLs or health-based contaminant levels) at this time; however, contamination has not been fully delineated. As a result, the remedy is not protective in the long term. Sample results for the three routinely-sampled residential wells that are a part of the LTGWMP have consistently detected VOCs that are Site related.

In order for the remedy to be protective in the long term, an effective contingency remedy as identified in the ROD must be implemented. Based on information gathered since the 2008 FYR, the groundwater pump and treatment portion of the contingency remedy identified in the ROD will address both the contamination and the continued migration of the plume. Source control measures should be further evaluated to determine the most appropriate technology for addressing the source contamination to eliminate further contamination of groundwater and surface water.

GPRA Measure Review

As part of this FYR the Government Performance and Results Act (GPRA) measures have also been reviewed. The GPRA Measures and their status are provided as follows:

Environmental Indicators

Human Health: Current Human Exposure Controlled (HEUC)
Groundwater Migration: Contaminated Ground Water Migration Not Under Control (GMNC)

Site-Wide RAU: The Site is not Site-Wide Ready for Anticipated Use (SWRAU) but is expected to achieve SWRAU by 09/30/2030.

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Five-Year Review Summary Form

SITE IDENTIFICATION

Site Name: Buckingham County Landfill

EPA ID: VAD089027973

Region: 3	**State:** VA	**City/County:** Dillwyn/Buckingham County

SITE STATUS

NPL Status: Final

Multiple OUs? No	**Has the site achieved construction completion?** Yes

REVIEW STATUS

Lead agency: EPA

Author name (Federal or State Project Manager): Christian Matta, EPA Remedial Project Manager (assistance provided by CDM Smith)

Author affiliation: U.S. EPA – Region 3 (assistance provided by CDM Smith)

Review period: September 2012 – June 2013

Date of site inspection: 02/28/2013

Type of review: Statutory

Review number: 3

Triggering action date: September 29, 2008

Due date *(five years after triggering action date)*: September 29, 2013

Five-Year Review Summary Form (continued)

Issues and Recommendations Identified in the Five-Year Review:

OU(s): 01	**Issue Category: Remedy Performance**
	Issue: Groundwater contamination detected in Cooper Creek surface water.
	Recommendation: Determine appropriate regulations and relevant screening levels (MCLs or health-based contaminant levels) to assess impacts of contaminated groundwater discharge to surface water bodies at the Site. A second surface water body located in close proximity to the southern Site boundary should be sampled to determine if COCs are present. Conduct additional delineation work in Cooper Creek to assess contaminant concentration trends over time and during low-flow stream conditions as well as stream flow and surface water to groundwater interaction. Develop a plan to mitigate discharge of COCs to surface water if contaminant levels exceed appropriate threshold.

Affect Current Protectiveness	Affect Future Protectiveness	Implementing Party	Oversight Party	Milestone Date
No	Yes	RP	EPA	2015

Issues and Recommendations Identified in the Five-Year Review:

OU(s): 01	**Issue Category: Remedy Performance**
	Issue: Groundwater contamination detected beyond the line of compliance wells.
	Recommendation: Delineate nature and extent of contamination and assess risk. Develop and implement a remedial strategy to eliminate or reduce the risk to an acceptable level. Source area needs additional delineation through additional data collection. A remedy needs to be developed which includes source control, addresses groundwater contamination and surface water contamination, as well as achieves hydraulic control of the groundwater plume to stop migration. Use available data to revise the conceptual site model (CSM) and assess the threat to human health and the environment. Use the CSM and assessment to revise remedial action objectives (RAOs) and develop a Site-wide remediation strategy that will address the RAOs. Utilize animal shelter groundwater well to collect samples to develop background level information. Evaluate background metals concentrations to assess Site geochemistry to determine the origin and fate of elevated metals concentrations. RPs should submit a work plan and schedule for design of pump and treat system contingency remedy called for in the ROD.

Affect Current Protectiveness	Affect Future Protectiveness	Implementing Party	Oversight Party	Milestone Date
No	Yes	RP	EPA	2015

Five-Year Review Summary Form (continued)

Issues and Recommendations Identified in the Five-Year Review:

OU(s): 01	**Issue Category: Remedy Performance**
	Issue: SVOCs detected in Cooper Creek surface water.
	Recommendation: Collect groundwater samples from MW-2, MW-27 and MW-31 clusters and analyze for SVOCs.

Affect Current Protectiveness	Affect Future Protectiveness	Implementing Party	Oversight Party	Milestone Date
No	Yes	RP	EPA	Fall 2013

Issues and Recommendations Identified in the Five-Year Review:

OU(s): 01	**Issue Category: Remedy Performance**
	Issue: Possible Site COCs detected in the three routinely sampled residential wells.
	Recommendation: Install monitoring wells in area between site and residential wells to determine if plume is migrating in direction of residential wells.

Affect Current Protectiveness	Affect Future Protectiveness	Implementing Party	Oversight Party	Milestone Date
No	Yes	RP	EPA	2015

Issues and Recommendations Identified in the Five-Year Review:

OU(s): 01	**Issue Category: Remedy Performance**
	Issue: Groundwater contamination above screening levels (MCLs or health-based contaminant levels) has been detected at several point-of-compliance wells on the west, northwest, and south side of the Site.
	Recommendation: Assess VOC concentration trends in MW-5B, MW-22B, and MW-23B to determine placement of bounding wells that are needed to the west and northwest of these wells to complete plume delineation in these areas. Assess metals trends in MW-12, MW-15, MW-23BL to determine placement of additional bounding wells needed outside of these well locations to complete plume delineation in this area. Continue to monitor metals concentrations in MW-7SU to aide in determining location of bounding wells needed south of the Site to complete plume delineation in this area.

Affect Current Protectiveness	Affect Future Protectiveness	Implementing Party	Oversight Party	Milestone Date
No	Yes	RP	EPA	2015

Five-Year Review Summary Form (continued)

Issues and Recommendations Identified in the Five-Year Review:

OU(s): 01	**Issue Category: Remedy Performance**			
	Issue: RCRA cap and security fence maintenance needs to be improved.			
	Recommendation: Perform regularly scheduled inspections, maintenance and corrective steps to address eroding areas, missing gate lock, damaged gas vent screens, clogged check dams, and ponding water on cap.			
Affect Current Protectiveness	**Affect Future Protectiveness**	**Implementing Party**	**Oversight Party**	**Milestone Date**
Yes	Yes	RP	EPA	Fall 2013

Sitewide Protectiveness Statement

Protectiveness Statement:

The remedy is protective in the short term. The landfill cap that is in place prevents exposure to the waste material. No human or environmental receptors are currently known to be exposed to Site-related contaminants above screening levels (MCLs or health-based contaminant levels). The remedy is not protective in the long term. The remedy is not functioning as intended nor as called for in the ROD. Contamination continues to migrate away from the capped landfill. Site-related contaminants such as 1,4-dioxane, chlorinated VOCs and metals, have migrated beyond POC wells where they have been detected in groundwater and surface water samples at levels exceeding screening levels (MCLs or health-based contaminant levels) identified in the ROD. A groundwater to surface water discharge has been confirmed in Cooper Creek. Site-related contaminants have been detected in Cooper Creek and trees near the creek. In addition, two SVOCs, bis(2-ethylhexyl)phthalate and diethyl phthalate, were detected in the stream. SVOCs have not been previously sampled for in ground water and are therefore not known confirmed Site-related contaminants of concern (COCs).

In order for the remedy to be protective in the long term, the extent of groundwater contamination should be fully delineated and the groundwater pump and treatment contingency remedy should be implemented. Source control measures called for in the ROD contingency remedy, or an appropriate alternative should be implemented to abate further contamination of groundwater.

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Section 1
Introduction

The purpose of a FYR is to determine whether the remedy at a site is protective of human health and the environment. The methods, findings, and conclusions of reviews are documented in FYR reports. In addition, FYR reports identify issues found during the review, if any, and provide recommendations to address them.

The U.S. Environmental Protection Agency (EPA) is preparing this FYR report pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) § 121 and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). CERCLA §121states:

> *If the President selects a remedial action that results in any hazardous substances, pollutants, or contaminants remaining at the site, the President shall review such remedial action no less often than each five years after the initiation of such remedial action to assure that human health and the environment are being protected by the remedial action being implemented. In addition, if upon such review it is the judgment of the President that action is appropriate at such site in accordance with section [104] or [106], the President shall take or require such action. The President shall report to the Congress a list of facilities for which such review is required, the results of all such reviews, and any actions taken as a result of such reviews.*

The Agency interpreted this requirement further in the NCP; 40 CFR §300.430(f)(4)(ii) states:

> *If a remedial action is selected that results in hazardous substances, pollutants, or contaminants remaining at the site above levels that allow for unlimited use and unrestricted exposure, the lead agency shall review such action no less often than every five years after the initiation of the selected remedial action.*

A FYR is required due to the fact that hazardous substances, pollutants, or contaminants remain at the Site above levels that may allow for unlimited use and unrestricted exposure (UU/UE). Because contamination levels do not allow for UU/UE, institutional controls (ICs) designed to prevent exposure to contamination through deed and land use restrictions are required.

EPA Region 3 has conducted a FYR of the Remedial Action (RA) implemented at the Buckingham County Landfill in Dillwyn, Buckingham County, Virginia. This review was conducted by the EPA with support from the Virginia Department of Environmental Quality (VDEQ) and CDM Federal Programs Corporation (CDM Smith) in 2013. This is the third FYR for the Buckingham County Landfill. The triggering action for this statutory review is the completion of the Second FYR in September 2008.

Section 2
Site Chronology

Table 2-1 lists the chronology of events for the Buckingham County Landfill.

Table 2: Chronology of Site Events

Event	Date
Site began operating as an open dump disposing municipal solid waste	1962
Virginia State Board of Health (VSBH) issues Sanitary Landfill Permit	November 1972
Sanitary landfill permit modified to allow for disposal of 50 gallons per week of industrial furniture making waste	1977
Municipal solid waste operations ceased and solid waste portion of landfill covered and closed under supervision of VSBH	1979
VSBH approved increase in the quantity of "special" waste from 30,000 to 40,000 gallons per month	1979
Site owner applied for interim status	1980
EPA performed a Preliminary Assessment of the Site	June 1, 1980
Buckingham County purchased Site and began closure	April 1982
Hazardous waste portion of landfill closed	1983
Hazard Ranking system (HRS) package completed	May 1, 1983
EPA performed a Site Inspection	July 1, 1983
Site proposed to the National Priority List (NPL)	April 10, 1985
First removal assessment completed	September 29, 1989
Final NPL Listing	October 4, 1989
RI/FS Negotiations held with RPs	January 31, 1991
First Administrative Order on Consent issued to several RPs to conduct RI/FS	January 31, 1991
Second Removal Assessment completed	March 26, 1991
Third Removal Assessment completed	June 28, 1991

Event	Date
EPA completes Human Health Risk Assessment	January 15, 1993
EPA completes Ecological Risk Assessment	April 20, 1993
Responsible Parties (RPs) complete RI/FS	May 1993
EPA completed Proposed Plan	May 1993
Record Of Decision (ROD) signature	September 30, 1994
EPA issued first Unilateral Administrative Order (UAO) to Thomasville Furniture to implement selected remedy	September 29, 1995
EPA issued Consent Decree for de minimis settlement	December 13, 1995
RPs completed Remedial Design (RD)	July 2, 1997
RPs completed Additional Groundwater Study	October 15, 1997
EPA issued draft Consent Decree for purposes of negotiating performance of work by Buckingham County	March 24, 1998
RPs initiated Long-Term Groundwater Monitoring Program	September 1998
RPs completed Remedial Action (RA) construction	February 16, 1999
EPA suspended Consent Decree negotiations with Buckingham County due to lack of willingness of County to negotiate.	January 21, 2000
EPA issued UAO to Buckingham County for performance of work and implementation of Institutional Controls	March 20, 2000
CDM Smith prepared Hydrogeological Analysis Report for EPA	February 2003
First FYR report prepared by EPA	September 2003
RPs installed 6 additional monitoring wells (2 Lower Saprolite wells, 4 Bedrock wells). Geophysical logging of 1 Bedrock well performed	November –December 2005
RPs installed 4 additional shallow (Upper Saprolite) monitoring wells	June 2007
RPs sampled full round of monitoring wells in preparation for 2nd FYR	June 2008
Second FYR report prepared by EPA, including Hydrogeological Analysis Update	September 2008
CDM Smith sampled for E. coli at residential well	March 12, 2009

Event	Date
CDM Smith conducted comprehensive residential groundwater well sampling up-gradient and down-gradient of Site	April and June 2009
RPs completed SI, installing 8 additional monitoring wells (5 Upper Saprolite wells, and 3 Bedrock wells). Geophysical logging performed in 1 Bedrock well. Vertical profiling performed in1 Bedrock well and 1 Lower Saprolite well	September – November 2009
RPs submitted a Focused Feasibility Report	June 2010
RPs completed stream and tree core sampling	September 2011
RPs completed chemical oxidation bench test field sampling.	April 20, 2012
CDM Smith conducted additional stream measurements and collected samples in Cooper Creek	February – July, 2012
RPs installed and surveyed 6 additional monitoring wells (3 Upper Saprolite wells, 1 Lower Saprolite well, 2 Bedrock wells)	October – December, 2012
RPs sampled full round of monitoring wells including newly installed wells	November – December, 2012
Third FYR report prepared by EPA, including Hydrogeological Analysis Update	August 2013

Section 3
Background

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3.1 Physical Characteristics

The Site is located along County Road 640 in Dillwyn, Buckingham County, Virginia approximately 3.5 miles southeast of the town of Buckingham. The intersection of U.S. Route 60 and U.S. Route 15 is approximately 1.5 miles northeast of the Site (see **Figure 2-1, Appendix A**).

The Site consists of a 2-acre hazardous waste disposal area (HWDA) and surrounding areas where contaminated groundwater has migrated. A 7-acre domestic waste landfill is located directly south of the disposal area. Several companies, including Thomasville Furniture Industries, Inc., used the Site to dispose of various wastes between 1962 and 1983. As a result of these disposal activities, the Site ground water is contaminated with metals, VOCs and the SVOC 1,4-dioxane (see **Figure 1, Appendix C**).

The Site is located in the Appalachian Piedmont Physiographic Province. The surface topography of the area is gently rolling. Elevations in the Site area vary between approximately 540 and 660 feet above sea level. Elevations in the immediate vicinity of the landfill range approximately from 580 to 620 feet above sea level.

Surface water flows from Cooper Creek located approximately 1,200 feet north/northeast of the landfill, into Warner Branch, then into Horsepen Creek, and into the Slate River. No surface water reservoirs are close enough to be impacted by potential contamination from Cooper Creek. The closest reservoir to the Site is approximately 3.5 miles to the north and does not receive drainage from Cooper Creek.

3.2 Land and Resource Use

The area of Buckingham County totals 373,760 acres, of which 77,293 acres, or 21 percent, was comprised of farms in 2007. The general vicinity of the Site is primarily rural, with several residences near the Site property. The residences obtain their drinking water from wells. The population is classified as mostly rural-urban, and in the 2010 census totaled 17,146.

Agriculture is an integral part of Buckingham County's economy and cash farm income totaled $32.6 million in 2007. According to the 2007 Census of Agriculture, there were 411 farms in the county, averaging 188 acres in size.

Forestry is also important for the County economy. The production of saw timber, railroad ties, and other items provides an important source of income and employment. Other jobs are provided by the area's thriving mineral industry, as Buckingham County slate is well known throughout the country as superior roofing material.

The Site is fenced and is primarily grassy, surrounded by forest. There is an animal shelter near the entrance to the Site. The Horsepen Lake Wildlife Management Area is located approximately three quarters of a mile west of the Site.

3.3 History of Contamination

From 1962 to 1982, the Site was owned and operated by Joseph Love. The Site was initially used for disposal of municipal solid waste, and received a sanitary landfill permit by the Virginia State Board of Health (VSBH). In 1977, the sanitary landfill permit was modified to allow for disposal of 50 gallons per week of industrial furniture-making waste. In 1979, the VSBH approved an increase in the quantity of "special" waste to 30,000 to 40,000 gallons per month.

In general, operations in the HWDA involved the receipt of drummed liquid wastes which were poured into an evaporation trench. Solids that remained after evaporation were relocated to a disposal trench. Drums were crushed and buried in a barrel disposal trench. This trench was not completely closed until 1983, when the hazardous waste portion of the Site was closed.

COCs in groundwater are primarily VOCs and include benzene, 1,2-bromoethane, 1,2-dibromo-3-chloropropane, 1,1-dichloroethene, 1,2-dichloropropane, cis- and trans-1,3-dichloropropene, 1,1,2,2-tetrachloroethane, acetone, methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, 1,1,2-trichloroethane, and 1,2-dichloroethane. A new contaminant of concern, the semi-volatile compound 1,4-dioxane, was identified and added to EPA's list in 2006.

Although metals were not on the initial list of COCs, some metals (aluminum, chromium, cobalt, iron and manganese) have been detected consistently and continuously at significant levels. Manganese, a naturally occurring metal at the Site as evident in the results from the background well, is continuously detected at concentrations exceeding EPA's screening levels (EPA's established maximum contaminant levels (MCLs) or the health-based contaminant levels). It has been detected in and beyond the POC wells and as far-reaching as Cooper Creek surface water.

Contaminants were detected in 2011 in the nearby surface water, Cooper Creek; evidence of the migration of groundwater contamination beyond the wells farthest from the landfill and Site property boundaries. 1,4-dioxane was detected along with several VOCs including, 1,1,1-trichloroethene, 1,1-dichloroethane, 1-1-dichloroethene, cis-1,2-dichloroethene, tetrachloroethane and trichloroethene.

In 2012, two SVOCs, bis(2-ethylhexyl)phthalate and diethyl phthalate and high levels of manganese and iron were detected in the Cooper Creek surface water.

3.4 Initial Response

The solid waste landfill was covered and closed in 1979 under the supervision of the VSBH; however, the commercial waste disposal operations continued. In April 1982, the County purchased the Site and contracted Schnabel Engineering Associates to close the landfill.

The Site was proposed to the National Priorities List (NPL) on April 10, 1985 and finalized on the NPL on October 4, 1989. A number of EPA Site inspections were conducted between January 1983 and April 1989. On January 31, 1991, several potentially responsible parties and EPA entered into an Administrative Order on Consent to conduct an RI/FS at the Site. Field work for the RI was conducted March through July 1992. The RI was accepted on March 24, 1993. The FS was accepted on May 3, 1993. The remedial design was accepted on July 2, 1997, and remedial construction was completed on February 16, 1999. Quarterly groundwater monitoring was instituted in April of 1998 and is ongoing.

3.5 Basis for Taking Action

As noted above, COCs in groundwater are primarily VOCs and include benzene, 1,2-bromoethane, 1,2-dibromo-3-chloropropane, 1,1-dichloroethene, 1,2-dichloropropane, cis- and trans-1,3-dichloropropylene, 1,1,2,2-tetrachloroethane, acetone, methylene chloride, tetrachloroethene, trichloroethene, vinyl chloride, 1,1,2-trichlorothane, and 1,2-dichloroethane. The source of contamination is the waste buried and dumped at the landfill. Before implementation of the landfill remedy, the risks posed by the contaminated on-site soils, groundwater and ponded leachate through incidental inhalation, incidental ingestion, and dermal contact were $2.6x10^{-1}$, which is in excess of a 10^{-6} excess cancer risk for future use. The calculated Hazard Indices (HI) based on a combined exposure due to the groundwater ingestion and volatile inhalation exceeded 1.0 for all age groups (58 for adults, 112 for children), which is higher than EPA's guidance level for evaluating non-cancer risks.

Section 4
Remedial Actions

4.1 Remedy Selection

The ROD for OU1 was signed on September 30, 1994. The ROD specified the following components:

- Groundwater monitoring
- RCRA multi-layer cap
- Optional excavation and off-site incineration of landfill waste and contaminated soil
- Preparation of a focused FS for the barrel trench
- Optional groundwater pump and treat with air stripping
- Perimeter fencing
- Deed and Access Restrictions

The Remedial Action Objective (RAO) for the Site was to protect human health and the environment from potential future risks associated with VOC contamination in the groundwater.

The EPA structured the selected remedy for this Site to allow for two options.

Option 1 – Consists of monitoring the groundwater and capping the HWDA. If groundwater monitoring detects Site-related contaminants in the POC wells at levels exceeding an MCL or RBC, then appropriate portions of the cap are to be removed and source control measures and groundwater treatment using an air stripper are to be implemented.

Option 2 – Consists of monitoring the groundwater, implementing the source control measures, and then capping the HWDA. If groundwater monitoring detects migration of the plume, as defined below, treatment of the groundwater using an air stripper is to be implemented.

The source control measure identified in the ROD for the eastern disposal trench consists of In-Situ Soil Vapor Extraction (ISVE), if a TS demonstrates that the technology is appropriate. If a TS shows that ISVE will not work, then excavation and off-site incineration will be implemented as the source control measure. For the barrel trench, the ROD specifies that this area will be evaluated through an FS and an appropriate source control measure will be selected by EPA in a separate decision document. Currently, the RPs have initiated a TS and will be in the field in late 2013/2014.

4.2 Remedy Implementation

In September 1995, EPA issued a Unilateral Administrative Order (UAO), EPA Docket No. III-95-65-DC to the RPs after remedial negotiations were unsuccessful. The UAO required the RPs to implement the remedy described in the ROD. The Remedial Design was approved by EPA in July 1997.

The RA began in April 1998. The ROD was drafted to structure the selected remedy for this Site to allow the RPs to pick from one of two options. The RPs chose to implement Option 1 which called for groundwater monitoring and capping of the HWDA. The groundwater monitoring portion of the remedy consists of development of a groundwater monitoring system involving installation of monitoring wells around the landfill cap and located no farther than 150 feet from the edge of the cap. This ring of monitoring wells forms the POC wells. If groundwater monitoring detects a Site-related COC in a POC well at concentrations exceeding an MCL or an RBC if no MCL has been established for the detected COC, then a contingency remedy shall be triggered. The components of the constructed RA included the following:

- Landfill regrading to achieve the grades and slopes for the acceptance of the cover system and subgrade preparation which involved grading and placement of compacted general fill;
- Installed first geosynthetic element on the prepared landfill;
- Constructed gas vent layer on top of the landfill constructed of a geocomposite drainage material;
- Gas trench installed, which was designed to minimize the lateral flow of landfill gas outside the landfill limits below the surface. The design included a peripheral gas collection trench just beyond the lateral extent of the landfill;
- Gas vent collection piping system consisted of flexible 4-inch perforated High Density Polyethylene (HDPE) pipe along the top of the gas trench connected to seventeen 4-inch HDPE conveyance pipes which were connected to seventeen peripheral passive vents along the crest of the cap. On the surface of the cap, an additional fourteen passive gas vents were installed with four horizontal perforated flexible HDPE feeder pipes to collect the gas and vent it passively through vent pipes;
- A geocomposite clay liner was placed, followed by a linear low density polyethylene liner;
- A geocomposite drainage layer was placed, followed by an 18-inch thick protective layer of compacted general fill on the cover system with a 6-inch thick topsoil layer with grass to serve as the protection layer over the underlying system;
- Surface water diversion ditches installed;
- Perimeter fencing installed;
- Implementation of the Long-Term Groundwater Monitoring Program (LTGWMP); and
- Deed restriction implemented for the property within the points of compliance, prohibiting residential development or use of groundwater as a potable source.

The Site achieved construction completion status when the Preliminary Close-Out Report (PCOR) was signed on September 21, 1998.

4.3 System Operation/Operation and Maintenance

The RPs are conducting long-term monitoring and maintenance activities at the Site in accordance with the LTGWMP Work Plan, submitted in February 1998 by Parsons Engineering Science. The LTGWMP calls for quarterly groundwater monitoring of the closest down-gradient residential wells and the landfill monitoring wells. The long term monitoring is ongoing.

In addition to the groundwater monitoring, O&M activities are also being conducted. The primary activities include:

- Visual inspection of the cap with regard to vegetative cover, settlement, stability, and any need for corrective action. In addition, the cap is scheduled for periodic mowing;
- Inspection of the drainage swales for blockage, erosion and instability, and any need for corrective action; and
- Inspection of the condition of the groundwater monitoring wells.

Landfill O&M activities have been identified which need to be improved. There has been limited maintenance of the cap, and there are erosion concerns at various locations on the landfill, a missing monitoring well cap and lock, overgrown vegetation, and stagnant water and algae growth in the drainage swale. Further information is presented in Section 6.5.

Also, as established in the ROD, long-term sampling continues to be conducted on a quarterly basis at compliance wells and three private wells. This quarterly sampling has been conducted by the RPs, with split sample collection and analysis by EPA. Prior to installation of additional monitoring wells in 2005, no VOC screening levels (MCLs or health-based contaminant levels) had been exceeded in groundwater samples collected from the compliance wells. Since then, VOC concentrations continue to be detected above screening levels in several of the wells installed beyond the POC line, north of the MW-27 cluster. 1,4-dioxane has continuously been detected above its screening level in several POC wells (including the latest monitoring wells installed in 2009 and 2012) since it was first analyzed for in 2006.

In 2011, 1,4-dioxane and several chlorinated VOCs were detected in multiple surface water samples within Cooper Creek, which is located approximately 1,200 feet north of the landfill. In July 2012, two SVOCs that are not previously known as Site-related contaminants, bis(2-ethylhexyl)phthalate and diethyl phthalate, were detected in surface water samples collected from Cooper Creek surface water.

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Section 5
Progress Since Last Five Year Review

The Second FYR in 2008 determined that the functionality of the then-current compliance well network to monitor contaminant migration was uncertain and the location of the groundwater contaminant plume was unknown. Groundwater contamination above screening levels (MCLs or health-based contaminant levels) was detected beyond the line-of-compliance. This was based upon conclusions presented in the Hydrogeological Analysis Update on the Effectiveness of Long-Term Groundwater Monitoring (CDM Smith, 2008), which indicated that additional data were required to characterize and monitor groundwater contamination. The 2008 FYR recommended that a series of boreholes be installed into the bedrock in the northern portion of the Site. It also recommended collecting discrete groundwater samples and conducting borehole geophysics in the bedrock to obtain a better understanding of the Site structure. Previously, there were no wells installed in the weathered (broken) bedrock zone north of the Site. A set of new monitoring wells were recommended to be installed in three separate areas, where hydraulic gradients and/or contaminant trends suggested the presence of additional groundwater contamination, in the shallow zone along the southern portion of the Site and in the intermediate zones in the western portions of the Site. The report also recommended that the source area needed delineation and remedial actions needed to be developed, including source removal to address groundwater contamination.

The most immediate threat posed by groundwater contamination was determined to be the potential discharge to the surface water.

The 2008 FYR concluded that since the position of the plume was unknown and more data were required, it could not be stated that the Site conditions were protective of human health and the environment. Based upon available data, no human or environmental receptors were exposed to Site contaminants at that time. Due to uncertainty over the nature and extent of groundwater contamination, further investigation and remedial action were necessary to conclude that the Site remedy was protective of human health and the environment.

The 2008 FYR also concluded that the RCRA cap and security fence had not been adequately maintained and recommended that more regularly scheduled maintenance and mowing be instituted.

Since the Second FYR in 2008, the RPs have continued the LTGWMP with quarterly sampling events. The RPs prepared a Focused Feasibility Study (FFS) report to develop and evaluate remedial alternatives to address current Site conditions. The report was submitted to EPA in June 2010. In addition, two rounds of new monitoring well installations have taken place. Comprehensive residential groundwater well samplings, a tree core and stream sampling and a bench-scale TS have also been conducted.

The first round of new well installations occurred in the fall of 2009 during the FFS field work. The field work included drilling and geophysical logging of 23 direct-push borings in and around the capped landfill area, rock coring and packer testing at MW-27B, drilling and installation of three Bedrock and five Upper Saprolite wells (MW-7SU, MW-27B, MW-29B, MW-29SU, MW-30SU, MW-31B, MW-31SU and MW-32SU) and a comprehensive round of monitoring well sampling.

The eight new wells were drilled to depths of approximately 660 ft. The packer test groundwater sample results at MW-27B showed some contamination, although most concentrations were below the MCLs. However, 1,4-dioxane was detected with concentrations above the screening levels (MCLs or health-based contaminant levels). Results from the packer test were used to determine screen placement. All three bedrock wells were installed such that the screens intersected the physically weathered upper bedrock zone. During the 2009 field work, a down-hole camera evaluation was conducted on MW-5BL to determine if well construction problems were affecting the well. The casing appeared to be in good condition, though approximately five feet of silt was present in the bottom of the well.

The eight new wells would form the new "outer wells". The new wells were sampled as part of the LTGWMP Round 43 quarterly sampling event. Results from this sampling event revealed high levels of VOCs, 1,4-dioxane and metals with a groundwater contamination plume direction heading northeast of the Site towards the nearby stream. 1,4-Dioxane concentrations exceeded the EPA's screening levels (MCLs or health-based contaminant levels) at MW-27B, MW-29B, MW-31B, MW-31SU and MW-32SU.

On March 12, 2009, CDM Smith conducted an independent sampling event of one of the three routinely sampled residential wells as part of oversight of the RP's LTGWMP. In addition to the standard LTGWMP analytes, *E. coli* samples were collected. The EPA requested the sampling event be conducted due to RP sampling events yielding unusual results, including contamination in laboratory blanks. Water samples were collected from a tap within a sink in the residence. None of the VOC contaminants detected exceeded the screening levels (MCLs or health-based contaminant levels) based on the Safe Drinking Water Act (SDWA) Maximum Contaminant Levels (MCLs). Several metals which occur naturally in groundwater and soils were detected but none exceeded the respective screening levels (MCLs or health-based contaminant levels). There was a positive detection for Total Coliform Bacteria in the duplicate sample collected at this well. Both results (Total Coliform Bacteria and *E. coli*) exceeded the EPA's maximum contamination level goal (MCLG) indicating that there was possible contamination from the septic system or waste related to agricultural uses. It was noted that potable water pipes vital to the building were damaged in the winter and were replaced which could account for the possible microbial contamination in the well. The pipes were damaged in two sections: one section leading into the bathrooms located in the front section of the building; and another section leading into the kitchen located in the rear of the building next to the bathroom sink where the samples were taken. The crawl space that housed the pipes is located about 30 feet from the septic tank. However, the length of time for which the pipes were damaged is unknown.

EPA tasked CDM Smith with conducting an independent sampling event of residential wells nearest to the Site which are not normally sampled to provide groundwater data from locations upgradient of the Site and to ensure all the closest residential wells to the Site have been evaluated since the groundwater plume is not fully delineated. The closest down-gradient residential wells are routinely sampled as part of the LTGWMP. The sampling activities occurred from April 27 through April 29, 2009. Groundwater samples were collected from 14 off-site residential drinking water wells. Only one organic compound, chloroform, was detected in one of the residential well samples. The compound was detected at a concentration well below the EPA's screening level. Several metals, which occur naturally in groundwater and soils, were detected in another residential well at concentrations below the EPA's screening levels (MCLs or health-based contaminant levels). However arsenic, iron and lead were detected at concentrations above their respective screening levels (MCLs or health-based contaminant levels). A subsequent re-sampling event was conducted between June 16 and June 17, 2009. Eight residential wells were re-sampled during this event. Three VOCs, chloroform, chloromethane and dichlorodifluoromethane, were detected in three different wells at concentrations below the screening levels (MCLs or health-based contaminant levels). Several metals were also detected at concentrations below the EPA's screening levels (MCLs or health-based contaminant levels).

The RPs conducted a tree core and stream sampling event in September 2011 to guide additional monitoring well placement as part of the continued groundwater delineation work. Data evaluation for this sampling event was submitted in the RPs' *Stream and Tree Sampling Report* dated February 2012. Nine sediment and surface water samples and 20 tree core samples were collected and analyzed for selected VOCs and 1,4-dioxane along Cooper Creek. Tree core samples were collected from trees along the stream as well as trees where the transect line between MW-27 and MW-31 intersects Cooper Creek. The stream runs east-southeast to west-northwest and passes within 1,200 feet of the Site and is a groundwater discharge area down-gradient of the Site. Several COCs including concentrations of 1,4-dioxane above EPA's screening level, were detected in several surface water and tree core samples. The presence of groundwater contamination of chlorinated VOCs and 1,4-dioxane in Cooper Creek indicated that the stream is a groundwater discharge area and that groundwater contamination has migrated into the stream. A continuous source of contamination is believed to exist since it is uncommon for VOCs to persist in surface water.

As a result of groundwater contamination detected in the stream, EPA determined that further stream study was necessary to better characterize and determine the groundwater contamination effects on Cooper Creek. The stream study involved stream conductivity, stream gauging and surface water sampling for VOCs, 1,4-dioxane, and total metals analysis. Surface water samples had not been previously analyzed for total metals or SVOCs as they are not listed as COCs. Only two locations were selected for the collection of samples to be analyzed for total metals analysis during the event. Along with chlorinated VOCs, the results yielded detections of several metals including aluminum, barium, beryllium, iron, manganese, nickel, sodium, vanadium and zinc. The manganese and iron concentrations at both locations far exceeded the EPA's screening levels (MCLs or health-based contaminant levels). Although not a part of the routine analysis, the surface water samples were inadvertently analyzed for SVOCs by the assigned laboratory. Two SVOCs, bis(2-ethylhexyl)phthalate and diethyl phthalate, were detected in the stream with bis(2-ethylhexyl)phthalate exceeding the EPA's screening level for groundwater. These contaminants are the first SVOCs, other than 1,4-dioxane, detected in the stream or within proximity of the Site.

Based on the availability of data at this current time and the current concentrations of contaminants detected in Cooper Creek and in the nearby groundwater monitoring wells, EPA does not consider this scenario to present an unacceptable risk to ecological receptors at and in the vicinity of the Site. However, additional assessment of Cooper Creek and the nearby surface water bodies are recommended to confirm this evaluation. This assessment should include surface water sample collection and analysis and water level readings in nearby water bodies and shallow groundwater monitoring wells.

A bench-scale TS of source area soils and groundwater was conducted by the RPs in April 2012 to evaluate the feasibility of using chemical oxidation to address COCs in soil and groundwater at the Site. This study was in response to the recommended action detailed in the 2008 FYR Report for the Site. The submitted report dated August 2012, identified catalyzed persulfate as the oxidant for use in a field TS.

A second set of monitoring well installations was conducted in the fall of 2012 to better delineate the contamination plume, in response to recommendations made in the 2008 Hydrogeological Analysis Report Update and the subsequent detection of contaminants in the nearby Cooper Creek. Six additional monitoring wells – three Upper Saprolite wells, one Lower Saprolite well and two Bedrock wells (MW-33SU, MW-33SL, MW-34SU, MW-34B, MW-35SU and MW-35B) – were installed well beyond the property lines. The MW-35 well pair was installed northwest of the stream and within approximately 20 feet from the intersection of the stream and the transect line between MW-27 and MW-31 wells. These newest round of wells were sampled as part of the Round 55 Quarterly Sampling activity. Several chlorinated VOCs were detected at each well at concentration levels below the EPA's screening levels (MCLs or health-based contaminant levels) except bromodichloromethane, chloroform and trichloroethene. 1-4-Dioxane was detected in groundwater samples collected from MW-34SU, MW-34B and MW-35SU with concentrations exceeding the EPA's screening level in the two MW-34 wells. Several metals were also detected with aluminum, cobalt, copper, iron, manganese, mercury, thallium and vanadium exceeding the EPA's screening levels (MCLs or health-based contaminant levels) in several of the wells. Data evaluation is ongoing for the Round 55 Quarterly Sampling activity.

Quarterly residential well sampling conducted as part of the LTGMP has detected low levels of contaminants consistent with Site-related contamination which implies movement of a groundwater plume down-gradient from the source area. However, no screening levels (MCLs or health-based contaminant levels), as determined in the ROD, have been exceeded in the residential well samples. Since September 4, 2008, the three routinely sampled residential wells have consistently contained detectable levels of VOCs as well as 1,4- dioxane which are consistent with the Site-related COCs. Although the contaminants have been found to be well below screening levels (MCLs or health-based contaminant levels), data collected from these samples indicate an increase in the number of contaminants detected during any given quarterly sampling event. In June 2008, only two contaminants were detected in these three residential wells. As of December 2012, a total of eleven contaminants have been detected, but not all during the same sampling event. Various combinations of the eleven contaminants are found during various sampling events.

Based on review of the LTGMP results since the 2008 FYR, and the results of the Stream and Tree Core Sampling effort, Site conditions warrant implementation of the groundwater pump and treatment portion of the contingency remedy identified in the ROD. The ROD states the following:

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> If any analytical result from a groundwater monitoring sample collected at the points of compliance exceeds an MCL or the health-based contaminant level if an MCL has not been established, for any Site-related contaminant, a confirmatory sample from the well where the exceedances occurred shall be collected and analyzed for all Site-related contaminants. If the analytical results from the confirmatory sample also exceeds the appropriate MCL or health-based level, the contingency actions for the option of the selected remedy that is being implemented (i.e., Option 1 or Option 2) shall be triggered.

The contingency remedy also identifies actions to be taken in the source area of the Site. However, the EPA has determined that evaluation of technologies in addition to those identified in the ROD is warranted for the source area and the groundwater plume in addition to the groundwater contingency remedy identified in the ROD.

Section 6
Five Year Review Process

6.1 Administrative Components

The Buckingham FYR team was led by EPA RPM Christian Matta, EPA Community Involvement Coordinator Vance Evans, Virginia Department of Environmental Quality (VA DEQ) Superfund and Voluntary Remediation project managers Kevin Greene, Tom Modena and Bob Nicholas, and included members from the EPA Region III Technical Advisory staff with expertise in hydrology, risk assessment and toxicology. The Site inspection was conducted by EPA, VDEQ and CDM Smith on February 28, 2013.

6.2 Community Involvement

A Fact Sheet was sent to residents in the vicinity of the Site to inform them of the current status of the Site. The Fact Sheet updated the Site progress and announced the initiation of the FYR. Point of contact information was provided.

Interviews were conducted on February 28, 2013. The Buckingham County officials and VDEQ project managers were interviewed.

A second public notice will be run in the newspaper announcing the completion of the FYR and the availability of the FYR Report in the information repository at the Buckingham County Library. In addition, a Fact Sheet will be prepared and distributed summarizing the process and findings of the FYR.

6.3 Document Review

The FYR consisted of a review of relevant documents including the Feasibility Study, Proposed Plan, ROD, and the RP's Remedial Design and Remedial Action Report, as well as the Long-Term Ground Water Monitoring Work Plan, Quarterly Groundwater Monitoring Reports, Stream and Tree Core Sampling Report, the bench-scale TS and the Revised Draft Hydrogeological Analysis on the Effectiveness of Long-Term Ground Water Monitoring – 2013 Update (CDM Smith 2013) (See **Appendix B**).

Review of the Consent Decrees and Unilateral Administrative Orders (UAOs), and deed restrictions was also conducted.

6.4 Data Review and Analysis

An evaluation of the groundwater plume movements based on data collected during the LTGWMP and stream sampling investigations, as well as other historical Site data, was completed in the CDM Smith report "Revised Draft Hydrogeological Analysis on the Effectiveness of Long-Term Groundwater Monitoring – 2013 Update," dated July 2013. The report is included as **Appendix A**.

As discussed in Section 5, additional monitoring wells were installed in 2009 and 2012, as part of the ongoing groundwater plume delineation effort to develop and evaluate remedial alternatives to address the failed remedy. Since the analysis of 1,4-dioxane began in February-March 2006, groundwater detection of this contaminant and chlorinated VOCs have been consistently and continuously detected at levels above the EPA's screening levels (MCLs or health-based contaminant levels) in the POC and non-POC wells showing a migration of contamination to the north-northeast toward Cooper Creek.

The RPs installed eight new wells (MW-7SU, MW-27B, MW-29SU, MW-29B, MW-30SU, MW-31SU, MW-31B, and MW-32SU) in the upper saprolite northeast of the MW-27 cluster in 2009. Groundwater samples collected from five of these new wells contained VOC and 1,4-dioxane concentrations above their respective screening levels (MCLs or health-based contaminant levels).

A stream and tree core sampling was conducted to determine the potential of groundwater contamination discharge to the nearby surface water; and to identify areas where additional monitoring wells may be needed. Results showed detections of chlorinated VOCs and 1,4-dioxane in the surface water and tree core sampling leading to the conclusion that the stream was a groundwater discharge area and contamination had migrated further beyond Site property lines.

In response to the stream and tree core sampling analytical results, six additional new monitoring wells (MW-33SU, MW-33SL, MW-34SU, MW-34B, MW-35SU and MW-35B) were installed further northeast and northwest of the Site to help delineate the groundwater contamination plume. Chlorinated VOCs, 1,4-dioxane and metal constituents were detected in the newly installed wells. Two of the six wells had 1,4-dioxane concentrations above the EPA's screening level. As a result, additional monitoring well installation will be needed to fully delineate the groundwater plume.

6.5 Site Inspection

The Site inspection occurred on February 28, 2013 and was conducted by representatives of EPA, VDEQ and CDM Smith. A landfill cap inspection was performed on the same day by Richard Opem, P.E., and Vanessa Aririguzo of CDM Smith. The inspection revealed that the landfill cap had not been properly maintained by Buckingham County. As a result, several O&M items were identified which need to be addressed as part of the 2013 O&M effort. The following was identified:

- The drainage swale running southeast to northwest on the cap is not adequately conveying water flow off the cap surface. Pools of water, algae growth, wet soil and vegetation from standing water was noted during the inspection, however persistent standing water has been noted during wet periods in the winter and spring. As a result, infiltration of water through the cap may be occurring;
- Riprap check dams located in the drainage swale are fully covered with vegetation; as a result, drainage away from the cap may be reduced;

- Erosion concerns at the fence line near the landfill back gate due to inadequate slope of the drainage swale;
- Various locations on and around the landfill cap have bare spots and may require soil amendments or additional topsoil;
- MW-3B within the landfill fence line is missing a monitoring well cap and lock;
- The protective concrete ring around MW-2SU is damaged;
- The padlock on the back gate does not lock;
- Several drainage pipes are damaged and or inverted; and
- Three gas vent screens are damaged.

Surface runoff from the landfill is directed to a perimeter drainage ditch, which then flows to Warner Branch and then offsite. Drainage features in place for runoff management include small riprap check dams, located at the entrance and exit points of the perimeter ditch. Although vegetative overgrowth is apparent on the perimeter ditch, due to the lack of maintenance, the perimeter drainage features are in good condition.

In addition, due to soil erosion and/or animals burrowing over an extended time period, a few gaps between the bottom of the Site security fence and the ground surface were noted. The Site Inspection Map and Checklist are included in **Appendices C and D, respectively**. Photographs from the Site inspection are included in **Appendix E**.

6.6 Interviews

Interviews were conducted with the Buckingham County officials and VDEQ officials.

Information gathered during the interviews is included in **Appendix F**.

Section 7
Technical Assessment

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Question A: Is the remedy functioning as intended by the decision documents?
No. A review of documents, applicable or relevant and appropriate requirements (ARARs), and the results of the Site inspection and the LTGWMP indicate that the remedy is not functioning as intended by the ROD. The capping of the landfill may have achieved the remedial objectives of controlling contaminant migration off-site by containing contaminated landfill soil and waste material and preventing dermal contact and incidental ingestion; however, groundwater contamination indicates dissolution of waste and contaminated groundwater has migrated and continues to migrate beyond the POC line and into Cooper Creek (see **Appendix A**). The implementation of the deed restrictions in 2000 have prevented exposure to contaminated groundwater, as outlined in the ROD.

Presently, O&M of the landfill cap and the drainage system needs to be improved. Actions to address erosion underneath the security fence, bare areas at various locations on the top of the cap, overgrown vegetation and standing water with algae growth in the drainage swale, damaged and inverted drainage pipes, a missing well lock and cap, and a damaged well protective concrete ring are needed. Inadequate drainage may contribute to water infiltration under the landfill cap which would lead to further contaminant migration from the landfill. The lock on the back gate is ineffective which could provide the opportunity for vandalism or trespassing and therefore jeopardizes the security of the landfill cap. These issues all contribute to weakening the protectiveness of the remedy.

The quarterly residential well sampling has indicated low levels of Site-related contaminants which indicates movement of a groundwater plume down-gradient from the source area. However, no screening levels (MCLs or health-based contaminant levels), as determined in the ROD, have been exceeded in the residential well samples. Sample results for the three routinely sampled residential wells that are a part of the LTGWMP collected since September 4, 2008 have consistently contained detectable levels of VOCs as well as 1,4- dioxane. Although the contaminants have been found to be well below screening levels (MCLs or health-based contaminant levels), data collected from these samples indicate an increase in the number of contaminants detected during any given quarterly sampling event. In June 2008, only two contaminants were detected in these three residential wells. As of December 2012, a total of eleven contaminants have been detected, but not all during the same sampling event. Various combinations of the eleven contaminants are found during various sampling events.

Groundwater contamination that has migrated beyond the POC line and into Cooper Creek is a potential long-term threat to the residential wells and direct human and ecological contact. A field TS is currently planned to determine a treatment contingency plan to address soil/waste and groundwater contamination.

Question B: Are the exposure assumptions, toxicity data, cleanup levels, and RAOs used at the time of the remedy still valid?

There have been no major changes in the physical conditions of the Site that would affect the protectiveness of the remedy. There is an eroded area at one corner of the cap which in the near future could lead to exposure of the landfill cap and/or waste material. For some contaminants, toxicity data and exposure assumptions have changed since the Baseline Risk Assessment for this Site was performed; however, those changes do not impact the protectiveness of the remedy or the clean-up goals identified in the ROD.

Changes in Standards and To Be Considered

There have been no new additions to the list of Site-related COCs since the addition of 1,4-dioxane. The ARARs that were included in the ROD have not been met through the remedial action. The ARARs include Virginia State DEQ and Water Control Board regulations, CERCLA, RCRA, the Clean Water Act, and the Safe Drinking Water Act. The remedy no longer appears to comply with MCLs, non-zero Maximum Contaminant Level Goals and EPA Health Advisory levels at the tap as POC detections have exceeded and continue to exceed EPA's screening levels (MCLs or health-based contaminant levels).

On February 17, 2012, EPA released the final non-cancer dioxin reassessment, publishing a non-cancer toxicity value, or reference dose (RfD), for 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in EPA's Integrated Risk Information System (IRIS). Based on this new RfD, today's levels would be lower than levels that were considered protective at the time the ROD was finalized. However, based on review of existing Site information there is no indication that dioxin contamination would be present at this site. Therefore the protectiveness of the remedy does not need to be reevaluated based on the new dioxin toxicity value.

Changes in Exposure Pathways, Toxicity, and Other Contaminant Characteristics

Site-related groundwater contaminants were detected in Cooper Creek indicating in the conclusion that the stream is a groundwater discharge area and that surface water exposure pathways should be assessed.

Question C: Has any other information come to light that could call into question the protectiveness of the remedy?

Analytical data indicate that the groundwater plume has moved beyond the current compliance well network in all directions from the Site. Although the leading edge of the groundwater contaminant plume has yet to be fully characterized, low levels of groundwater contaminants in Cooper Creek indicate that the stream is a groundwater discharge area. Trace level detections of compounds in the three routinely sampled residential wells may be Site related.

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Section 8
Issues

Table 3 - Issues

Issue	Currently Affects Protectiveness (Y/N)	Affects Future Protectiveness (Y/N)
Groundwater contamination detected in Cooper Creek surface water.	N	Y
Groundwater contamination detected beyond the point-of-compliance wells.	N	Y
SVOCs detected in Cooper Creek surface water.	N	Y
Site-related COCs detected in the three routinely sampled residential wells.	N	Y
Groundwater contamination above screening levels (MCLs or health-based contaminant levels) has been detected at several point-of-compliance wells on the west, northwest, and south side of the Site.	N	Y
RCRA cap and security fence maintenance needs to be improved.	Y	Y

Section 9
Recommendations and Follow-up Actions

Some of the recommendations and follow-up actions are based upon issues described in the CDM Smith report "Revised Draft Hydrogeological Analysis on the Effectiveness of Long-Term Ground Water Monitoring – 2013 Update," dated July 2013 (See **Appendix A**).

Table 4 – Recommendations and Follow-Up Actions

Issue	Recommendations/ Follow-up Actions	Party Responsible	Oversight Agency	Milestone Date	Affects Protectivesness? (Y/N)	
					Current	Future
Groundwater contamination detected in Cooper Creek surface water.	Determine appropriate regulations and relevant screening levels (MCLs or health-based contaminant levels) to assess impacts of contaminated groundwater discharge to surface water bodies at the Site. A second surface water body located in close proximity to the southern Site boundary should be sampled to determine if COCs are present. Conduct additional delineation work in Cooper Creek to assess contaminant concentration trends over time and during low-flow stream conditions as well as stream flow and surface water to groundwater interaction. Develop a plan to mitigate discharge of COCs to surface water if contaminant levels exceed appropriate threshold.	RP	EPA	2015	N	Y

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Groundwater contamination detected beyond the line of compliance.	Delineate nature and extent of contamination and assess risk. Develop and implement a remedial strategy to eliminate or reduce the risk to an acceptable level. Source area needs additional delineation through additional data collection. A remedy needs to be developed which includes 1) source control, 2) addresses groundwater contamination and surface water contamination emanating from the source and 3) achieves hydraulic control of the groundwater plume to stop migration. Use available data to revise the conceptual site model (CSM) and assess the threat to human health and the environment. Use the CSM and assessment to revise remedial action objectives (RAOs) and develop a Site-wide remediation strategy that will address the RAOs. Utilize animal shelter groundwater well to collect samples to develop background level information. Evaluate background metals concentrations to assess Site geochemistry to determine the origin and fate of elevated metals concentrations. RPs should submit a work plan and schedule for design of pump and treat system contingency remedy called for in the ROD.	RP	EPA	2015	N	Y

SVOCs detected in Cooper Creek surface water.	Collect groundwater samples from MW-2, MW-27 and MW-31 clusters and analyze for SVOCs.	RP	EPA	Fall 2013	N	Y
Possible Site COCs detected in the three routinely sampled residential wells.	Install monitoring wells in area between site and residential wells to determine if plume is migrating in direction of residential wells.	RP	EPA	2015	N	Y
Groundwater contamination above screening levels (MCLs or health-based contaminant levels) has been detected at several point-of-compliance wells on the west, northwest, and south side of the Site.	Assess VOC concentration trends in MW-5B, MW-22B, and MW-23B to determine placement of bounding wells that are needed to the west and northwest of these wells to complete plume delineation in this area. Assess metals trends in MW-12, MW-15, MW-23BL to determine placement of additional bounding wells needed outside of these well locations to complete plume delineation in this area. Continue to monitor metals concentrations in MW-7SU to aide in determining location of bounding wells needed south of the Site to complete plume delineation in this area.	RP	EPA	2015	N	Y
RCRA cap and security fence maintenance needs to be improved.	Perform regularly scheduled inspections, maintenance and corrective steps to address eroding areas, missing gate lock, damaged gas vent screens, clogged check dams, and ponding water on cap.	RP	EPA	Fall 2013	Y	Y

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Section 10
Protectiveness Statement

The assessment of this FYR found that the remedy is protective in the short term and was constructed in accordance with the requirements of the Record of Decision (ROD), dated September 30, 1994. The landfill cap that is in place prevents exposure to the waste material. The quarterly groundwater monitoring is also in accordance with the ROD. None of the optional remedies (off-site incineration, in situ soil vapor extraction) have been implemented. The remedy is not functioning as designed. However, no human or environmental receptors are currently known to be exposed to Site-related contaminants above screening levels (MCLs or health-based contaminant levels). Groundwater contamination above screening levels (MCLs or health-based contaminant levels) continues to be detected in the monitoring wells installed well beyond the POC line in 2009. Groundwater contamination has also been detected in the nearby stream and the new monitoring wells installed in 2012.

The remedy is not protective in the long term. The remedy is not functioning as intended nor as called for in the ROD, because several Site-related contaminants have migrated beyond point of compliance (POC) wells, and are detectable in samples collected from the newly installed monitoring wells at levels exceeding screening levels (MCLs or health-based contaminant levels) identified in the ROD. Several site-related contaminants have been detected in Cooper Creek as well as two SVOCs, bis(2-ethylhexyl)phthalate and diethyl phthalate, that have not previously been sampled for in surface water.

Sample results for the three routinely-sampled residential wells that are a part of the LTGWMP have consistently contained detectable levels of VOCs as well as 1,4-dioxane since September 4, 2008. These constituents are all known Site-related contaminants. Although the contaminants are below screening levels (MCLs or health-based contaminant levels), data collected from these samples indicate an increase in the number of contaminants detected during any given quarterly sampling event. In June 2008, only two contaminants were detected in these three residential wells. As of December 2012, eleven different contaminants have been detected. Not all eleven contaminants are detected at the same time; rather, detections of combinations of the eleven contaminants are detected over all the sampling events.

Institutional controls identified in the ROD are in place and are meant to prevent the installation of wells in the HWDA of the Site. The Agency issued a Unilateral Administrative Order (UAO) requiring the County to put in place institutional controls in the form of deed restrictions.

In order for the remedy to be protective in the long term, an effective contingency remedy must be implemented to address the threats posed by the Site. Based on information gathered since the 2008 FYR, the extent of groundwater contamination should be fully delineated and the groundwater pump and treatment contingency remedy identified in the ROD should be implemented to address both the contamination and the continued migration of the plume. Source control measures need to be further evaluated to determine the most appropriate technology for addressing all disposal trenches and the barrel trench to eliminate further contamination of groundwater and surface water.

Section 11
Next Review

The next FYR for the Buckingham County Landfill Superfund Site is required to be completed within five years of the signing of this report.

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Appendix A

Revised Draft Hydrogeological Analysis on the Effectiveness of Long-Term Groundwater Monitoring – 2013 Update

Response Action Contract
for Remedial Planning and Oversight Activities
in EPA Region III
U.S. EPA Contract No. EP-S3-07-06

Revised Draft Hydrogeological Analysis on the Effectiveness of Long-Term Groundwater Monitoring – 2013 Update

Buckingham County Landfill
Buckingham County, Virginia

Work Assignment No.: 030-RSBD-03M8
Document Control No.: 3330-030-RT-OTHR-02147

July 2013

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Abbreviations and Acronyms

1,1-DCE	1,1-dichloroethene
1,1,1-TCA	1,1,1-trichloroethane
1,1-DCA	1,1-dichloroethane
1,2-DCA	1,2-dichloroethane
1,1-DCE	1,1-dichloroethene
2D	two-dimensional
3D	three-dimensional
CD	compact disc
cis-1,2-DCE	cis-1,2-dichloroethene
COC	chemical of concern
EPA	U.S. Environmental Protection Agency
ft	feet
ft bgs	feet below ground surface
ft msl	feet above mean sea level
ft/ft	feet per foot
FFS	Focused Feasibility Study
FYR	Five-Year Review
GIS	Geographic Information System
HWDA	hazardous waste disposal area
LTGWMP	Long-Term Groundwater Monitoring Program
MCL	Maximum Contaminant Level
µg/L	micrograms per liter
MCL	Maximum Contaminant Level
MVS	Mining Visualization System
MW	monitoring well
PCE	tetrachloroethene
POC	point-of-compliance
RAC	Response Action Contract
RI	Remedial Investigation
ROD	Record of Decision
RSL	EPA Region 3 Regional Screening Level
RP	responsible party
SI	supplemental investigation
SVOC	semi-volatile organic compound
TC	tree core
TCE	trichloroethene
VOC	volatile organic compound
VDEQ	Virginia Department of Environmental Quality

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Section 1

Introduction

CDM Federal Programs Corporation (CDM Smith) was tasked by the U.S. Environmental Protection Agency (EPA) under Region 3 Response Action Contract (RAC) 2 (Contract EP-S3-07-06) Work Assignment 030-RSBD-03M8 to provide remedial investigation/feasibility study (RI/FS) oversight support at the Buckingham County Landfill Superfund Site (the Site). As part of this work, EPA tasked CDM Smith to update the 2008 Final Hydrogeological Analysis Update on the Effectiveness of Long-Term Groundwater Monitoring for the Site (2008 Hydrogeological Analysis) (CDM Smith 2008). This 2013 update (2013 Hydrogeological Analysis) provides a current description of hydrogeological conditions at the Site, summarizes contamination trends and extents, and will support EPA's Third Five-Year Review (FYR) for the Site. This report supports conclusions developed regarding subsurface groundwater contamination at the Site in conjunction with the updated three-dimensional (3D) model also developed for EPA by CDM Smith.

1.1 Background

This section was compiled partially from the EPA website presenting Site Background and Cleanup History descriptions for the Buckingham County Landfill Superfund Site (EPA 2013).

The Buckingham County Landfill Site occupies eight acres, including a two-acre hazardous waste disposal area (HWDA), near Dillwyn, Virginia. Primitive disposal operations at the Site involved emptying solvent and paint waste into a series of trenches, where the by-products of evaporation, known as still bottoms, were buried and remain today. Crushed drums were placed in another trench where they remain today, as well. The landfill stopped accepting wastes in 1982.

An initial remedial investigation (RI) in 1992 showed that on-site groundwater wells were contaminated with very high levels of volatile organic compounds (VOCs). Potential risks exist if people ingest or come into direct contact with this contaminated groundwater. An estimated 1,100 people use groundwater wells for drinking water within three miles of the Site, and approximately 40 people live within one half mile of the Site.

EPA's Record of Decision (ROD), which describes the cleanup methods to be used, was issued in September 1994 and contained two options:

- Option 1 - Monitoring the groundwater and installing a cap over the HWDA.
- Option 2 - Monitoring the groundwater, limited off-site treatment, and installing a cap over the HWDA, but if migration of the contaminated plume was detected, Option 2 also included a contingency plan to pump and treat the groundwater.

A landfill cap was completed in 1998 by the RPs. A groundwater study was also conducted in 1998 by the RPs to design the Long-Term Groundwater Monitoring Program (LTGWMP), and the first round of groundwater sampling was completed in September 1998. The LTGWMP included designation of a set of point-of-compliance (POC) wells surrounding the landfill.

EPA attempted to negotiate a consent decree with the Site's responsible parties (RPs) to carry out the remedy in the ROD; however, a settlement was never reached. EPA then negotiated a de minimis settlement with three parties who were responsible for only a small amount of waste. After EPA's attempts to get the main RPs and Buckingham County to agree to implement the remedy in the ROD, EPA finally issued a Unilateral Administrative Order in 2000 to the RPs to perform the remedial action, which they implemented with the LTGWMP.

In 2003, CDM Smith, under contract to EPA, prepared the first Hydrogeological Analysis on the Effectiveness of Long-Term Groundwater Monitoring (2003 Hydrogeological Analysis) (CDM Smith 2003). The purpose of this 2003 report was to analyze the effectiveness of the RPs' LTGWMP and to identify whether the compliance monitoring wells were properly located to effectively monitor and detect groundwater contaminants that may be migrating from beneath the landfill.

The RPs' consultant (Parsons) installed additional monitoring wells in November 2005, as recommended in the 2003 Hydrogeological Analysis. The first LTGWMP event after the RPs' installation of additional monitoring wells was conducted in February/March 2006. Concentrations of several VOCs and 1,4-dioxane were detected above their respective screening levels in groundwater from one of the new POC wells located north of the Site. Until the first quarter of 2006, quarterly reports prepared by the RPs LTGWMP had consistently noted that no VOC screening levels had been exceeded in groundwater samples collected from the original POC wells. But exceedances were consistently detected in the new northern POC well during the first year of monitoring.

In December 2006, EPA met again with the RPs to discuss the elevated contamination levels in the groundwater (mainly 1,4-dioxane VOC contamination). The RPs agreed to sample additional monitoring wells and install four more monitoring wells. Based on the data from those wells, EPA determined that the remedy implemented at the Site was not functioning as intended and a new remedy was needed for the Site.

In 2008, CDM Smith, under contract to EPA, prepared a second Hydrogeological Analysis Update on the Effectiveness of Long-Term Groundwater Monitoring (2008 Hydrogeological Analysis). As a result of the recommendations in this report, EPA negotiated with the RPs to perform a supplemental investigation (SI) and Focused Feasibility Study (FFS). The RPs performed the SI in November 2009, during which they installed additional monitoring wells and soil borings. The RPs summarized this work in the Focused Feasibility Study Report prepared by the RPs (Parsons 2010). The RPs installed three additional well clusters approximately 600 feet northeast from the landfill boundary during the SI. The RPs' sampling of these wells during the LTGWMP Round 43 quarterly sampling event revealed high levels of VOCs, 1,4-dioxane, and metals in the groundwater, indicating that a groundwater plume was extending from the Site past the POC line to the northeast toward Cooper Creek.

In September 2011, the RPs conducted a stream and tree core investigation for the RPs along a transect between the Site monitoring wells and Cooper Creek and along the creek itself. Low levels of chlorinated VOCs and 1,4-dioxane were detected in some of the tree core and surface water samples from the creek, resulting in the conclusion that Cooper Creek is a groundwater discharge area. The RPs' *Stream and Tree Core Sampling Report* submitted by the RPs describing this work (Parsons 2012) recommended that additional groundwater wells be installed in the vicinity of Cooper Creek to improve delineation of groundwater impacts to the creek.

In November 2012, working for the RPs, Parsons installed and sampled three additional monitoring well clusters between 800 and 1,200 feet to the north/northeast of the landfill, at the edge of the estimated current groundwater plume. These northernmost monitoring wells will provide additional information on the nature and extent of the leading edge of the groundwater plume, which has now reached Cooper Creek and is likely discharging Site contaminants into the creek. Several Site contaminants, including chlorinated VOCs, 1,4-dioxane, and metals, were detected above screening levels at the new monitoring wells in November 2012.

Working for the RPs, Parsons has been conducting quarterly residential well sampling of three residential wells located over 2,000 feet west/northwest of the Site to identify whether contaminated groundwater has reached those residential wells. No screening levels have been exceeded in the residential well samples collected through August 2012. However, sample results for the three residential wells collected since September 4, 2008 have consistently contained low, but detectable, levels of VOCs as well as 1,4-dioxane, which are consistent with Site-related COCs.

1.2 2008 Hydrogeological Analysis Recommendations

The 2008 Hydrogeological Analysis (CDM Smith 2008) presented recommendations to further characterize the groundwater contaminant plume prior to implementing remedial actions. These recommendations were assessed during the preparation of this 2013 report to determine which have been addressed to date. All of the 2008 recommendations except for the Shallow Zone well installation recommendation have been fully or partially addressed by Parsons over the past 5 years.

- *The Upper Intermediate, Lower Intermediate, and Upper Bedrock Hydrologic Zones are all under-sampled in the northern portion of the Site. The extent of groundwater contamination in the area north-northeast of the HWDA has not been delineated. In addition, bedrock structural information is not available in the northern area.* This recommendation was addressed by the RPs' installation of additional borings and groundwater wells in 2009 in this area to define the bedrock lithology and improve characterization of this portion of the plume.
- *Inspection of historic aerial photographs revealed trench areas (e.g., the barrel trench) that did not appear to have been investigated. These areas should be addressed by a direct-push technology drilling program to determine if there are other sources for the groundwater contamination.* This recommendation was addressed during RPs' 2009 SI by advancing direct push borings to more fully characterize the source area.
- *Boreholes should be advanced adjacent to wells MW-6S, MW-19S, and MW-13 (a transect of three boreholes). Boreholes should also be advanced north of MW-26SU and MW-27SU. Discrete groundwater samples should be collected during borehole advancement through the saprolite and broken bedrock stratigraphic units for VOC and 1,4-dioxane analysis. Log the open bedrock intervals with borehole geophysical tools (recommend caliper, acoustic televiewer, and borehole flow meter); use the data to help build a hydrogeologic framework. To save on drilling costs, nested or multi-port monitoring wells should be installed at selected zones in each borehole (i.e., high flow zones, interconnectedness with other zones, and/or elevated contamination).* This recommendation was addressed by the installation of SB-19S adjacent to MW-19S during RPs' 2009 SI. Discrete groundwater samples were collected from this soil boring in addition to standard stratigraphic logging. Boreholes were not advanced north of MW-26SU or MW-27SU, but a new monitoring well (MW-27B) was installed in this vicinity. A suite of borehole

geophysical logging tools was run in MW-27B: caliper, temperature, conductivity, gamma ray, downhole camera, and heat pulse flow meter.

- *There are no Shallow Zone wells in the southern portion of the Site. There also is no groundwater data available between the source area and the POC line to the south and west. Shallow Zone wells should be attempted in the vicinity of the MW-7 and MW-24 clusters.* This recommendation has not been addressed. The RPs installed MW-7SU since 2008 in the Upper Intermediate Zone south of the landfill and collected groundwater samples from the well, but no Shallow Zone wells have been installed near the MW-7 or MW-24 clusters.

- *There are no upper intermediate wells in the western portions of the Site. This is a potentially high groundwater flow zone that could carry contaminants more readily through the subsurface. To address this data gap, a transect of three boreholes should be drilled across the western area of the Site using the same methods as described above for the northern area.* Since 2008 the RPs have not installed any additional boreholes in the western portions of the Site. CDM Smith's 2013analysis of the 3D Site Model contaminant distributions indicates that low concentration groundwater plumes are currently not bounded to the west of MW-5B or northwest of MW-22B and MW-23B. The 2013 3D Site Model plume contaminant concentration confidence level in this area of the Site is low because of the lack of bounding wells outside of the POC line.

- *Lower Bedrock well MW-5BL appears to have been damaged during well installation. Well re-development performed in September 2006 revealed the presence of bentonite and filter sand inside the well indicating the well screen separated from the riser pipe. Given this wells downgradient position and the apparent increasing 1,1-DCE concentrations in MW-5B in the upper bedrock, MW-5BL should be abandoned and replaced.* During the RPs' 2009 SI, a downhole camera was placed in MW-5BL to check for problems in well construction to resolve previous issues noted with the well. The casing appeared to be in good condition, although it was noted that approximately five feet of silt were present in the bottom of the well. This well was not redeveloped. Presently, the RPs have identified this well to be in acceptable condition.

- *The RPs should begin to plan for implementation of the contingencies, or propose alternative technologies that may have been developed since the time the ROD was issued in 1994.* The RPs began a bench-scale treatability study in 2012 to evaluate the effectiveness of catalyzed sodium persulfate in remediating contaminated soil and groundwater in the landfill source area (Spectrum 2012). The study is ongoing. At EPA's direction, CDM Smith reviewed the treatability study report and documented several issues and raised several questions related to the effectiveness and applicability of the study (CDM Smith 2013a).

1.3 Report Purpose and Organization

The purpose of this report is to update the analysis of groundwater movement and contamination trends at the Site and to analyze the effectiveness of the LTGWMP. This report updates the 2008 Hydrogeological Analysis and evaluates whether the POC monitoring wells are properly located to effectively monitor or intercept groundwater contaminants that may be migrating from beneath the landfill. This report also presents an assessment of the Cooper Creek investigation area north of the landfill. A component of the evaluation and assessment is accomplished with images and analyses created using the three dimensional geostatistical model (3D Site Model) which was updated using November 2011 groundwater data. The 3D Site Model was created using Mining Visualization System

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(MVS) software version 9.6 and is an update from the 2008 3D Site Model. The electronic 3D Site Model files are on compact disk submitted as Appendix A to this report.

This report provides the results of CDM Smith's hydrogeological analysis. The report is organized into the following sections:

- Section 1 – Introduction
- Section 2 – Site Description
- Section 3 – Groundwater Movement
- Section 4 – Groundwater Contamination Evaluation and Summary
- Section 5 – Groundwater to Surface Water Discharge Evaluation
- Section 6 – Conclusions and Recommendations
- Section 7 – References

Section 2

Site Description

This section contains background information to support the hydrogeological analysis. The information was taken from the Final Remedial Investigation Report (Engineering Science, Inc. 1993), Long-Term Groundwater Monitoring Program Work Plan (Parsons Engineering Science, Inc. 1998), and the Additional Monitoring Well Installation Summary Report, September 2005 - January 2006 Event (CDM Smith 2006).

2.1 Location and Physiography

The Buckingham County Landfill Superfund Site is located along County Road 640 in central Buckingham County, Virginia, near Dillwyn, Virginia and approximately 3.5 miles southeast of the county seat location of Buckingham. The intersection of U.S. Route 60 and U.S. Route 15 is approximately 1.5 miles northeast of the Site. The Site location and a site map are shown on **Figure 2-1.**

The Site is located in the Appalachian Piedmont Physiographic Province. The surface topography of the area is gently rolling. Elevations in the Site area vary between approximately 540 and 660 feet above mean sea level (ft msl). Elevations in the immediate vicinity of the landfill range approximately from 580 to 620 ft msl.

2.2 Geology

The geology of the Site is typical to the Piedmont Province: bedrock overlain by saprolite and residuum. **Figure 2-2** presents the geologic framework beneath the Site. The bedrock underlying the Site is the Chopawamsic Formation (Virginia Department of Mines, Minerals, and Energy 2007). The Chopawamsic Formation consists of dark green to gray amphibole gneiss and schist and biotite-quartz-feldspar gneiss with interlayered amphibole gneiss (USGS 2007).

Foliation and lineament analyses were performed by the RPs' contractor (Engineering Science) during the RI in an attempt to identify the directional trend of the fractures. These analyses were based on aerial photograph interpretations and field surface outcrop observations. Based on these observations and interpretations, Engineering Science found that the average foliation strike is to N34^{0}E and dips 82^{0}SE. Lineaments were also identified to trend to the northeast with a second set that trends perpendicular (to the northwest) (Engineering Science 1993).

Borehole geophysical logging results indicate that there may be one dominant fracture orientation that has undergone post-genesis folding. **Figure 2-3** displays the fracture trends based on the borehole geophysical data, specifically acoustic televiewer data. It should be noted that the figure shows two fracture planes extending entirely across the Site due to the lack of borehole geophysical data throughout the Site to confirm the folded plane hypothesis. The general fracture orientations at MW-5BL and MW-7BL were similar to the foliation strike and dip identified during the RI. However, the general fracture orientations at MW-22BL and MW-23BL were approximately N15^{0}W with a 60^{0} to 75^{0} dip to the northeast (CDM Smith 2006). The axis of the fold appears to trend west-southwest to east-northeast through the northern portion of the Site north of the landfill cap.

A transition zone of highly fractured, partially weathered rock exists between the competent bedrock and the overlying saprolite. The structure described for the competent bedrock would extend through the weathered rock zone. This weathered zone ranges from approximately 10 feet (MW-1B) to 63 feet thick (MW-22B).

Overlying the Weathered Bedrock is unconsolidated saprolite and residuum. The saprolite has been divided into Upper and Lower Saprolite Stratigraphic Layers. The Lower Saprolite is generally medium-grained to coarse-grained (sand and silty sand), semi-consolidated, material that can be penetrated by a hollow-stem auger but not by standard split-spoon sampling. This unit would be expected to retain most of the structure of the parent rock.

The Upper Saprolite is generally finer-grained (primarily micaceous silt and fine sandy silt) than the Lower Saprolite layer, and begins to lose the relict structure. The Residuum Stratigraphic Layer at the Site consists of reddish silty clay to clayey silt with no relict structure. The combined thickness of these two layers ranges from approximately 37 feet at MW-25B to 95 feet at MW-7BL and MW-24B. The thickness of the Residuum is generally less than 20 feet.

2.3 Hydrology

Surface drainage at the Site is directed to Cooper Creek to the north and to the Warner Branch of Cooper Creek to the south. A drainage ditch located west of the Site discharges surface water into an unnamed tributary of the Warner Branch. The unnamed tributary flows toward the south-southwest, off the Site and is intermittent. On-site drainage features have only been damp during visits to the Site near periods of high precipitation and do not intersect the water table.

As demonstrated in the expanded views in Figure 2-3, the boundaries between the five stratigraphic layers are highly irregular. As a result, monitoring wells with similar completion elevations may be screened in different stratigraphic layers. In addition, the boundaries are gradational, with transitions between stratigraphic layers rather than discrete boundaries. Because of this, the stratigraphic layers within which wells are screened have initially been mis-identified on several occasions. There are also at least two wells (MW-13 and MW-19S) for which the determination of a stratigraphic layer was inconclusive. One well (MW-2SL) is screened across three stratigraphic layers. Because of these factors, the monitoring wells have primarily been grouped in this report according to similar elevations, as follows:

- **Shallow Hydrologic Zone** (Well completion elevations above 555 ft msl) – The majority of wells screened in this zone are in the Upper Saprolite Stratigraphic Layer. This zone also includes wells screened in Lower Saprolite and Weathered Bedrock (in the case of MW-25SL, due to its relative higher land surface elevation).

- **Upper Intermediate Hydrologic Zone** (Well completion elevations from 525 to 555 ft msl) – Wells in this zone are screened predominantly in Upper or Lower Saprolite, with wells screened fully or partially in Weathered Bedrock at MW-2SL and MW-12.

- **Lower Intermediate Hydrologic Zone** (Well completion elevations from 475 to 525 ft msl) – The majority of wells in this zone are screened in Weathered or Upper Bedrock with one exception. MW-07SL is screened in the Lower Saprolite.

- **Upper Bedrock Hydrologic Zone** (Well completion elevations from 425 to 475 ft msl) – All of the wells in this zone are screened in the Upper Bedrock Stratigraphic Layer.

- **Lower Bedrock Hydrologic Zone** (Well completion elevations below 425 ft msl) - All of the wells in this zone are screened in the Lower Bedrock Stratigraphic Layer.

In this report, monitoring wells will continue to be referred to in accordance with the stratigraphic layer within which the screened intervals are positioned. In this way, the effects of differing lithologies on groundwater flow within a hydrologic zone may be more easily recognized. The grouping of wells based on their screen elevations alone, without considering stratigraphy, also support an unbiased assessment of site characterization to determine areas of the Site that are undercharacterized or where the groundwater plume is not bounded to assess the effectiveness of the LTGWMP. In some sections of this report (*e.g.*, where the effect of a particular stratigraphy on groundwater flow is discussed), analysis of hydrologic characteristics or behaviors based on stratigraphy alone are presented, but most figures and report sections are presented by grouping wells by hydrologic zone (elevation). The presentation of hydrogeochemical findings based on hydrologic zone, in addition to the typical stratigraphic layer approach, also allows for unique analyses and visualizations utilizing horizontal slices from the 3D model that are layered and viewed together.

Table 2-1 identifies the stratigraphic unit (layer) and hydrologic zone, as well as the screened interval elevations of each Site monitoring well.

Figure 2-4 presents historical groundwater elevations grouped by hydrologic zone. As would be expected, groundwater levels within each hydrologic zone demonstrate similar responses over the historical record. The average groundwater level elevation decreases from the Shallow Hydrologic Zone to the Lower Bedrock Hydrologic Zone. There are some outliers in the Shallow Hydrologic Zone that show exaggerated responses compared to other wells in the zone. This is likely due to the proximity of these wells to the land surface, whereas water level response in deeper wells is dampened by the overlying soil. The Shallow Hydrologic Zone also has a higher variability in stratigraphy compared to deeper zones which may be contributing to some of the response in the outlier wells.

Figure 2-5 presents the average historical groundwater elevation at the Site (i.e. all individual wells averaged) along with daily rainfall averages. Sixty-day rolling average daily rainfall values were calculated and plotted to dampen the effects of individual rainfall events. As the chart shows, increases and decreases in Site average groundwater levels are preceded by similar responses in precipitation.

The cross-section presented on **Figure 2-6** provides a comparison of stratigraphic layers to hydrologic zones. As shown on the figure, each hydrologic zone – in essence a band of constant elevation – crosses one or more stratigraphic layers across the extent of the investigation area.

The water table generally occurs within the Upper Saprolite Stratigraphic Layer; however, the water table is not encountered until the Lower Saprolite and Weathered Bedrock Stratigraphic Layers in higher areas of the Site (e.g., at MW-20S and MW-25SL). Groundwater elevations and depths to water measured in November 2011 (Round 51) are presented on **Table 2-2**. Depth to water in the Upper Saprolite (water table) wells ranged from approximately 20 feet below ground surface (ft bgs) at MW-5S (near the unnamed tributary) to approximately 37 ft bgs at MW-2SU to 49 feet bgs at MW-13 (in the higher elevations of the landfill).

In the Upper and Lower Saprolite Stratigraphic Layers, groundwater flow may be controlled by relict fractures. However, as the saprolite becomes more weathered and the relict structures are lost, groundwater occurrence and movement is expected to occur between the grains of the weathered material.

Depth to groundwater in the Upper and Lower Bedrock Stratigraphic Layer wells in November 2011 ranged from approximately 13 ft bgs in MW-5B to approximately 49 ft bgs in MW-22BL.

Groundwater occurrence and flow in the bedrock stratigraphic layers is controlled by secondary openings (or fractures). There also may be structural control of groundwater flow within the bedrock with flow moving along the strike to the northwest.

The average groundwater level for all Site wells is generally in the same range as it was when the 2008 Hydrogeological Analysis was performed. The average groundwater level for 2011 was about one foot lower in the first part of the year (January – May) and about one foot higher later in the year (May – November), when compared to the 2008 average groundwater level.

Section 3

Groundwater Movement

This section describes groundwater movement at the Site based on three parameters: horizontal hydraulic gradients, vertical hydraulic gradients, and groundwater velocity. The purpose of conceptualizing the movement of groundwater is to aid in the analysis of the hydrogeological system and to help determine the effectiveness of the LTGWMP.

3.1 Horizontal Gradients

Figure 3-1 through **Figure 3-5** illustrate the potentiometric surfaces of the Shallow, Upper Intermediate, Lower Intermediate, Upper Bedrock, and Lower Bedrock Hydrologic Zones, respectively, for the November 2011 quarterly sampling event (Round 51), which was the most recent comprehensive event conducted prior to the preparation of this report. Round 51 groundwater level elevations are provided in Table 2-2. These figures also display the stratigraphic layer boundaries along a constant elevation plane set at an elevation equal to the average screen midpoint for the wells screened in that hydrologic zone. This stratigraphic layer guide can be used to assess potential impacts of geology on groundwater flow patterns within each hydrologic zone.

Figure 3-1 shows the November 2011 potentiometric surface for the Shallow Hydrologic Zone. Groundwater flow in the western portion of the Site is to the west with groundwater in this zone flowing westward from the general area of a bedrock high located to the east of the landfill. Based on gradients, groundwater in the eastern portion of the Site flows in a northwestern direction, and turns to the north where the land surface elevation drops north of the landfill. The horizontal gradient in November 2011 in the Shallow zone ranged from 0.017 feet per foot (ft/ft) between MW-1S and MW-5S in the southern side of the Site, to 0.021 ft/ft between MW-19S and MW-26SU in the northeast. The hydraulic gradient in the vicinity of Cooper Creek is not shown, because water levels at the MW-33/34/35 clusters were not available in November 2011, as the wells had not yet been installed. This new well potentiometric data, in addition to water levels from piezometers installed near the creek in February 2013, are expected to define groundwater flow patterns and clarify the understanding of groundwater/surface water interaction near Cooper Creek. The stratigraphy at the center (vertical midpoint) of the Shallow Hydrologic Zone indicated on Figure 3-1 suggests some potential impacts of geology on local flow patterns. Horizontal hydraulic gradients are slightly lower in the Lower Saprolite than the Upper Saprolite. The transition between Lower and Upper Saprolite is not a discrete one, so hydraulic conductivities in these two stratigraphic layers may not differ substantially. In addition, the Bedrock/Lower Saprolite mound centered east of the landfill may be enhancing the radial flow patterns in the vicinity of MW-20S, though the main driver for this flow pattern may be the northeast-oriented fracture in this area.

Figure 3-2 displays the November 2011 potentiometric surface for the Upper Intermediate Hydrologic Zone. This zone consists of monitoring wells completed in a variety of stratigraphic layers ranging from Upper Saprolite to Bedrock. The potentiometric surface, in general, slopes to the northwest in the vicinity of the Site and to the north between the Site and Cooper Creek. In the far southwestern portion of the Site, groundwater flows eastward from MW-12 toward MW-7S. Using Site contaminants as groundwater tracers, there also appears to be a north-northeastern component in the Upper Intermediate Hydrologic Zone gradient, with tetrachloroethene (PCE) concentrations above the

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MCL (5 µg/L) in MW-27B, MW-30SU, and MW-31SU. These monitoring wells are located downgradient from the presumed source area which is indicated on these maps by the locations of the former evaporation, disposal, and barrel trenches. The horizontal gradient was 0.015 ft/ft between MW-21S and MW-2SL during the November 2011 event. The stratigraphy at the center of the Upper Intermediate Hydrologic Zone indicated on the Figure 3-2 does not suggest any strong impacts of stratigraphy on local flow patterns. Horizontal hydraulic gradients appear relatively consistent across all stratigraphic layers.

The Lower Intermediate Hydrologic Zone potentiometric surface is displayed on Figure 3-3. This hydrologic zone consists of monitoring well screens within the Lower Saprolite, Weathered Bedrock, and Upper Bedrock. The fairly uniform horizontal gradient is to the northwest in the vicinity of the landfill and to the north between the landfill and Cooper Creek. The horizontal gradient of the Lower Intermediate Hydrologic Zone ranged from 0.003 ft/ft between MW-1B and MW24-SL, to 0.005 ft/ft between MW-7SL and MW-24SL. The stratigraphy at the center of the Lower Intermediate Hydrologic Zone indicated on the figure does not suggest any strong impacts of geology on local flow patterns. Horizontal hydraulic gradients appear relatively consistent across all stratigraphic layers.

The potentiometric surface for the Upper Bedrock Hydrologic Zone is displayed on Figure 3-4. The groundwater contours indicate that the gradient is toward the west across most of the Site. In the western portion of the study area, however, the gradient is toward the east. Water levels indicate a gradient from MW-05B toward MW-03B and MW-24B. Gradients in November 2011 ranged from approximately 0.007 ft/ft between MW-5B and MW-24B, to 0.011 ft/ft between MW-4BR and MW-20B.

Figure 3-5 presents the potentiometric surface for the Lower Bedrock Hydrologic Zone. Horizontal gradients in this zone are toward the west, from the landfill toward MW-22BL and MW-05BL.

In summary, the potentiometric surfaces presented on Figure 3-1 through Figure 3-5 indicate that the horizontal gradient in the Shallow, Upper Intermediate, and Lower Intermediate Hydrologic Zones is, in general, to the northwest in the vicinity of the landfill, and to the north between the landfill and Cooper Creek. Horizontal gradients in the Upper Bedrock and Lower Bedrock Hydrologic Zones are to the west. Horizontal gradients to the north in a local flow regime between the Site and Cooper Creek are expected, because the land surface slopes to the north (toward the creek) and the gradient is expected to follow the land surface. Horizontal gradients in the local flow regime in the southwestern corner of the Site also follow land surface topography. In this area of the Site, the land surface and potentiometric surfaces slope toward Warner Branch; however, due to the intermittent nature of this stream near the Site, and based on groundwater plume maps, groundwater does not typically appear to discharge to the Warner Branch. During extreme high groundwater events, Warner Branch may receive discharge, but no data were collected to validate this assumption.

Potentiometric surface contours shown on Figure 3-1 through Figure 3-5 indicate that horizontal gradients in the Shallow Hydrologic Zone are slightly higher than in the Upper Intermediate Hydrologic Zone. Gradients in the Upper and Lower Intermediate Hydrologic Zones are similar. Horizontal gradients in the Upper Bedrock Hydrologic Zone are considerably lower than those in the overlying zones. Horizontal gradients in the Lower Bedrock hydrologic zone were the highest of any zone in November 2011, though only four wells were sampled in that zone from which gradients were calculated.

3.2 Vertical and Flow Net Gradients

Table 3-2 summarizes vertical gradient directions between nested monitoring wells for November 2011, February 2012, May 2012, and August 2012. The four dates represent the seasonal changes for the last full year of monitoring. Vertical gradients are more often downward than upward at the Site, when considering all periods and well clusters, although only three well clusters (MW-1, MW-23, and MW-24) are consistently downward throughout the year. The ten well clusters where a consistent downward gradient was not present are: MW-2, MW-4, MW-5, MW-7, MW-20, MW-22, MW-25, MW-27, MW-29, and MW-31.

The MW-2 cluster located in the source area experienced a split vertical gradient, with convergent flow from the upper and lower wells in the cluster toward MW-2SL in November 2011 and August 2012. Flow was consistently upward in February 2012 and was divergent from MW-2SL (flowing upward and downward toward the upper and lower wells) in May 2012.

The MW-4 POC well cluster, located about 150 feet north of the landfill, experienced consistently upward gradients during all periods.

The MW-5 POC well cluster, located near the southwest corner of the landfill, experienced consistently downward gradients through the assessed year, except for November 2011, when water levels were lower than in other periods. During November 2011, there was an upward gradient from MW-5SL to MW-5S and divergent flow from MW-5B towards the nearest upper and lower wells.

The MW-7 POC well cluster, located just south of the landfill, experienced a complex vertical gradient pattern, with gradients reversing from season to season. Generally flow gradients were downward at this cluster, with divergent flow from MW-7SU during February and May of 2012. Like the MW-5 cluster, the MW-7 shallow well pair reversed gradient during the drier November 2011 period and exhibited an upward rather than a downward gradient.

The MW-20 well cluster, located just off the eastern side of the landfill, experienced an upward gradient between MW-20B and MW-20S during all periods except February 2012, during which the gradient was downward.

The MW-22 POC well cluster, located off the northwest corner of the landfill, experienced downward gradients generally, with divergent flow away from MW-22B during May and August 2012.

The MW-25 well cluster, located about 150 feet east of the landfill, experienced upward gradients in February and May 2012, but downward gradients in August 2012.

The MW-27 well cluster, located north of the landfill and just north of the MW-4 well cluster, experienced upward gradients for the two periods for which data were available, May and August 2012.

The MW-29 well cluster, located north of the landfill and just north of the MW-23 well cluster, experienced a downward gradient in all periods, except for August 2012, when the gradient switched direction.

The opposite pattern existed in the MW-31 well cluster, located approximately 800 feet northeast from the landfill, which experienced an upward vertical gradient during all periods, but a downward gradient in August 2012.

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Upward gradients exist at many of the bedrock wells including MW-2B, MW-20B, MW-27B, and MW-31B. These wells, most of which are located in the Upper Bedrock or Weathered Bedrock Stratigraphic Layers are all currently contaminated with COCs. Upward gradients at these locations are likely restricting the downward migration of contamination into the deeper bedrock.

Potentiometric surface contours, from which vertical gradients may be interpreted, are presented visually on the hydrogeochemical cross-sections on **Figure 3-6** and **Figure 3-7**. These cross-sections were created by slicing the 3D Site Model with a vertical plane. The benefit of this technique is that a large amount of data may be synthesized and presented together on the cross-sections. Potentiometric surface flow net contours are shown on the cross-sections as an indication of the groundwater gradient. These contours were created by interpolating the November 2011 water level dataset together and generating a 3D representation of hydraulic heads. This 3D model of heads was then sliced and projected onto the cross-section. This method of generating head contours results in a more accurate representation than selecting a subset of wells and contouring heads in two dimensions, as is generally done when creating two–dimensional (2D) contour maps. The cross-sections contain some 3D elements (e.g., the land surface and groundwater wells) in addition to the 2D vertical slice. The view is perpendicular to the 2D vertical slice, which also displays stratigraphic contacts and PCE concentrations from November 2011.

As shown on Hydrogeochemical Cross-Section A-A' (Figure 3-6), the flow net groundwater head contours indicate that the average hydraulic gradient is downward beneath the landfill and downward and to the north between the landfill and Cooper Creek. The 2-foot head contours align well with the estimated groundwater PCE plume, which indicates transport of PCE along a flow path that is perpendicular to the head contours projected onto the cross-section. As Cooper Creek is approached, the lateral gradient begins to point upward toward the creek, indicating the groundwater's eventual discharge to the surface water body.

The Hydrogeochemical Cross-Section B-B' (Figure 3-7) presents a transect across the plume (perpendicular to the main plume axis). The flow net head contours displayed on this cross-section provide information about horizontal and vertical groundwater movement along this transect. The head contours show that the average hydraulic gradient beneath the Site is to the west and northwest, which is in agreement with the 2D potentiometric surface maps presented on Figures 3-1 to 3-5. A downward vertical gradient is prevalent in the upper reaches of the section, but the gradient is more lateral from east to west within the bedrock layers.

3.3 Groundwater Velocity

Horizontal groundwater velocities were calculated for the Shallow, Upper Intermediate, Lower Intermediate, and Upper Bedrock Hydrologic Zones to estimate travel times in selected areas.

Engineering Science performed aquifer testing during the RPs' 1993 RI which included pump testing in MW-2SL, with MW-2SU, MW-2B, and the former MW-11 used as observation wells. Slug testing was performed in MW-1B, MW-1S, MW-3S, MW-4S, MW-5S, MW-6S, MW-7S, MW-8S, and MW-10S. Wells MW-1S, MW-2SU, MW-3S, MW-4S, MW-5S, MW-6S, MW-8S, and MW-10S are considered to be in the Shallow Hydrologic Zone. MW-2SL and MW-7S are considered to be Upper Intermediate Hydrologic Zone wells, and MW-1B and MW-2B are classified as Lower Intermediate Hydrologic Zone wells. Data from the RI aquifer tests were used to estimate hydraulic conductivity values, which are needed to calculate groundwater velocities. These hydraulic conductivities were used to estimate groundwater velocities for the Shallow, Upper Intermediate, and Lower Intermediate Hydrologic Zones.

The RPs' contractor performed borehole packer testing during installation of the four deep bedrock monitoring wells (MW-5BL, MW-7BL, MW-22BL, and MW-23BL) in the fall of 2005. Packer test data from the 125-foot to 135-foot interval of MW-5BL and from the 153-foot to 163-foot interval of MW-7BL were used to estimate hydraulic conductivities and groundwater velocity for the Upper Bedrock Hydrologic Zone.

Groundwater velocity provides a tool in which advective travel times of a contaminant may be estimated. Advective travel considers only groundwater velocity in the movement of a contaminant, although other factors (e.g., dispersion, sorption, and biodegradation) may influence the travel times. Advective movement provides a simple estimate of the time required for a contaminant to travel from one point to another. Groundwater velocity can be estimated using the equation:

$V = (K/n_e) \times (dh/dl);$

Where

K is the hydraulic conductivity (in feet/day) of the aquifer material,

n_e is the effective porosity (unitless) of the aquifer material, and

dh/dl is the hydraulic gradient (unitless).

Groundwater velocity calculations are provided on **Table 3-1**. Groundwater velocities were calculated by CDM Smith based on water levels from four sampling events from Round 51 (November 2011) to Round 54 (August 2012). Table 3-1 also presents the Round 36 (March 2008) groundwater velocities from the 2008 Hydrogeological Analysis for comparison, and they are similar to velocities calculated from the 2011 and 2012 data. Groundwater velocities were averaged for all five events presented in Table 3-1 to determine an overall average velocity for each well pair. Average groundwater velocities are estimated to be 0.08 ft/day in the Shallow Hydrologic Zone, 0.06 ft/day in the Upper Intermediate Hydrologic Zone, 0.03 ft/day in the Lower Intermediate Hydrologic Zone, and 1.14 ft/day in the Upper Bedrock Hydrologic Zone. Groundwater velocities do not change significantly between events in the Shallow, Upper Intermediate, and Lower Intermediate Hydrologic Zones. In the Upper Bedrock Hydrologic Zone, groundwater velocities exhibit a range from approximately 0.6 ft/day to 1.8 ft/day.

The flowpath distance from shallow well MW-2SU (location near the HWDA center where elevated concentrations of groundwater contaminants were identified during the RI) to shallow well MW-26SU (a well downgradient and north of MW-2SL, beyond the line of compliance) is approximately 460 feet. The flowpath distance is calculated by following a path perpendicular to potentiometric contours rather than a straight line between the two wells. At a velocity of 0.08 ft/day, the advective travel time for a contaminant to move from MW-2SU to MW-26SU is estimated to be approximately 16 years. The travel time between MW-2SU and MW-22SU (a well approximately 420 feet downgradient and west of MW-2SU) is estimated to be 14 years.

Travel time in the Upper Intermediate Hydrologic Zone between MW-2SL and a point between MW-29SU and MW-27B (approximately 360 feet downgradient) is estimated to be 16 years. Travel time in the Lower Intermediate Hydrologic Zone between MW-2B and the MW-29B (located approximately 440 feet downgradient) is estimated to be approximately 40 years. In the Upper Bedrock Hydrologic Zone, the travel time from MW-4B to MW-3B (located approximately 430 feet downgradient to the west) is estimated to be 1 year.

Calculated average groundwater velocities should be considered estimates due to uncertainty in hydraulic conductivity values. Also, and perhaps most importantly, these travel time estimates assume a relatively straight path (perpendicular to potentiometric contours) through a single hydrologic zone. However, based on Site data, and on knowledge of the qualities of a fractured rock system, the contaminant paths are likely circuitous – they cross multiple hydrologic zones, experience multiple hydraulic conductivity zones, and several gradient changes.

3.4 Influence of Geologic Structure on Groundwater Flow

Regionally, the Buckingham quadrangle structural geology includes acute isoclinical folds and high angle reverse faults in northeastern trending pre-Triassic rocks (Engineering Science 1993). The Piedmont crystalline aquifer system in which the Site is located is composed primarily of intrusive igneous and metamorphic rocks. Groundwater in this area is typically encountered in fractured/foliated crystalline bedrock or in the overlying residuum and saprolite. The analysis of regional and local geology presented in the 1993 RI indicated that the presence of fractures in the bedrock and lower saprolite influence the groundwater flow at the Site.

There are two sets of joints mapped in the rocks of the Buckingham quadrangle. Strike joints, which trend northeast/southwest are nearly parallel to the strike and minor folds, and dip steeply or are vertical. Cross joints are perpendicular to the strike and trend toward the northwest. The cross joints also have steep dips (Engineering Science 1993).

Nine lineaments (joints, faults, fractures, and foliations) are evident within a one-half mile radius of the site which are not associated with streams but are visible in aerial photographs of the area. Four of these lineaments strike from the southwest to the northeast, nearly paralleling the strike of the bedding planes in the area. Five other lineaments strike from the northwest to the southeast. Lineaments are important with respect to groundwater flow because these features, which have secondary porosities, can act as preferential groundwater paths within the saprolite (Engineering Science 1993).

Site-specific fractures were analyzed from acoustic televiewer logs of four boreholes: MW-7BL, MW-5BL, MW-22BL and MW-23BL (CDM Smith 2006). The analysis concluded that there may be one dominant fracture orientation that has undergone post-genesis folding; fractures on the northwest limb of the fold trend northwest and dip northeast, while those on the southeast limb of the fold trend northeast and dip southeast. A relatively consistent and open fracture zone was encountered in three of the four bedrock boreholes at depths of 193 to 209 ft bgs. The elevation of these zones at the four locations ranges from 392 ft in MW-7BL to 412 ft in MW-22BL. This fracture zone was not found in MW-5BL.

An alternative scenario which may be prevalent at the site is that two separate fracture zones that intersect near the southwest corner of the Site. Figure 2-3 displays the fracture orientations based on the alternative scenario. The general fracture orientations at MW-5BL and MW-7BL are at an average strike of N340E and a dip of 820SE. The general fracture orientations at MW-22BL and MW-23BL are approximately N150W with a 60 to 750 dip to the northeast (CDM Smith 2006).

In many places the saprolite retains the original structure of the parent rock and generally the saprolite becomes more granular and competent and more closely resembles the parent rock/bedrock as depth increases. The more competent saprolite above the bedrock has been referred to as disintegrated or weathered rock (Engineering Science 1993). In the Upper and Lower Saprolite stratigraphic layers, groundwater flow may be controlled by relict fractures, which create zones of higher transmissivity and may act as preferential pathways for groundwater flow. However, as the saprolite becomes more weathered and the relict structures are lost, groundwater occurrence and movement is expected to occur between the grains of the weathered material.

Fracture-controlled groundwater transmissivity is consistent with findings of hydraulic conductivity (aquifer pumping) tests performed during the 1993 RI, that concluded that groundwater flow at the Site was strongly influenced by fractures, bedding planes, and foliation planes in the upper bedrock and saprolite, which create preferential flow paths and an anisotropy in the aquifer (Engineering Science 1993).

The fracture zone striking to the northeast (Figure 2-3) runs approximately parallel to the central axis of the groundwater plume extending from the landfill to Cooper Creek and has been identified as the likely conduit for site contaminants. The fracture plane striking to the northwest is also a potential conduit for site contaminants as evidenced by potentiometric surface contours indicating horizontal flow to the north and northwest in the vicinity of the fracture plane. However, strong evidence of a substantial groundwater plume does not currently exist in this portion of the site. The lack of contamination in monitoring wells to the northwest may indicate that the fracture zones are not well hydraulically connected in the contaminated hydrologic zones.

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Section 4

Groundwater Contamination Evaluation and Summary

4.1 Contamination Trends

Groundwater contaminant concentration trends are presented for three representative COCs (PCE, TCE, and 1,1-DCE) for wells in which screening levels have been exceeded on **Figure 4-1** through **Figure 4-11**. The order of charts presented is from highest to lowest concentration. These VOCs were selected as representative COCs, because they were detected at levels significantly above their screening levels in November 2011 and were also detected in groundwater beneath the HWDA at concentrations significantly above their respective screening levels during the 1993 RI. Concentration trend charts were created only for wells that had an exceedance of the relevant screening level (MCL or EPA Region 3 Regional Screening Level [RSL]) at any time in their history. Charts are grouped by the hydrologic zone and present data from the earliest LTGWMP round in which they were sampled through LTGWMP Round 51 (November 2011). Hydrologic zones not represented by charts had no exceedances. Although CDM Smith has collected varying percentages of split samples for each LTGWMP event, the RPs' data are presented in this report for consistency and in order to use comprehensive datasets.

Figure 4-1 presents PCE concentration trends for Shallow Hydrologic Zone wells in which PCE has been detected above the screening level of 5 µg/l. To provide spatial reference, these charts are also shown on the map on Figure 3-1. Source area well MW-2SU still has the highest levels of PCE on the Site. PCE levels at this well increased since the 2008 Hydrogeological Analysis, from 600 µg/l in June 2008 to approximately 1,000 µg/l in May 2010, before decreasing again to 370 µg/l in November 2011. The overall PCE concentration at MW-2SU is decreasing, but changes are irregular. Locations MW-9SU and MW-6S do not exhibit a consistent PCE concentration trend, while the PCE concentration at MW-27SU has dropped significantly since the well was first sampled in July 2007. All three of these wells still have PCE levels several times above the screening level in November 2011. Location MW-19S has only had one PCE result above 5 µg/l since 2005, and it appears to be decreasing in concentration. As shown on Figure 3-1, a slice through the plume at the center elevation of this hydrologic zone (570 ft msl) reveals PCE in groundwater within Upper and Lower Saprolite primarily, with some extending into the Residuum.

Figure 4-2 presents PCE concentration trends for Upper Intermediate Hydrologic Zone wells in which PCE has been detected above the screening level of 5 µg/l. These charts are also shown on the map on Figure 3-2. The only well in this group that exhibits a clear decreasing trend is MW-2SL. The other wells exhibit relatively steady concentrations or slight overall increasing trends. The highest PCE concentration detected in this zone is in MW-27B, with a slight overall increasing trend based on four sampling events leading up to a PCE level of 440 µg/l in November 2011. MW-31SU which, like MW-27B, is located downgradient from the Site in the central axis of the plume leading to Cooper Creek, is showing a slight overall increasing PCE trend since it was first sampled in November 2009. The third well in this zone with PCE levels well above the screening level is MW-21S. PCE levels at MW-21S were decreasing steadily from September 2004 (72 µg/l) until May 2010 (35 µg/l), before increasing to 110 µg/l in November 2011. Like MW-2SU, PCE levels at the other source area well, MW-2SL, have exhibited a decreasing trend since 2005, with PCE detected (5.5 µg/l) just above the screening level in November 2011. PCE levels at MW-30SU and MW-4SU have remained relatively close to 5 µg/l since sampling began at these wells. As shown on Figure 3-2, a slice through the plume at the center elevation of this hydrologic zone (545 ft msl) reveals PCE in groundwater within Upper and Lower Saprolite primarily, with some smaller areas extending into the Residuum and Weathered Bedrock.

Figure 4-3 presents PCE concentration trends for Lower Intermediate Hydrologic Zone wells in which PCE has been detected above the screening level of 5 µg/l. These charts are also shown on the map on Figure 3-3. PCE levels in MW-2B, MW-20B, and MW-31B have remained relatively consistent since monitoring began. PCE levels at MW-31B have vacillated between approximately 250 µg/l and 350 µg/l since this well was installed. PCE was detected at 270 µg/l in November 2011 in MW-31B. The other two wells in this zone have much lower concentrations, with PCE in MW-20B ranging from 5 to 15 µg/l (just above the screening level). PCE levels in MW-2B remain around 2.5 µg/l (just below the screening level). In November 2011, PCE was detected at MW-20B at 16 µg/l and at MW-2B at 1.1 µg/l. As shown on Figure 3-3, a slice through the plume at the center elevation of this hydrologic zone (515 ft msl) reveals PCE in groundwater within Bedrock and Weathered Bedrock primarily, with some extending into the Lower Saprolite.

Figure 4-4 presents PCE concentration trends for the single Upper Bedrock Hydrologic Zone well in which PCE has been detected above the screening level of 5 µg/l. This chart is also shown on the map on Figure 3-4. MW-3B shows relatively low levels of PCE, with an increasing trend from 2005 (1.2 µg/l) until November 2011 (5.7 µg/l)

PCE has not been detected above the screening level of 5 µg/l in any Lower Bedrock Hydrologic Zone wells.

Figure 4-5 presents TCE concentration trends for Shallow Hydrologic Zone wells in which TCE has been detected above the screening level of 0.44 µg/l (RSL). TCE trends in these wells were similar to PCE trends, with a decreasing TCE trend at source area well MW-2SU and a significant TCE drop at MW-27SU in November 2011. MW-9SU and MW-6S do not exhibit clear TCE trends, although they exhibited TCE levels many times above the screening value in November 2011. TCE was not detected above 5 µg/L (MCL) at or beyond the POC line during the LTGWMP prior to installation of MW-27SU in the spring of 2007.

Figure 4-6 presents TCE concentration trends for Upper Intermediate Hydrologic Zone wells in which TCE has been detected above the screening level of 0.44 µg/l (RSL). All of the wells in this zone exhibit relatively consistent TCE concentrations over time. MW-27B has the highest TCE levels in this zone. MW-27B , MW-31SU, and MW-30SU exhibit slight overall increasing TCE trends leading up to November 2011, with an occasional drop in concentrations between events. All wells in this zone have TCE levels many times above the screening level except MW-2SL (0.66 µg/l in November 2011).

Figure 4-7 presents TCE concentration trends for the single Lower Intermediate Hydrologic Zone well in which TCE has been detected above the screening level of 0.44 µg/l (RSL). TCE levels at MW-31B (like PCE levels) have remained relatively consistent, with TCE being detected at a level (56 µg/l) many times the screening level in November 2011.

TCE has not been detected above the screening level of 0.44 µg/l (RSL) in any Upper Bedrock Hydrologic Zone wells.

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Figure 4-8 presents TCE concentration trends for the single Lower Bedrock Hydrologic Zone well in which TCE has been detected above the screening level of 0.44 µg/l (RSL). MW-23BL has had only one TCE detection above the screening level, in February 2006. Since then TCE has not been detected in this well.

Figure 4-9 presents 1,1-DCE concentration trends for the Shallow Hydrologic Zone wells in which 1,1-DCE has been detected above the screening level of 7 µg/l (MCL). Once again the highest levels of this COC have been detected at source area well MW-2SU, with very high levels also at MW-9SU, MW-27SU, MW-26SU, and MW-6S. 1,1-DCE levels at several wells in this zone experienced large drops between June 2007 and November 2009, with 1,1-DCE not detected in June 2008, before rebounding to pre-drop levels by November 2011. All wells in this zone detected 1,1-DCE at levels above the screening level during the most recent sampling in May 2010 (for MW-27SU and MW-26SU) or November 2011 (for MW-2SU and MW-9SU) except for MW-28SU and MW-6S. 1,1-DCE was detected just below the screening level in MW-28SU in November 2011. 1,1-DCE was not detected in MW-6S in June 2008 and the well has not been sampled since.

Figure 4-10 presents 1,1-DCE concentration trends for the Upper Intermediate Hydrologic Zone wells in which 1,1-DCE has been detected above the screening level of 7 µg/l (MCL). 1,1-DCE levels have been relatively steady in MW-27B, MW-31SU, and MW-30SU, while no strong trends are discernible in the other wells in this zone. MW-27B has the highest levels of 1,1-DCE in this zone, with 650 µg/l detected in November 2011. 1,1-DCE at MW-31SU and MW-30SU appears to be slightly increasing overall, with levels of 220 and 41 µg/l, respectively, detected in 2011. 1,1-DCE in source area well MW-2SL has decreased overall since 2004, and 1,1-DCE was detected just above the screening level in November 2011. MW-4SU and MW-21S have shown relatively low levels of 1,1-DCE over time, and both wells had detections of 1,1-DCE below the screening level in November 2011. 1,1-DCE had not been detected above the screening level of 7 µg/L (MCL) in the compliance wells until the installation of MW-4SU in 2005. Wells in this zone also experienced large drops in 1,1-DCE detections between June 2007 and November 2009, before rebounding to pre-drop levels by 2010/2011.

Figure 4-11 presents 1,1-DCE concentration trends for the Lower Intermediate Hydrologic Zone wells in which 1,1-DCE has been detected above the screening level of 7 µg/l (MCL). The only well with elevated 1,1-DCE levels in this zone was MW-31B, which appears to show a decreasing trend, but still had a level of 360 µg/l in November 2011. 1,1-DCE has been detected at relatively high levels periodically in MW-2B, but since November 2009, it has been decreasing, with a detection of only 2.6 µg/l of 1,1-DCE (below the screening level) in November 2011.

1,1-DCE has not been detected above the screening level of 7 µg/l in any Upper Bedrock Hydrologic Zone or Lower Bedrock Hydrologic Zone wells.

Concentration trend charts were not created for metals, but chromium, cobalt, and manganese all exceeded their respective screening levels at POC wells in November 2011. Chromium was detected just over 100 µg/l (MCL) at MW-23BL. Cobalt was detected at over 200 times the screening level (RSL of 0.47 µg/l) in MW-2SL. Manganese was detected at over 300 times the screening level (RSL of 32 µg/l) at MW-4SU. In addition to these three metals, iron was detected at over 50 times the screening level (RSL of 1100 µg/l) in MW-19S, arsenic was detected at over 350 times the screening level (RSL of 0.045 µg/l) at MW-23BL, and thallium was detected at over 90 times the screening level (RSL of 0.016 µg/l) at MW-2SL.

PCE concentration trends (for wells exceeding the screening level of 5 µg/l) are compared to the sampled monitoring well groundwater levels on **Figure 4-12** through **Figure 4-15**. The relationship between precipitation and onsite average groundwater level was presented on Figure 2-5. Figures 4-12 through 4-15 extend this interaction to PCE concentration levels in specific wells. These charts indicate a relationship between groundwater level and PCE concentration. As shown on Figure 4-12, detected PCE concentrations in Shallow Hydrologic Zone samples collected from MW-2SU, MW-9SU, and MW-19S were low when the water levels were low, and the PCE levels were high when the water levels were high. The relationship could be described as fairly strong, with concentrations in MW-2SU, for example, exhibiting changes of up to 200%. The other wells in this zone did not exhibit a relationship between groundwater levels and PCE concentrations (MW-6S and MW-27SU).

The Upper Intermediate Hydrologic Zone PCE concentration and groundwater level comparison is presented on Figure 4-13. The wells in this zone that demonstrate a positive relationship between PCE concentration and groundwater level are MW-27B, MW-31SU, MW-2SL, MW-30SU, and MW-4SU. MW-21S does not appear to demonstrate a relationship. Wells in the Lower Intermediate Hydrologic Zone and the Upper Bedrock Hydrologic Zone (shown on Figure 4-14 and 4-15, respectively) appear to exhibit a weak inverse relationship between PCE concentration and groundwater level. This behavior is demonstrated on the chart for MW-20B. As water levels in the well increase, PCE concentrations tend to decrease and vice versa.

The mechanisms that are driving the relationship between water levels and PCE concentrations may be hypothesized. For the shallow water table wells like MW-2SU, it is possible that higher water levels allow for enhanced leaching of residual PCE soil contamination that may exist in the source area above the water table. For deeper wells within the Shallow Hydrologic Zone and Upper Intermediate Hydrologic Zone, it is possible that overall higher water levels are acting to enhance mobilization of contaminants across the Site and flush them through the subsurface. For the deepest wells in the Lower Intermediate Hydrologic Zone and the Upper Bedrock Hydrologic Zone, the inverse relationship may be explained by dilution effects.

4.2 Nature and Extent of Contamination

The nature and extent of contamination at the Site was visualized with standard 2D Geographic Information System (GIS) maps and using a 3D computer model. In addition to the PCE plumes presented on Figure 3-1 through Figure 3-5, concentration contour maps for an additional five COCs were created. **Figure 4-16** through **Figure 4-25** present contour maps for Upper and Lower Saprolite groundwater and for Bedrock groundwater for the following contaminants: TCE, cis-1,2-dichloroethene (cis-1,2-DCE), 1,1-DCE, vinyl chloride, and manganese. Based on direction from EPA, CDM Smith prepared this set of figures to provide additional representations of contamination at the Site, based on the most recent data collected. Many of these figures had already been created for the Round 55 November 2012) Quarterly Monitoring Technical Memorandum (CDM Smith 2013b). These additional figures were incorporated into this report with minimal changes to prevent reproduction of effort. Because Round 55 included sampling of monitoring well clusters 33, 34, and 35, which are located at elevations significantly below many of the other wells, wells were grouped for contouring by their stratigraphic layer and not by hydrologic zone. In Figure 4-16 through Figure 4-25, wells screened in Upper or Lower Saprolite are grouped together for presentation, and wells screened in Bedrock or Weathered Bedrock are grouped together for presentation. This grouping resulted in a few instances where concentrations at a single well cluster between the upper and lower well (e.g., Upper and Lower Saprolite well) differed significantly. In these cases the higher of the two values was chosen for contouring.

As presented on Figure 4-16, TCE in Upper and Lower Saprolite Stratigraphic Zone groundwater is present above 1 μg/L in a plume that extends from the southeastern corner of the landfill (in the vicinity of the former trenches) to north and then to the northeast. The plume generally aligns with potentiometric contours, though, its central axis more closely aligns with the northeastern-oriented fracture in the vicinity. Following a trend seen with other contaminants, there are elevated concentration areas of the plume around the former trench area and then northeast of MW9SU, with a lower concentration portion connecting the elevated areas.

As presented on Figure 4-17, TCE in Upper and Lower Bedrock Stratigraphic Zone groundwater is predominately present above 1 μg/L between MW-27B and MW-31B, with isolated detections beneath the eastern and western sides of the landfill. The bedrock plume also aligns well with the groundwater flow direction indicated by the potentiometric surface.

As presented on Figure 4-18, cis-1,2-DCE is present in Upper and Lower Saprolite Stratigraphic Zone groundwater above 1 μg/L in a plume that follows groundwater contours and extends from an elevated concentration area centered around MW-2SU downgradient to the north and northeast extending to MW-34SU.

As presented on Figure 4-19, cis-1,2-DCE is present in Upper and Lower Bedrock Stratigraphic Zone groundwater above 1 μg/L in a plume that follows groundwater contours and extends from MW-3B to MW-31B. This plume is relatively larger in the vicinity of the landfill than other bedrock plumes.

As presented on Figure 4-20, 1,1-DCE in Upper and Lower Saprolite Stratigraphic Zone groundwater is present above 1 μg/L in a plume that follows groundwater contours and extends from an elevated concentration area centered at MW-2SU and generally follows the horizontal gradient to the northeast before terminating in another elevated concentration area at MW-31SU.

As presented on Figure 4-21, 1,1-DCE in Upper and Lower Bedrock Stratigraphic Zone groundwater is present above 1 μg/L in a plume that follows groundwater contours and extends from MW-2B to the northeast to MW-31B. There are elevated concentrations between MW-27B and MW-31B. There is a drop off in concentrations downgradient of MW-2B (source area) before increasing again at MW-27B.

As presented on Figure 4-22, vinyl chloride in Upper and Lower Saprolite Stratigraphic Zone groundwater is present above 2 μg/L in a plume that follows groundwater contours and extends from MW-4SU to MW-31SU, with an isolated elevated concentration area centered at MW-2SU.

As presented on Figure 4-23, vinyl chloride in Upper and Lower Bedrock Stratigraphic Zone groundwater is only present in MW-31B.

As presented on Figure 4-24, manganese in Upper and Lower Saprolite Stratigraphic Zone groundwater is present above 32 μg/L in a pervasive plume that extends from the source area downgradient to elevated concentration areas at MW-4SU and MW-34SU. Untypically, compared to other COCs, manganese was also detected at elevated concentrations at MW-33SU, which is located downgradient and to the northwest of the landfill approximately 300 feet south of Cooper Creek.

As presented on Figure 4-25, manganese in Upper and Lower Bedrock Stratigraphic Zone groundwater is present above 32 μg/L in a plume that follows groundwater contours and extends from MW-27B downgradient to MW-31B. Untypically, manganese was also detected at elevated levels in MW-35B, which is located to the north of Cooper Creek. It is undetermined whether this result is due to contamination originating from the Site or due to elevated background levels of manganese.

November 2011 groundwater plumes were visualized using the 3D Site Model and are presented on **Figure 4-26** through **Figure 4-30.** The 3D Site Models have also been provided as electronic files on a compact data disc (CD) in **Appendix A** of this report and may be interactively viewed using free viewer software. Electronic files may be referenced for more detailed analyses. For wells that were not sampled in November 2011, the most recent available sample data were used in order to produce a spatially comprehensive 3D Site Model. In addition to groundwater well data, groundwater samples from soil borings collected during the RPs' 2009 SI were incorporated into the 3D Site Model to provide further delineation in the vicinity of the former trenches. 3D Site Model contaminant concentrations and sampling event information are presented on **Table 4-2**.

The 3D Site Model shows a transparent 3D plume volume for each contaminant, set to a 3D contour cutoff (generally set to the MCL or RSL) for display purposes, superimposed on a vertical slice which displays 2D concentration contours below the 3D plume cutoff. The slices (or cross-sections) also display lines indicating the transition lines between stratigraphic zones (i.e. the stratigraphic contact surfaces). The model views include each borehole with well screens colored using the same color scale as both the plumes and concentration slices and a land surface created using a detailed digital elevation model. These 3D Site Model views do not include contaminant data from monitoring well clusters 33, 34, or 35, as per agreement with EPA, because data from these wells was not collected prior to model development and were not scoped for this update. Thus all concentrations shown north of monitoring well clusters 30, 31, and 32 are estimated. However, the plumes shown provide a reasonable estimate of contaminant extent given the data available.

Figure 4-26 presents PCE in groundwater in a variety of views. The main portion of the PCE plume above the 5 µg/l MCL extends from the landfill boundary approximately 1,200 feet to the northeast, extending almost to Cooper Creek at this time. There is also a component of the plume above 5 µg/l of PCE centered around the vicinity of the former disposal trenches. The highest PCE concentrations fall within the Weathered Bedrock, while the plume exceeding 5 µg/l of PCE extends across the Upper Saprolite, Lower Saprolite, and Weathered Bedrock layers.

PCE plume slices are also presented on the potentiometric surface maps for hydrologic zones that had PCE present at their elevation (Figures 3-1 to 3-3). Slices were exported from the model for each hydrologic zone at the average elevation of the middle of the well screens for all wells in each zone. Plume slices are based on a contouring of all groundwater wells in three dimensions and thus are more accurate and representative than standard 2D contouring. The accuracy of the estimated plume contours is highest in areas of higher data density and lower in areas of less data (e.g., near the plume edge). These figures show that the PCE plume extent is largest in the Upper Intermediate Hydrologic Zone and Lower Intermediate Hydrologic Zone (well completion elevations from 475 ft msl to 555 ft msl). The highest PCE concentrations in the plume are located in the vicinity of the source area (disposal trenches), just north of the landfill (monitoring well clusters 26, 27, and 28), and in the vicinity of monitoring well cluster 31. In general the alignment of the PCE plume agrees with estimated potentiometric surface contours. For example on Figure 3-1, the shallow portion of the PCE plume appears to follow the shallow water table contours to the northwest. On Figures 3-2 and 3-3, the plume extends to the north toward Cooper Creek, and potentiometric contours also indicate flow in a northern direction. The PCE plumes slices shown for the Upper Intermediate Hydrologic Zone and the Lower Intermediate Hydrologic Zone actually indicate a plume that is moving to the north and northeast. While there is no estimated eastward component of flow based on the measured water levels at the Site, this slight disconnect may be due to transport occurring within the complex network of fractures.

Figure 4-27 presents 3D groundwater plumes for PCE and its breakdown products. 3D plumes are presented using plume cutoffs equal to their screening level. The plumes depicted for all of the COCs shown here exhibit similar shapes and extents, except for vinyl chloride, which is a significantly smaller plume. The plumes for PCE, TCE, cis-1,2-DCE, and 1,1-DCE are all extending almost to Cooper Creek (based on their selected screening level cutoffs). The PCE, TCE, and 1,1-DCE plumes all show a higher concentration zone near the source area, with a slight decrease in concentrations to the northeast past the landfill boundary. Then concentrations increase again further to the northeast toward Cooper Creek. The highest concentrations in the PCE plume were detected just north of the landfill and at MW-31B, which is located approximately half way between the landfill and Cooper Creek. This is also shown on the PCE plume slice from the model shown on Figure 3-3. The cis-1,2-DCE plume is unique for this group of COCs in that it shows a prominent lobe in the western portion of the landfill due to high detections at MW-3B and MW-5B. The 3D Site Model indicates that this part of the plume is not bounded by wells to the west at a similar depth within the bedrock. The vinyl chloride plume is relatively small and is centered around monitoring well clusters MW-4 and MW-19.

Figure 4-28 presents 3D groundwater plumes for other VOCs and one semivolatile organic compounds (SVOC) that have been defined as COCs for the Site. The groundwater plumes for 1,1-dichloroethane (DCA) and methylene chloride are similar in shape and extent to the PCE plume described above, based on the screening level cutoffs used in the 3D plumes (MCL or RSL). Due to differing screening levels used to present the 3D plume for each contaminant, the shapes of the plumes appear to vary significantly, but analysis of the vertical slice with concentration contours indicate that the overall plumes are similar. Generally, the plumes originate in the vicinity of the source area (former disposal trench area) and extend to the northeast, almost to Cooper Creek. The 1,1-trichloroethane (1,1-TCA) 3D plume high concentrations appear to be relatively small, as visualized, due to the high cutoff level applied to the model (MCL of 200 µg/l). In contrast, the 1,4-dioxane plume appears to be the largest, based on the low plume screening level cutoff used for visualization (RSL of 0.67 µg/l). The 1,4-dioxane plume has a lobe extending to the northwest from the northwest corner of the landfill due to detections just above 10 µg/l at MW-22B and MW-23B. The size of this lobe may be somewhat exaggerated due to the lack of bounding wells to the west or northwest of the two wells with detections at this depth. The benzene plume is also presented using a low 3D plume cutoff level of 0.39 µg/l (RSL). The methylene chloride and benzene groundwater plumes both have high concentrations in the vicinity of the landfill source area and then again surrounding MW-31B.

Figure 4-29 presents 3D groundwater plumes for three metals that were detected in November 2011 at concentrations in excess of their respective screening levels. The 3D plumes are presented with plume cutoffs equal to their screening levels, except for cobalt, which is presented above 10 µg/l due to a very low screening level value. Chromium in groundwater above 100 µg/l appears as high concentrations located in three areas of the Site; just off the northwest corner of the landfill (due to MW-15 and MW-23BL), in the vicinity of the source area (due to MW-20S), and just off the southwest corner of the Site (due to MW-12). Cobalt in groundwater above 10 µg/l is shown distributed across most of the landfill, with small lobes to the northwest (around MW-15) and to the north of the landfill (around the MW-4 cluster). Cobalt is also shown extending to the south of the landfill due to detections at the MW-2 cluster and at MW-21S. The plume is shown extending to the south due to the lack of bounding low concentration or non-detect samples to the south at similar elevations. Manganese above 32 µg/l (RSL) is widely distributed across the landfill and, unlike the other two metals presented here, also shows a significant plume extending to the northeast toward Cooper Creek.

Figure 4-30 presents a 3D groundwater uncertainty plume for PCE along with the approximate locations of the three new monitoring well clusters that were installed in November 2012. The PCE plume in this figure is colored by uncertainty and not by concentration. Uncertainty is a parameter calculated by MVS based on the spacing of the wells and on the magnitude of the concentration detected in a well. When the uncertainty is visualized, portions of the plume that are both under-characterized (i.e. sparse well spacings) and at a higher concentration (based on the nearest results that are available), are assigned a high uncertainty. Figure 4-30 presents the PCE plume with a 3D plume cutoff of 1 µg/L rather than 5 µg/l in order to visualize a larger portion of the plume. The figure demonstrates visually that the three new monitoring wells installed in November 2012 were placed at reasonable locations to detect and "bound" the leading edge of the groundwater plume. The figure also shows a lobe extending off the western side of the landfill centered around MW-5B and MW-22B. The PCE detections at these wells are low (<5 µg/l), but because this portion of the plume is not bounded by wells without detections to the west of the most westward PCE detections, the model is interpolating and displaying a PCE plume extending further to the west.

The point of compliance wells that were sampled during Round 51 (November 2011) were: MW-4SU, MW-4B, MW-7SU, MW-7SL, MW-5SL, MW-5B, MW-5BL, MW-22BL, and MW-23BL. Of these POC wells the following wells had screening level exceedances of various COCs in November 2011: MW-4SU, MW-5B, MW-5SL, MW-7SL, MW-7SU, MW-22BL, and MW-23BL. The following summary of POC results is from the RPs' Round 51 Long-Term Monitoring Report (Parsons 2012). Some screening levels listed below may have changed since the report was submitted if the screening level was based on an RSL.

- Screening levels for the following VOCs: 1,1,-DCA (2.4 µg/l), 1,2-DCA (0.15 µg/l), benzene (0.39 µg/l), cis-1,2-DCE (28 µg/l), PCE (0.072 µg/l), TCE (0.44 µg/l), and vinyl chloride (0.015 µg/l) were exceeded in POC wells.
- Four VOCs were detected above comparison levels in MW-4SU; 1,1-DCA at 460 µg/l, benzene at 9.9 µg/l, PCE at 5.8 µg/l, and vinyl chloride at 25 µg/l.
- Four VOCs were detected above comparison levels at MW-5B; benzene at 0.99 µg/l, cis-1,2-DCE at 82 µg/L, PCE at 3.2 µg/l, and TCE at 2 µg/l.
- Two VOCs were detected above screening levels at MW-5SL; 1,2-DCA at 0.36 µg/l and PCE at 0.54 µg/l. The PCE exceedance is based on the November 2011 screening level of 0.072 µg/l. As of November 2012 the PCE screening level is 5 µg/l.
- One VOC was detected above the screening levels at MW-5BL; PCE at 0.16 µg/l. The PCE exceedance is based on the November 2011 screening level of 0.072 µg/l. As of November 2012 the PCE screening level is 5 µg/l.
- Two VOCs were detected above screening levels at MW-7SL; benzene at 0.5 µg/l and PCE at 0.41 µg/l. The PCE exceedance is based on the November 2011 screening level of 0.072 µg/l. As of November 2012 the PCE screening level is 5 µg/l.
- 1,4-dioxane was detected above the screening level (0.67 µg/l) at MW-4SU, MW-5B, MW-7SL, MW-7SU, MW-22BL, and MW-23BL.
- Manganese and cobalt exceeded screening levels (320 and 4.7 µg/l, respectively) at MW-04SU, and chromium exceeded the screening level (100 µg/l) at MW-23BL.

In summary, eight out of the nine POC wells sampled during November 2011 had at least one screening level exceedance, although several of the exceedances were relatively minor. The one POC well that did not have an exceedance was MW-4B (Upper Bedrock Hydrologic Zone). 3D plumes were used to investigate the exceedances in the POC wells and to provide additional information to

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determine the effectiveness of these wells in monitoring the groundwater plume. The 3D groundwater plumes presented in the figures in this report show that the MW-4 POC cluster is in the primary area where groundwater contaminants have moved past the POC wells and are migrating beyond the Site. This has been an issue since 2009. The groundwater plumes migrating off the Site in this area include PCE, several other VOCs, 1,4-dioxane, and manganese. The 3D plumes show contamination starting at the landfill and moving to the north and downward in elevation from the Site toward Cooper Creek. The drop in the plume elevation as it moves to the north mirrors the drop in the land surface. As shown in the 3D plumes produced for most chemicals, contamination in this lobe of the plume is primarily distributed throughout the Upper and Lower Saprolite and Weathered Bedrock stratigraphic layers.

The 3D models indicate several other areas of the Site near POC wells in which the groundwater plume extends past the POC wells. One is to the west of MW-5B. The cis-1,2-DCE plume contains a prominent lobe in the western portion of the landfill due to high detections at MW-3B and MW-5B. This feature is also shown in the PCE plume on Figure 4-30. This area is not bounded by wells to the west at a similar depth within the bedrock. Detections at these wells have been relatively low. The November 2011 horizontal gradient in this area (Upper Bedrock Hydrologic Zone) is to the east from MW-5B toward the landfill, which would limit contaminant transport off of the Site. The 2008 Hydrogeological Report, however, indicated consistent westward flow in the Upper Bedrock Hydrologic Zone in this area.

3D plumes also indicate potential contamination outside of the POC line to the northwest of MW-22B and MW-23B. The 1,4-dioxane plume in the 3D Site Model contains a lobe at this location due to detections at these two wells above 10 µg/L. Again, this area is not bounded by any clean wells without COC detections to the west, which is why the model displays the plume extending substantially to the northwest away from the Site. Water levels at these wells were not available for November 2011, but the 2008 Hydrogeological Analysis shows horizontal gradients to the west and southwest in this vicinity.

The 3D plumes for cobalt, chromium, and manganese show additional areas where it is possible that some amount of Site contamination is migrating past the POC wells. Contributions from natural background metals concentrations make it difficult to determine what component of these plumes is due specifically to elevated metals levels from the landfill. The chromium 3D plume shows a high concentration at depth to the northwest of MW-23BL. It also shows small lobes extending off of the Site in the Shallow Hydrologic Zone around MW-12 and MW-15. The cobalt 3D plume has a high concentration around and to the northwest of MW-15. The cobalt plume also is shown extending to the south of the landfill through the Residuum and Upper and Lower Saprolite layers due to large detections at MW-2SL and MW-2SU without any bounding wells located at similar depths to the south. Cobalt was not detected at the MW-24 cluster or in any of the POC wells in the MW-7 cluster, but these well screens are located below the elevation of the MW-2 cluster wells. Because the 3D Site Model estimates plume extent by placing a higher emphasis on wells located at the same vertical elevation, the cobalt plume is not being bounded to the south of the landfill. The manganese plume is unique among the 3D plumes in that it shows elevated levels (above the screening level of 32 µg/l) extending beyond the Site boundaries on all sides. Unlike the other two metals, there is also a prominent northward lobe of the manganese plume extending toward Cooper Creek. Metals occur naturally at the Site (e.g., manganese was detected at 779 µg/l in background well MW-1S). The degree to which elevated metals concentrations are Site-related is currently a subject of investigation.

Using the elevation-based hydrologic zone designations, a systematic analysis of the degree of Site characterization was performed to determine areas of the Site that are currently under-characterized (e.g., where the plume is unbounded). This analysis was performed by comparing well locations in each hydrologic zone to the PCE 5 µg/L (MCL) contour line. There are currently no Shallow Hydrologic Zone wells (well completion elevations above 555 ft msl) bounding the >5 µg/L PCE plume to the south (e.g., in the vicinity of monitoring well clusters 7 or 24). Potentiometric surface contours do not suggest groundwater flow to the south; however, in this area of the Shallow Hydrologic Zone. There are currently no Upper Intermediate Hydrologic Zone wells (well completion elevations from 525 to 555 ft msl) bounding the plume to the west in the vicinity of the MW-22 well cluster or to the southeast of MW-21S. Like the Shallow Zone; however, horizontal gradients in these areas are perpendicular to, rather than towards, the edge of the plume, decreasing the likelihood that contaminants may be found beyond the current plume bounds. However, hydraulic gradient alone is not a pure indicator of contaminant transport, as evidenced by the main lobe of the plume extending to the northeast into Cooper Creek. There are currently no Lower Intermediate Hydrologic Zone wells (well completion elevations from 475 to 525 ft msl) bounding the plume to the south of MW-21S or to the east of MW-26SU. Horizontal gradients in these areas are perpendicular to, rather than towards, the edge of the plume. There are currently no Upper Bedrock Hydrologic Zone wells (well completion elevations from 425 to 475 ft msl) or Lower Bedrock Hydrologic Zone wells (well completion elevations below 425 ft msl) bounding the plume to the south of MW-21S or east of the MW-25 cluster.

The lobe of the PCE plume extending to Cooper Creek is predominately distributed within the Upper and Lower Intermediate Hydrologic Zones. The plume in the Upper Hydrologic Zone is currently not bounded to the east of MW-32SU or to the west of MW-30SU, although relatively low detections at these two wells in Round 55 indicate that the edge of the PCE plume is being approached. The leading edge of the PCE plume is found primarily within the Lower Intermediate Hydrologic Zone and is adequately characterized, though the northwest corner of the leading edge of the plume (between monitoring well clusters 33 and 34) is not bounded by a well in this zone. The leading edge of the PCE plume is not bounded by wells in the Upper or Lower Bedrock Hydrologic Zones, though analysis of spatial contamination trends and the 3D Model suggest PCE contamination is not likely present in these deeper zones in this area.

Figure 4-31 presents a comparison of PCE concentrations in the Upper Intermediate Hydrologic Zone groundwater between November 2009 (Round 43) and November 2012 (Round 55). Round 43 was chosen because it was the first date for which data were collected from the MW-30/31/32 clusters. Round 55 was chosen as it is the most recent dataset. As the figure shows, the change in PCE levels over the three years has not been consistent at each well location. Slight increases were observed in the source area, but at the most contaminated well near the plume midsection (MW-27B) a PCE concentration decrease was observed. At the most contaminated downgradient well (MW-31SU), a PCE concentration increase was observed. However, it does not appear that significantly higher levels of Site contamination (PCE) are quickly approaching Cooper Creek. Some of this concentration variability may be impacted by precipitation (water level conditions) and bio-attenuation. The average Site groundwater level for November 2012 was approximately three feet lower than November 2009. Future sampling of the three new monitoring wells installed in November 2012 will provide information to characterize the leading edge of the groundwater plume.

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Section 5

Groundwater to Surface Water Discharge Evaluation

In September 2011, the RPs conducted a tree core and stream sampling investigation along a transect between the Site monitoring wells and Cooper Creek and along the creek itself. Chlorinated VOCs and 1,4-dioxane were detected in some of the tree core and surface water samples from the creek at low levels, resulting in the conclusion that Cooper Creek is a groundwater discharge area. The RPs' investigation report (Parsons 2012) recommended that additional groundwater wells be installed in the vicinity of Cooper Creek to improve delineation of groundwater impacts. The RPs subsequently installed additional wells in this area in November 2012.

In February, May, and July 2012, CDM Smith conducted additional creek investigation field events on behalf of EPA, during which stream infrared imagery was taken, electrical conductivity values were measured, and creek surface water and sediment samples were collected. The infrared imagery investigation was submitted with the Round 52 Oversight Report (CDM Smith 2012). Reporting for the other investigations will be submitted to EPA in a future report. Interpretation of electrical conductivity and infrared images has been inconclusive as far as indicating areas of groundwater/surface water interaction. Chlorinated VOCs, SVOCs (including 1,4-dioxane), and metals were detected in surface water samples collected by CDM Smith, providing additional evidence of potential groundwater impacts to Cooper Creek.

In February and March 2013, CDM Smith installed sets of piezometers and staff gauges at three locations along and to the south of Cooper Creek for EPA. Water level readings from the piezometers and staff gages will be used to improve understanding of the groundwater/surface water interaction at Cooper Creek.

The 3D Site Model has been extended to the north to include Cooper Creek, and a much more detailed land surface (digital elevation model) has been added to define the creek valley. The creek and surface water sampling locations have been added to the 3D Site Model to aid in interpretation. Groundwater plumes shown on Figures 3-6, 3-7, and 4-16 through 4-19 clearly show that Site contamination is moving from the landfill to the north-northeast within the Upper and Lower Saprolite and Weathered Bedrock layers and dropping in elevation (following the land surface elevation) as Cooper Creek is approached. The current 3D plumes show the leading edge of the groundwater plume intersecting Cooper Creek and indicate that low levels of groundwater contamination are likely entering Cooper Creek.

The fracture planes underlying the Site (shown on Figure 2-3) have been described as potential conduits for groundwater contaminants. The fracture plane aligned in a northeast-southwest direction seems to provide a potential preferential pathway for groundwater contamination to move from the landfill toward Cooper Creek. The second fracture plane (northwest-southeast alignment) is another potential conduit for groundwater contamination to migrate off of the Site and reach farther downstream segments of the creek. For example, 1,4-dioxane was detected in tree core 9 (TC-9), which is located approximately 1,000 feet downstream from the main groundwater plume/stream intersection and approximately in line with the axis of the second fracture plane. In November 2012, the RPs installed an additional monitoring well cluster (MW-33SU/B) to detect any potential lobe of the groundwater plume in this area, however no data was available at the time of the 3-D Model development.

CDM Smith performed an analysis of the receiving waters of Cooper Creek using the Virginia Department of Environmental Quality (VDEQ) online map tool. As shown on **Figure 5-1**, water flows from Cooper Creek, into Warner Branch, then into Horsepen Creek, and then into the Slate River. No surface water reservoirs are close enough to be impacted by potential contamination from Cooper Creek. The closest reservoir to the Site is approximately 3.5 miles to the north and does not receive drainage from Cooper Creek.

Section 6

Conclusions and Recommendations

CDM Smith has updated the 2008 Hydrogeological Analysis and the 2008 3D Site Model using water level data and analytical data from field studies conducted since 2008. The primary analytical dataset used to present the updated contamination summary was the comprehensive November 2011 sampling event. Site water levels from quarterly events conducted between November 2011 and August 2012 were analyzed to describe groundwater movement at the Site. Conclusions and recommendations are presented below.

6.1 Conclusions

The conclusions are grouped by general topic and are presented in the following order: horizontal and vertical hydraulic gradients, influence of geologic structure on groundwater flow, concentration trends, concentration versus precipitation, POC exceedance summary, groundwater to surface water discharge, site characterization, and plume uncertainty.

Horizontal Gradients

Potentiometric surface maps indicate that the horizontal hydraulic gradient in the Shallow, Upper Intermediate, and Lower Intermediate Hydrologic Zones is, in general, to the northwest in the vicinity of the landfill, and to the north (which is perpendicular to topography) between the landfill and Cooper Creek. Horizontal gradients in the Upper Bedrock and Lower Bedrock Hydrologic Zones are to the west. Horizontal gradients in the southwestern corner of the Site in the layers above bedrock are also perpendicular to topography. The horizontal gradients trend toward a tributary to Warner Branch; however, because this stream is intermittent near the Site and a contaminant plume does not extend to the stream, it is not likely that contaminated groundwater has entered Warner Branch. Contamination has not been detected in the shallow groundwater wells just north of Warner Branch (MW-5S, MW-12). Horizontal gradients in the southern portion of the Site are relatively uniform to the west or northwest, whereas the northern portion of the Site has a more complicated flow system. The stratigraphy within the Shallow Hydrologic Zone suggests some potential impacts of geology on local flow patterns. Horizontal hydraulic gradients are slightly lower in the Lower Saprolite than the Upper Saprolite. The transition between Lower and Upper Saprolite is not a discrete one, so hydraulic conductivities in these two stratigraphic layers may not differ substantially. In addition, the Bedrock/Lower Saprolite mound centered east of the landfill may be enhancing the radial flow patterns in the vicinity of MW-20S, though the main driver for this flow pattern may be the northeast-oriented fracture in this area. Varying stratigraphy in the Upper and Lower Intermediate Hydrologic Zones does not appear to have a significant effect on flow patterns in those zones.

Horizontal gradients in the Shallow Hydrologic Zone are slightly higher than in the Upper Intermediate Hydrologic Zone. Gradients in the Upper and Lower Intermediate Hydrologic Zones are similar. Horizontal gradients in the Upper Bedrock Hydrologic Zone are considerably lower than those in the overlying zones. Horizontal gradients in the Lower Bedrock hydrologic zone were the highest of any zone in November 2011, though only four wells were sampled in that zone from which gradients were calculated.

Vertical and Flow Net Gradients

Vertical hydraulic gradients are detected at many nested wells across the Site. However, there are many locations exhibiting upward gradients and even convergent and divergent flow toward or away from wells within nested clusters with at least three wells screened at different elevations. Upward gradients exist at many of the bedrock wells including MW-2B, MW-20B, MW-27B, and MW-31B. These wells, most of which are located in the Upper Bedrock or Weathered Bedrock Stratigraphic Layers are all currently contaminated with COCs. Upward gradients at these locations are likely restricting the downward migration of contamination into the deeper bedrock.

Cross-sectional groundwater head (flow net) contours indicate that the general hydraulic gradient is downward beneath the landfill and downward and to the north between the landfill and Cooper Creek. The observed hydraulic gradient aligns well with the prevailing gradient suggested by the estimated groundwater 3D PCE plume, which shows transport of PCE along a flow path that is perpendicular to the head contours projected onto the cross-section. Closer to the creek, the lateral gradient begins to move upward toward the creek.

Cross-sectional head contours on a transect perpendicular to the main plume axis show that the average horizontal groundwater gradient beneath the Site is to the west and northwest, which is in agreement with plan view potentiometric surface maps. Inflections in the head contours in the Upper Saprolite and Weathered Bedrock stratigraphic layers provide visual evidence of the complex vertical gradients experienced at many nested wells across the Site. The groundwater gradient is more lateral from east to west through the plume in the source area and within the bedrock layers.

Influence of Geologic Structure on Groundwater Flow

Groundwater occurrence and flow in the Residuum and Upper Saprolite layers (Shallow and Upper Intermediate Hydrologic Zones) are likely controlled by the openings (or pore spaces) between the grains and fragments of these very weathered materials. The direction of groundwater flow likely follows the hydraulic gradient in the upper reaches of the Residuum. At depth, in the bedrock and saprolite, the occurrence and flow of groundwater is likely controlled by fractures and structure in the rock, and relict structure in the saprolite. The directions of the groundwater flow paths are likely discrete and tortuous, which is typical for fractured bedrock hydrogeology. A comparison of stratigraphy to potentiometric surface contours for each hydrologic zone, however, did not indicate that transitioning between stratigraphic layers was strongly affecting groundwater flow paths within a given zone.

Concentration Trends

The highest concentrations of PCE, TCE, and 1,1-DCE continue to be found in the source area (MW-2SU, MW-2SL). The next highest detections in groundwater tend to be to the north of the Site along the central axis of the plume at MW-9S, MW-27SU, MW-27B, MW-31SU, and MW-31B. PCE has been detected in MW-27B and MW-31SU at relatively high and consistent concentrations since these wells were installed in 2009. Source area wells exhibit decreasing trends over time.

PCE contamination in groundwater above the MCL (5 µg/L) within the Shallow Hydrologic Zone occurs primarily in the Upper and Lower Saprolite, with some extending into the Residuum. PCE in groundwater above the MCL within the Upper Intermediate Hydrologic Zone occurs primarily within the Upper and Lower Saprolite, with some smaller areas extending into the Residuum and Weathered Bedrock. PCE in groundwater above the MCL in the Lower Intermediate Hydrologic Zone occurs primarily within Bedrock and Weathered Bedrock, with some extending into the Lower Saprolite.

Concentration Versus Precipitation

Contaminant concentrations in some upper zone wells (MW-2SU, MW-2SL, MW-4SU, MW-9SU, MW-19S, MW-27B, MW-31SU, and MW-30SU) demonstrate a positive relationship with groundwater level. Concentration levels in some deeper wells (MW-3B, MW-20B, and MW-31B) demonstrate an inverse relationship with groundwater level. When interpreting concentration trends, the impact of precipitation should be taken into account, especially at these 11 wells.

POC Exceedance Summary

The nine POC wells that were sampled during Round 51 (November 2011) were: MW-4SU, MW-4B, MW-7SU, MW-7SL, MW-5SL, MW-5B, MW-5BL, MW-22BL, and MW-23BL. Seven of the nine POC wells had screening level exceedances: MW-4SU, MW-5B, MW-5SL, MW-7SL, MW-7SU, MW-22BL, and MW-23BL.

Groundwater to Surface Water Discharge

The 3D plumes for PCE and other COCs suggest that Cooper Creek is a groundwater discharge area. Contaminant concentrations detected in tree cores collected near the creek and in creek surface water samples also suggest Cooper Creek is a groundwater discharge location. The direction and alignment of the PCE and other contaminant plumes (VOC and metals) are in agreement with cross-sectional head contours. However, the leading edge of the groundwater plume is not fully characterized.

Site Characterization

The 3D plumes for PCE and other COCs suggest the main area in which contamination has moved past the POC wells is north of the MW-4 cluster, which is where the main lobe of the groundwater plume emanating from the Site is located. Secondary areas where contamination has the potential to be found beyond POC wells are west of MW-5B and northwest of MW-22B and MW-23B. Additionally, the 3D plumes for three metals indicate additional areas where contamination may have moved past POC wells. These areas impacted by metals include northwest of MW-23BL, around MW-12 and MW-15, and south of the landfill in the Shallow and Upper Intermediate Zones.

Using the elevation-based hydrologic zone designations, an analysis of the degree of Site characterization was performed to determine areas of the Site that are currently under-characterized (e.g., where the plume is unbounded). This analysis was performed by comparing well locations in each hydrologic zone to the PCE 5 µg/L (MCL) contour line. There are currently no Shallow Hydrologic Zone wells bounding the groundwater plume to the south. There are currently no Upper Intermediate Hydrologic Zone wells bounding the plume to the west in the vicinity of the MW-22 well cluster or to the southeast of MW-21S. There are currently no Lower Intermediate Hydrologic Zone wells bounding the plume to the south of MW-21S or to the east of MW-26SU. There are currently no Upper Bedrock Hydrologic Zone wells or Lower Bedrock Hydrologic Zone wells bounding the plume to the south of MW-21S or east of the MW-25 cluster. Horizontal gradients, in general, along the west, south, and east sides of the Site are perpendicular to, rather than towards, the edge of the plume, decreasing the likelihood that contaminants may be found beyond the current plume bounds. However, hydraulic gradient alone is not a pure indicator of contaminant transport, as evidenced by the main lobe of the plume extending to the northeast into Cooper Creek. The lobe of the plume extending to Cooper Creek is predominantly distributed within the Upper and Lower Intermediate Hydrologic Zones. The plume in the Upper Hydrologic Zone is currently not bounded to the east of MW-32SU or to the west of MW-30SU, although relatively low detections at these two wells in Round 55 indicate that the edge of the plume is being approached. The leading edge of the PCE plume is found primarily within the Lower Intermediate Hydrologic Zone and is adequately characterized, though the northwest corner of the leading edge of the plume (between well clusters 33 and 34) is not currently bounded by a well in this zone. The leading edge of the plume is not bounded by wells in the Upper or Lower Bedrock Hydrologic Zones, although analysis of spatial contamination trends and the 3D model suggest contamination is not likely present in these deeper zones in this area.

Plume Uncertainty
A 3D uncertainty analysis suggests that the three new wells installed by the RPs in November 2012 were placed at reasonable locations to detect and bound the leading edge of the groundwater plume.

6.2 Recommendations

The following activities are recommended to continue improving characterization of the groundwater plume and to improve the understanding of the surface water/groundwater interaction at the Buckingham County Landfill Superfund Site.

- Use the data collected to date, and the data collected in response to these recommendations, to develop a comprehensive conceptual site model (CSM). Use the CSM to develop remedial action objectives (RAOs) and a sitewide remediation strategy that will address the RAOs.

- Perform investigations to improve definition of the horizontal and vertical extent of the contaminant plume across the Site. Consider the installation of additional monitoring wells, soil borings, or in-situ technologies such as a membrane interface probe (MIP). Consider the use of downhole geophysics during these investigations to provide higher resolution geologic/stratigraphic data.

- Continue to assess low-level concentration trends in POC and other outlying wells along the west, south, and east sides of the landfill. Continue to assess VOC concentration trends in MW-5B, MW-22B, and MW-23B to determine if placement of additional bounding wells is needed to the west and northwest of these existing wells. Continue to assess metals concentration trends in MW-12, MW-15, and MW-23BL to determine if additional bounding wells are needed outside of these existing well locations. Continue to monitor metals concentrations in MW-7SU to determine if additional bounding wells are needed south of the Site in the Shallow Zone above the elevation of MW-7SU. None of these wells has exceeded the screening level of 5 µg/l for PCE, although some wells have been detected just above screening levels. Monitor these wells to determine concentration trends and, if screening levels are consistently exceeded in the future, consider the installation of additional bounding wells.

- Continue to monitor concentrations on a quarterly basis at the new well clusters located in the vicinity of Cooper Creek (MW-33/34/35). Collect additional surface water samples during low-flow and high-flow stream conditions to compare with the new monitoring well results, including the analysis of SVOCs in surface water and groundwater to confirm additional potential COCs. Continue to monitor rising PCE levels at MW-31SU.

- Collect additional samples from Warner Branch surface water to determine the presence of COCs in this tributary, which is located closer to local residences. Develop a plan for mitigating discharge of Site contaminants to surface water if levels exceed appropriate thresholds.

- Evaluate background metals concentrations and assess Site geochemistry to determine the origin and fate of elevated metals concentrations. Sample the groundwater well at the animal shelter upgradient from the Site to provide additional background level information.

- Collect water level readings from the staff gauges and piezometers installed along Cooper Creek in February and March 2013 several more times throughout the year. Use these data to develop potentiometric surface contours leading up to the creek and to estimate creek flow rates for determining whether fluctuations in the gaining area of the creek are due to groundwater discharge.

Section 7

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ORIGINAL

Table 2-1
Monitoring Well Stratigraphic Units and Hydrologic Zones

Well #	Date Installed	Ground Elevation (ft)	TOC Elevation (ft)	Top of Screen Depth (ft)	Bottom of Screen Depth (ft)	TOS Elevation (ft)	BOS Elevation (ft)	Stratigraphic Unit
Shallow (Well completion elevations above 555 ft amsl)								
MW-01S	11/16/82	617.2		42	47	575.2	570.2	Upper Saprolite
MW-2SU	4/13/92	612.0		32.5	42.5	579.5	569.5	Upper Saprolite
MW-3S	5/20/82	610.2		29	34	581.2	576.2	Upper Saprolite
MW-4S	4/11/92	614.6		33	43	581.6	571.6	Upper Saprolite
MW-5S	3/18/86	586.4		19	28	567.4	558.4	Upper Saprolite
MW-6S	4/10/92	611.1		32	42	579.1	569.1	Upper Saprolite
MW-8S	11/16/82	615.3		43.7	48.7	571.6	566.6	Upper Saprolite
MW-9S	3/17/86	612.4		39	49	573.4	563.4	Upper Saprolite
MW-9SU	6/1/07	611.3		40.5	50.5	570.8	560.8	Upper Saprolite
MW-10S	3/18/86	606.9		39	48	567.9	558.9	Upper Saprolite
MW-13	4/23/82	623.6		45	50	578.6	573.6	SU/SL
MW-15	3/18/86	610.9		40	48	570.9	562.9	Upper Saprolite
MW-19S	11/19/96	611.4		39	49	572.4	562.4	SU/SL
MW-20S	11/19/96	615.7		38	48	577.7	567.7	Lower Saprolite
MW-22SU	12/12/05	606.8		40	50	566.8	556.8	Upper Saprolite
MW-25S	8/17/98	621.8		20.8	40.8	601.0	581.02	Lower Saprolite
MW-25SL	11/7/05	623.1		47	57	576.1	566.1	Weathered Bedrock
MW-26SU	5/29/07	609.8		38	48	571.8	561.8	Upper Saprolite
MW-27SU	5/30/07	602.7		28	38	574.7	564.7	Upper Saprolite
MW-28SU	5/31/07	603.5		32	42	571.5	561.5	Upper Saprolite
Upper Intermediate (Well completion elevations 525 - 555 ft amsl)								
MW-2SL	11/25/86	610.6		34	64	576.6	546.6	SU/SL/WB
MW-4SU	11/3/05	612.2		51.8	61.8	560.4	550.4	Lower Saprolite
MW-7S	4/22/82	594.4		40	45	554.4	549.4	Upper Saprolite
MW-7SU	11/9/09	593.88	596.56	60	70	536.56	526.56	Upper Saprolite
MW-12	4/22/82	588.2		39.2	44.2	549.0	544.0	Weathered Bedrock
MW-21S	11/20/96	609.8		50	60	559.8	549.8	Lower Saprolite
MW-25B	8/19/98	622.0		63.1	83.1	558.9	538.9	Upper Bedrock
MW-27B	11/10/09	607.24	609.76	70	80	539.76	529.76	Upper Bedrock
MW-29SU	9/29/09	611.83	611.46	60	70	551.46	541.46	Upper Saprolite
MW-30SU	11/6/09	601.5	604.11	65	75	539.11	529.11	Upper Saprolite
MW-31SU	10/28/09	601.21	603.9	65	75	538.9	528.9	Upper Saprolite
MW-32SU	10/29/09	605.01	608.01	70	80	538.01	528.01	Upper Saprolite
Lower Intermediate (Well completion elevations 475 - 525 ft amsl)								
MW-1B	4/13/92	617.9		93	103	524.9	514.9	Upper Bedrock
MW-2B	4/22/92	611.8		71.5	91.5	540.3	520.3	Upper Bedrock
MW-5SL	8/20/98	584.6		63.5	83.5	521.1	501.1	Weathered Bedrock
MW-7SL	5/21/97	593.3		76	96	517.3	497.3	Lower Saprolite
MW-20B	5/5/97	615.4		85	105	530.4	510.4	Upper Bedrock
MW-22SL	5/1/97	605.6		85	105	520.6	500.6	Weathered Bedrock
MW-23SL	5/1/97	610.4		90	110	520.4	500.4	Weathered Bedrock
MW-24SL	5/22/97	586.2		70	90	516.2	496.2	Weathered Bedrock
MW-29B	11/3/09	613.14	612.41	87	97	525.41	515.41	Upper Bedrock
MW-31B	10/27/09	601.46	603.97	80	90	523.97	513.97	Upper Bedrock
MW-33SU	11/10/12	579.87	582.18	73	83	506.87	496.87	upper saprolite
MW-34SU	10/27/12	582.88	584.73	51.6	61.6	531.28	521.28	upper saprolite
MW-34B	10/29/12	581.26	583.06	86	76	495.26	505.26	upper bedrock
MW-35SU	11/14/12	552.71	555.98	41	51	511.71	501.71	upper saprolite
MW-35B	11/13/12	553.41	555.06	29.5	39.5	523.91	513.91	upper bedrock
Upper Bedrock (Well completion elevations 425 - 475 ft amsl)								
MW-3B	4/21/92	606.9		140.5	150.5	466.4	456.4	Upper Bedrock
MW-4B	4/22/92	615.0		119.7	149.7	495.3	465.3	Upper Bedrock
MW-5B	4/20/92	586.1		128	138	458.1	448.1	Upper Bedrock
MW-22B	8/20/98	606.9		122.5	142.5	484.4	464.4	Upper Bedrock
MW-23B	4/30/97	610.5		130	150	480.5	460.5	Upper Bedrock
MW-24B	5/22/97	586.1		135	145	451.1	441.1	Upper Bedrock
MW-33SL	11/9/12	578.05	580.53	134	124	444.05	454.05	lower saprolite
Lower Bedrock (Well completion elevations below 425 ft amsl)								
MW-5BL	10/26/05	584.8		210	220	374.8	364.8	Lower Bedrock
MW-7BL	11/1/05	592.7		195	205	397.7	387.7	Lower Bedrock
MW-22BL	12/16/05	606.6		264	274	342.6	332.6	Lower Bedrock
MW-23BL	10/31/05	611.2		204	214	407.2	397.2	Lower Bedrock

Notes:
Elevations in feet above mean sea level.
Depths in feet below ground surface.
WB - Weathered Bedrock, SL - Lower Saprolite, SU - Upper Saprolite; A / indicates well is screened over more than one stratigraphic unit.

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Table 2-2
Groundwater Elevations - Round 51 (November 2011)

Well ID	Groundwater Elevation	Depth to Water
MW-1S	578.86	39.4
MW-1B	578.19	40.78
MW-2SU	575.59	37.39
MW-2SL	574.76	39.76
MW-2B	576.06	36.82
MW-3S	NA	NA
MW-3B	572.11	36.82
MW-4S	NA	NA
MW-4SU	574.85	39.97
MW-4B	574.91	39.45
MW-5S	566.4	19.9
MW-5SL	571.98	15.4
MW-5B	573.7	13.38
MW-5BL	562.03	25.5
MW-6S	573.74	38.32
MW-7S	574.61	17.8
MW-7SL	576.09	20.52
MW-7SU	576.62	20.1
MW-7BL	575.05	19.75
MW-8S	574.67	42.31
MW-9S	572.88	39.6
MW-9SU	571.07	41.49
MW-10S	567.84	39.02
MW-12	578.11	9.26
MW-13	573.43	48.64
MW-15	568.96	42.78
MW-19S	575.16	39.15
MW-20S	577.23	41.41
MW-20B	577.26	41.06
MW-21S	577.61	35.1
MW-22SU	567.82	41.7
MW-22SL	NA	NA
MW-22B	NA	NA
MW-22BL	559.51	49.94
MW-23SL	NA	NA
MW-23B	NA	NA
MW-23BL	568.25	45.75
MW-24SL	575.65	13.56
MW-24B	572.18	16.8
MW-25S	NA	NA
MW-25B	578.97	45.44
MW-25SL	NA	NA
MW-26SU	570.31	41.32
MW-27SU	NA	NA
MW-27B	571	39.41
MW-28SU	571.99	33.91
MW-29SU	570.43	41.4
MW-29B	570.36	42.78
MW-30SU	564.72	39.75
MW-31SU	565.35	39
MW-31B	566.11	38.64
MW-32SU	570.5	37.92

Notes: NA = not available
Upper Saprolite (SU) wells used to define water table

Table 3-1
Groundwater Velocity Calculations

ORIGINAL

Shallow Zone

K values	ft/day
MW-03S	2.10E-01
MW-04S	3.00E-01
MW-05S	7.15E-01
MW-10S	4.20E+00
Average K	1.36E+00
Geometric Mean K	6.59E-01

Gradients	Round 36 Mar-08	Round 51 Nov-11	Round 52 Feb-12	Round 53 May-12	Round 54 Aug-12	All Dates Average
MW-01S to MW-05S	0.013	0.017	0.009	0.011	0.009	
MW-19S to MW-26SU	0.031	0.021	0.021	0.019	0.030	
Average Gradient	0.0220	0.0190	0.0150	0.0147	0.0194	
Geometric Mean Gradient	0.0201	0.0190	0.0136	0.0142	0.0162	
assume porosity for sandy silt[2]	0.3					
Average GW velocity (ft/day)	**0.10**	**0.09**	**0.07**	**0.07**	**0.09**	**0.08**
Geo Mean GW velocity (ft/day)	0.04	0.04	0.03	0.03	0.04	

Upper Intermediate Zone

K values	ft/day
MW-02SL (from pump test)	1.5

Gradients	Round 36 Mar-08	Round 51 Nov-11	Round 52 Feb-12	Round 53 May-12	Round 54 Aug-12	All Dates Average
MW-21S - MW-02SL	0.015	0.015	0.012	0.013	0.006	
Assume porosity silty sand[2]	0.3					
Groundwater velocity (ft/day)	**0.08**	**0.07**	**0.06**	**0.07**	**0.03**	**0.06**

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Table 3-1
Groundwater Velocity Calculations

Lower Intermediate Zone

K values	ft/day
MW-02B (from pump test)	1.70E+00
MW-01B (from slug tests)	1.09E+00
Average K	1.40E+00
Geometric Mean K	1.36E+00

Gradients	Round 36 Mar-08	Round 51 Nov-11	Round 52 Feb-12	Round 53 May-12	Round 54 Aug-12	All Dates Average
MW-01B to MW-24SL	0.010	0.005	0.005	0.008	0.006	
MW-07SL to MW-24SL	0.015	0.003	0.003	0.010	0.018	
Average Gradient	0.0124	0.0038	0.0043	0.0090	0.0120	
Geometric Mean Gradient	0.0122	0.0037	0.0042	0.0089	0.0104	
assume weathered rock porosity^2	0.45					
Average GW velocity (ft/day)	**0.04**	**0.01**	**0.01**	**0.03**	**0.04**	**0.03**
Geo Mean GW velocity (ft/day)	0.04	0.01	0.01	0.03	0.03	

Upper Bedrock Zone

K values	ft/min	ft/day
MW-05BL (125 - 135)	3.88E-03	5.59E+00
MW-07BL (153 - 163)	8.69E-04	1.25E+00
Average K	3.42E+00	
Mean K	2.64E+00	

Gradients	Round 36 Mar-08	Round 51 Nov-11	Round 52 Feb-12	Round 53 May-12	Round 54 Aug-12	All Dates Average
MW-04BR to MW-20B	0.018	0.011	0.013	0.019	0.003	
MW-24B to MW-05B	0.034	0.007	0.021	0.023	0.017	
Average Gradient	0.0261	0.0090	0.0170	0.0211	0.0100	
Mean Gradient	0.0247	0.0088	0.0165	0.0211	0.0073	
Assume fracture porosity^1	0.05					
Average GW velocity (ft/day)	**1.78**	**0.62**	**1.16**	**1.45**	**0.69**	**1.14**
Geo Mean GW velocity (ft/day)	1.31	0.46	0.87	1.11	0.39	

Table 3-1
Groundwater Velocity Calculations

ORIGINAL

	Groundwater Elevations:				
	Round 36	Round 51	Round 52	Round 53	Round 54
Wells	**Mar-08**	**Nov-11**	**Feb-12**	**May-12**	**Aug-12**
MW-01B	584.67	578.19	580.09	581.58	580.32
MW-01S	585.85	578.86	580.56	582.00	581.06
MW-02SL	580.42	574.76	576.88	577.46	577.51
MW-04B	578.28	574.96	576.10	576.87	577.05
MW-05B	569.00	573.70	569.38	569.59	570.07
MW-05S	576.53	566.40	574.36	574.22	574.80
MW-07SL	581.30	576.09	577.86	578.83	579.80
MW-19S	580.90	575.16	576.19	577.01	576.53
MW-21S	583.44	577.61	579.16	580.05	578.61
MW-22B (replaced w/ well below)	573.61	DRY	568.93	570.67	568.37
MW-20B	581.89	577.26	578.76	580.77	577.70
MW-22SL (replaced w/ well below)	573.44	DRY	569.04	570.58	567.82
MW-24SL	579.09	575.65	577.33	577.29	577.05
MW-24B	576.74	572.18	574.06	574.78	573.86
MW-26SU	573.62	570.31	571.20	572.65	569.47

	Distance (ft)
MW-04BR to MW-22B	557.602535
MW-04BR to MW-20B	203.070235
MW-24B to MW-05B	224.838794
MW-21S - MW-02SL	194.858597
MW-01S to MW-05S	716.445351
MW-19S to MW-26SU	234.221941
MW-01B to MW-22SL	811.719098
MW-01B to MW-24SL	544.359685
MW-07SL to MW-22SL	531.641675
MW-07SL to MW-24SL	152.350523

1 - Freeze and Cherry, 1979, page 37
2 - Todd, DK, 1980, page 28
Groundwater elevations obtained from Parsons Monitoring Reports (Round 36, 51, 52, 53 & 54)
groundwater velocity calculated by: $V=K/n_e*dh/dl$

The effective porosity value was not measured at the site. The values used in the calculations are based on field observations and literature values. A more representative velocity value would be estimated if site-specific effective porosity values were available.

Table 3-2

Groundwater Elevations and Vertical Gradient Directions - November 2011 through August 2012

	Round 51		Round 52		Round 53		Round 54	
	November 14, 2011		February 14, 2012		May 21, 2012		August 21, 2012	
Well ID	Water Level	Direction of Vertical Gradient	Water Level	Direction of Vertical Gradient	Water Level	Direction of Vertical Gradient	Water Level	Direction of Vertical Gradient
MW-1S	578.86	↓	580.56	↓	582	↓	581.06	↓
MW-1B	578.19		580.09		581.58		580.32	
MW-2SU	575.59	↓	576.63		576.23		577.67	↓
MW-2SL	574.76		576.88	↑	577.46	↓↑	577.51	
MW-2B	576.06	↑	577.20	↑	576.77		578.78	↑
MW-3S	DRY		NA		NA		NA	
MW-3B	572.11		573.53		573.65		574.12	
MW-4S	DRY		575.5		576.58		576.4	
MW-4SL	574.85		575.72	↑	576.61	↑	576.7	↑
MW-4BR	574.96	↑	576.1	↑	576.87	↑	577.05	↑
MW-5S	566.40		574.36	↓	574.22	↓	574.80	↓
MW-5SL	571.98	↑	573.18	↓	573.45	↓	574.22	↓
MW-5B	573.70	↓↑	569.38	↓	569.59	↓	570.07	↓
MW-5BL	562.03		562.31		565.22		563.63	
MW-7S	574.61	↑	578.41	↓	580.08	↓	579.2	
MW-7SL	576.09	↑	577.86		578.83		579.8	↓↑
MW-7SU[b]	576.62	↓↑	578.45	↓↑	579.25	↓↑	579.29	↓
MW-7BL	575.05		577.09		577.5		578.81	
MW-20S	577.23		579.16	↓	579.66		577.51	
MW-20B	577.26	↑	578.76		580.77	↑	577.7	↑
MW-22SU	567.82		569.15	↓	570.67	↓	568.21	↓
MW-22SL	DRY		569.04	↓	570.58		567.82	
MW-22B	DRY		568.93	↓	570.67	↓↑	568.37	↓↑
MW-22BL	559.51		560.99		562.44		560.58	
MW-23SL	DRY		571.83	↓	573.96	↓	571.25	↓
MW-23B	DRY		571.03	↓	573.25	↓	570.84	↓
MW-23BL	568.25		569.71		571.07		568.79	
MW-24SL	575.65		577.33	↓	577.29	↓	577.05	↓
MW-24B	572.18		574.06		574.78		573.86	
MW-25S	DRY		NA		580.43		578.07	↓
MW-25SL	DRY		579.27		580.87	↑	577.54	
MW-25B	578.97		583.45	↑	NA		NA	
MW-27SU[a]	DRY		NA		572.3		565.41	
MW-27B	571.00		572.13		573.44	↑	571.00	↑
MW-29SU[b]	570.43	↓	571.7	↓	572.98	↓	569.96	
MW-29B[b]	570.36		571.62		572.96		570.73	↑
MW-31SU[b]	565.35		566.88		568.25		566.13	↓
MW-31B[b]	566.11	↑	567.68	↑	569.08	↑	565.74	

Arrows indicate direction of vertical gradient

Red cells indicate upward gradient

Blue cells indicate downward gradient

Purple cells indicate divergent gradient

Empty cell indicates data is not available to determine direction.

Water level elevations in feet msl

NA- not applicable; no water level reported

Groundwater levels provided by Parsons (2012)

a - Well installed in May - June 2007

b - Well installed in September - November 2009

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Table 4-1
November 2012 Screening Levels

Metals	Reporting Detection Limit	Nov 2012 Screening Level (µg/L)	RSL - Tap Water (HQ=1) (µg/L)	RSL - Tap Water (HQ=0.1) (µg/L)	MCL (µg/L)
Aluminum	200	1600	16000	1600	
Antimony	60	0.6	6	0.6	6
Arsenic	10	0.045	0.045	0.045	10
Barium	200	290	2900	290	2000
Beryllium	5	1.6	16	1.6	4
Cadmium	5	0.69	6.9	0.69	5
Calcium	5000	NA	NA		
Chromium	10	100 (MCL)	NA		100
Cobalt	50	0.47	4.7	0.47	
Copper	25	62	620	62	1300
Iron	100	1100	11000	1100	
Lead	10	15 (MCL)	NA		15
Magnesium	5000	NA	NA		
Manganese	15	32	320	32	
Mercury	0.2	0.063	0.63	0.063	2
Nickel	40	30	300	30	
Potassium	5000	NA	NA		
Selenium	35	7.8	78	7.8	50
Silver	10	7.1	71	7.1	
Sodium	5000	NA	NA		
Thallium	25	0.016	0.16	0.016	2
Vanadium	50	7.8	78	7.8	
Zinc	60	470	4700	470	

Notes:
All units in micrograms per liter (µg/L)
November 2012 Regional Screening Level (RSL) Summary Table Source:
http://www.epa.gov/reg3hwmd/risk/human/rb-concentration_table/Generic_Tables/index.htm
RSL - cancer benchmark value = 1E-06; non-cancer HQ = 0.1
Action level is the lower value of either the RSL or MCL. If MCL value used as the Action Level it has been noted, otherwise the RSL was used.
*Contaminant of Concern (COC) as listed in the 1994 ROD (1,4-dioxane added after 1994)
Blank values indicate no screening level exists.

Table 4-1
November 2012 Screening Levels

VOCs	Reporting Detection Limit	Nov 2012 Screening Level (µg/L)	RSL - Tap Water (HQ=1) (µg/L)	RSL - Tap Water (HQ=0.1) (µg/L)	MCL (µg/L)
1,1,1-Trichloroethane	0.5	200 (MCL)	7500	750	200
1,1,2-trichloro-1,2,2-trifluoroethane	0.5	5300	53000	5300	
1,1,2-Trichloroethane*	0.5	0.24	0.24		5
1,1-Dichloroethane	0.5	2.4	2.4		
1,1-Dichloroethene*	0.5	7 (MCL)	260	26	7
1,2,3-Trichlorobenzene	0.5	0.52	5.2	0.52	
1,2-Dichlorobenzene	0.5	28	280	28	600
1,2-Dichloroethane*	0.5	0.15	0.15		5
1,2-Dichloropropane*	0.5	0.38	0.38		5
1,3-Dichlorobenzene	0.5	NA	NA		
1,4-Dichlorobenzene	0.5	0.42	0.42		75
1,4-Dioxane*	2	0.67	0.67		
2-Butanone	5	490	4900	490	
2-hexanone	5	3.4	34	3.4	
4-Methyl-2-Pentanone	5	100	1000	100	
Acetone*	5	1200	12000	1200	
Benzene	0.5	0.39	0.39		5
Bromochloromethane	0.5	8.3	83	8.3	
Bromoform	0.5	7.9	7.9		80
Bromomethane	0.5	0.7	7	0.7	
Carbon Disulfide	0.5	72	720	72	
Carbon Tetrachloride	0.5	0.39	0.39		5
Chlorobenzene	0.5	7.2	72	7.2	100
Chloroethane	0.5	NA	NA		
Chloroform	0.5	0.19	0.19		80
Chloromethane	0.5	19	190	19	
Cis-1,2-Dichloroethene	0.5	2.8	28	2.8	70
Cis-1,3-Dichloropropene*	0.5	NA	NA		
Cyclohexane	0.5	1300	13000	1300	
Dichlorodifluoromethane	0.5	19	190	19	
Ethylbenzene	0.5	1.3	1.3		700
Isopropylbenzene	0.5	NA	NA		
Methyl acetate	0.5	1600	16000	1600	
Methyl tert-butyl ether	0.5	12	12		
Methylbenzene (toluene)	0.5	86	860	86	1000
Methylcyclohexane	0.5	NA	NA		
Methylene Chloride*	0.5	5 (MCL)	9.9		5
m,p-xylene	0.5	19	190	19	
o-xylene	0.5	19	190	19	
Styrene	0.5	100 (MCL)	1100	110	100
Tetrachloroethene*	0.5	5 (MCL)	9.7		5
Toluene	0.5	86	860	86	1000
Total xylenes	0.5	19	190	19	10000
Trans-1,2-Dichloroethene	0.5	8.6	86	8.6	100
Trans-1,3-Dichloropropene*	0.5	NA	NA		
Trichloroethene*	0.5	0.44	0.44		5
Trichlorofluoromethane	0.5	110	1100	110	
Vinyl Chloride*	0.5	0.015	0.015		2
Xylenes(total)	0.5	19	190	19	10000

Table 4-2
3D Site Model Contaminant Concentrations Input File

easting	northing	top_depth	bot_depth	PCE	TCE	cis-1,2-DCE	1,1-DCE	Vinyl Chloride	1,1,1-TCA	1,1-DCA	1,4-Dioxane	MethyleneChloride	Benzene	Chromium	Cobalt	Manganese	Well_Name	Surf_Elevation	Sampling Round Detect
				ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L	ug/L			
11478614.91	3710574.79	93.0	103	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.95	<0.5	<0.5	6.8	<50	25	MW01B	617.9	Round 43 (11/23/09)
11478619.66	3710574.79	42	47	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.95	<0.5	<0.5	3	4.4	779	MW01S	617.2	Round 43 (11/23/09)
11478333.65	3710822.74	71.5	91.5	1.1	0.31	17	2.6	0.67	0.84	8.2	8	6	4	<10	4.4	1160	MW02B	611.8	Round 51 (nov 11)
11478325.27	3710821.26	34	64	5.5	0.66	23	7.6	3.1	7.5	37	18	7	6	<10	104	9220	MW02SL	610.6	Round 51 (nov 11)
11478325.27	3710821.26	32.5	42.5	370	100	1400	870	<0.5	920	3600	1100	1200	<0.5	34	204	23200	MW02SU	612	Round 51 (nov 11)
11478088.66	3710959.14	140.5	150.5	5.7	3.5	150	<0.5	<0.5	<0.5	<0.5	4	4	2	1.6	<50	643	MW03B	606.9	Round 51 (nov 11)
11478090.24	3710974.96	29	34	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	missing	<0.5	<0.5	7.5	<50	504	MW03S	610.2	Round 26 (6/14/05)
11478519.56	3711013.65	119.7	149.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.16	<0.95	0	<0.5	<10	<50	29.4	MW04B	615	Round 51 (nov 11)
11478535.66	3711024.01	33	43	0.6	<0.5	0.49	<0.5	<0.5	0.44	3.8	3	<0.5	<0.5	<10	<50	14.2	MW04S	614.6	Round 45 (5/20/10)
11478513.58	3711025.67	51.8	61.8	5.8	<0.5	20	<0.5	25	13	460	170	<0.5	10	2.3	45	9840	MW04SU	612.2	Round 51 (nov 11)
11477930.24	3710808.83	128	138	3.2	2.0	82.0	<0.5	<0.5	<0.5	<0.5	2	2	1	<10	<50	19.6	MW05B	586.1	Round 51 (nov 11)
11477950.27	3710785.87	210	220	0.16	0.19	9.3	<0.5	<0.5	0.12	0.16	<0.95	1	<0.5	52.8	<50	<15	MW05BL	584.8	Round 51 (nov 11)
11477928.04	3710797.76	19.0	28	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.95	<0.5	<0.5	missing	missing	missing	MW05S	586.4	Round 37 (6/4/08)
11477934.26	3710800.06	63.5	83.5	0.56	0.33	13	<0.5	<0.5	<0.5	<0.5	<0.95	0	<0.5	<10	<50	25.2	MW05SL	584.6	Round 51 (nov 11)
11478326.76	3710956.92	32	42	16	1.1	0.57	<0.5	<0.5	200	240	2	3	1	missing	missing	missing	MW06S	611.1	Round 37 (6/4/08)
11478206.9	3710597.35	195	205	<0.5	0.14	0.32	<0.5	<0.5	<0.5	0.92	3	1	0	<10	<50	<15	MW07BL	592.7	Round 43 (11/23/09)
11478222.91	3710577.06	40	45	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.95	<0.5	<0.5	missing	missing	missing	MW07S	594.4	Round 37 (6/4/08), 1,4-dioxane collected in Round 31 (1/17/07)
11478217.18	3710590.13	76	96	0.41	0.14	0.72	<0.5	<0.5	0.07	0.73	5	1	<0.5	2.3	<50	61.1	MW07SL	593.3	Round 51 (nov 11)
11478218.78	3710599.26	60	70	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	1	<0.5	<0.5	1.6	3.9	184	MW07SU	593.88	Round 51 (nov 11)
11478256.03	3711079.96	43.7	48.7	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.95	0	<0.5	1.5	<50	7.2	MW08S	615.3	Round 43 (11/23/09)
11478430.41	3711048.82	39	49	1.6	1	0.53	<0.5	<0.5	0.9	0.96	<0.95	0.58	<0.5	missing	missing	missing	MW09S	612.4	Round 37 (6/4/08)
11478425.56	3711100.473	40.5	50.5	35	49	<0.5	150	<0.5	130	330	12	<0.5	<0.5	2.1	<50	66	MW09SU	611.3	Round 51 (nov 11)
11477892.33	3710980.64	39	48	0.82	<0.5	0.67	1.2	<0.5	0.55	0.65	3	<0.5	<0.5	13.2	2.4	80.9	MW10S	606.9	Round 43 (11/23/09)
11478004.06	3710700.42	39.2	44.2	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.68	<0.95	<0.5	<0.5	123	25.2	1950	MW12	588.2	Round 43 (11/23/09)
11478554.9	3710928.78	45	50	0.33	0.55	1.8	<0.5	<0.5	0.7	1.3	2	<0.5	<0.5	4.2	<50	91.4	MW13S	623.6	Round 51 (nov 11)
11478089.74	3711144.51	40	48	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.95	<0.5	<0.5	147	36.8	2460	MW15	610.9	Round 43 (11/23/09)
11478464.41	3710941.88	39	49	<0.5	<0.5	<0.5	<0.5	<0.5	16	600	260	<0.5	11	1.5	37	3260	MW19S	611.4	Round 51 (nov 11)
11478527.93	3710814.2	85	105	16	2.7	2.8	3	<0.5	1.3	4.3	7	1	1	<10	<50	486	MW20B	615.4	Round 51 (nov 11)
11478539.03	3710808.76	38	48	1.6	0.87	1.9	<0.5	<0.5	0.14	0.82	2	0	0	346	53.6	7680	MW20S	615.7	Round 51 (nov 11)
11478418.44	3710649.71	50	60	110	14	8	<0.5	<0.5	4.9	6.1	10	<0.5	<0.5	6.9	62.3	12700	MW21S	609.8	Round 51 (nov 11)
11477956.93	3711048.75	122.5	142.5	1.9	0.16	2.3	3.9	<0.5	1.1	2	13	0	<0.5	<10	<50	4.5	MW22B	606.9	Round 45 (5/20/10)
11477938.58	3711037.93	264.0	274	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	0.14	0.78	0.99	<0.5	<10	<50	<15	MW22BL	606.6	Round 51 (nov 11)
11477959.37	3711056.39	85	105	1.8	0.13	1.9	3.6	<0.5	0.98	1.7	10	0	<0.5	7.6	<50	9.2	MW22SL	605.6	Round 45 (5/20/10)
11477946.66	3711051.18	40	50	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.95	<0.5	<0.5	8.3	3.1	182	MW22SU	606.8	Round 43 (11/23/09)
11478138.43	3711125.33	130	150	0.28	<0.5	1.4	<0.5	<0.5	0.1	<0.5	11	1	<0.5	11.9	<50	78.9	MW23B	610.5	Round 45 (5/20/10)
11478125.82	3711121.94	204	214	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2	0	<0.5	120	<50	<15	MW23BL	611.2	Round 51 (nov 11)
11478149.82	3711126.58	90	110	0.2	0.23	2.2	<0.5	<0.5	<0.5	0.46	5.2	1.3	0.38	5.1	<50	19.2	MW23SL	610.4	Round 45 (5/20/10)
11478079.88	3710637.79	135	145	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.95	<0.5	<0.5	33.3	<50	2.8	MW24B	586.1	Round 43 (11/23/09)
11478086.57	3710633.04	70	90	<0.5	<0.5	0.16	<0.5	<0.5	<0.5	<0.5	0.83	0.15	<0.5	2.2	<50	1.2	MW24SL	586.2	Round 43 (11/23/09)
11478637.79	3710842.62	63.1	83.1	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	2.1	1	<0.5	<10	<50	5.1	MW25B	622.04	Round 45 (5/20/10)
11478664.92	3710839.61	47	57	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.95	0	<0.5	<10	<50	4.5	MW25SL	623.1	Round 43 (11/23/09)
11478574.7	3711148.338	38	48	3.2	0.53	61	17	9.5	4.7	130	30	1.6	<0.5	4.5	<50	72.6	MW26SU	609.8	Round 45 (5/20/10)
11478492.97	3711150.44	70	80	440	110	160	650	<0.5	340	910	280	89	<0.5	4.6	<50	731	MW27B	607.24	Round 51 (nov 11)
11478495.25	3711200.646	28	38	49	10	8.7	38	<0.5	28	46	21	0.93	0.34	7.1	<50	34	MW27SU	602.7	Round 45 (5/20/10)
11478407.47	3711199.436	32	42	0.98	1.8	<0.5	5.7	<0.5	4.1	11	0.64	0.27	<0.5	5.4	<50	19.2	MW28SU	603.5	Round 51 (nov 11)
11478200.97	3711224.83	87	97	0.34	0.25	4.2	<0.5	<0.5	<0.5	0.55	7.7	1.2	0.13	<10	<50	39.3	MW29B	613.14	Round 51 (nov 11)
11478211.91	3711233.98	60	70	0.89	0.54	13	<0.5	<0.5	<0.5	0.53	3.7	0.76	<0.5	1.8	<50	514	MW29SU	611.83	Round 51 (nov 11)
11478572.5	3711498.3	65	75	6.4	10	<0.5	41	<0.5	28	50	4.2	0.84	<0.5	3.7	<50	49.7	MW30SU	601.5	Round 51 (nov 11)
11478727.94	3711510.41	80	90	270	56	210	360	<0.5	190	480	190	38	5.6	2.6	<50	276	MW31B	601.46	Round 51 (nov 11)
11478725.83	3711518.85	65	75	180	37	83	240	<0.5	120	200	64	10	<0.5	<10	<50	121	MW31SU	601.21	Round 51 (nov 11)
11478834.53	3711373.55	70	80	2.4	3.1	5.9	1.3	<0.5	0.16	4.2	6.3	0.22	0.12	<10	<50	277	MW32SU	605.01	Round 51 (nov 11)
11478378.03	3710715.05	20	24	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	missing	3100	<0.5	missing	missing	missing	GP-1	614.4	GW GP sep 09
11478285.19	3710897.53	20	21	0.97	0.42	0.99	<0.5	missing	8.2	10	<0.95	0.66	<0.5	missing	missing	missing	GP-14	611.9	GW GP sep 09
11478210.73	3710936.37	24	25	<0.5	<0.5	<0.5	<0.5	missing	<0.5	0.54	<0.95	0.86	<0.5	missing	missing	missing	GP-15	607.5	GW GP sep 09
11478068.2	3710955.76	26	27	<0.5	<0.5	0.49	<0.5	missing	<0.5	<0.5	<0.95	0.72	<0.5	missing	missing	missing	GP-16	605.2	GW GP sep 09
11478050.74	3710894.68	69	71	0.14	<0.5	1.3	<0.5	<0.5	<0.5	<0.5	missing	0.26	0.31	missing	missing	missing	GP-17SL	601.2	GW GP sep 09
11478050.74	3710894.68	41	43	<0.5	<0.5	0.11	<0.5	<0.5	<0.5	<0.5	missing	0.13	<0.5	missing	missing	missing	GP-17SU	601.2	GW GP sep 09
11477972.36	3710868.1	28	30	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	missing	0.48	<0.5	missing	missing	missing	GP-21	593.9	GW GP sep 09
11478294.53	3710675.48	25	27	<0.5	<0.5	0.26	<0.5	2	<0.5	0.33	missing	<0.5	1.3	missing	missing	missing	GP-23	600.4	GW GP sep 09
11478440.47	3710667.4	40	41	56	0.36	0.13	3.8	<0.5	5.9	4.9	missing	0.17	0.49	missing	missing	missing	GP-9A	612.3	GW GP sep 09
11478471.56	3710948.51	40	42	<0.5	<0.5	4.2	<0.5	<0.5	<0.5	150	missing	<0.5	<0.5	missing	missing	missing	SB-19S	611.6	GW GP sep 09
11478471.56	3710948.51	48	50	<0.5	<0.5	4.5	<0.5	<0.5	<0.5	230	missing	<0.5	<0.5	missing	missing	missing	SB-19S	611.6	GW GP sep 09
11478471.56	3710948.51	58	60	<0.5	<0.5	14	<0.5	13	7.5	330	missing	2.7	<0.5	missing	missing	missing	SB-19S	611.6	GW GP sep 09
11478471.56	3710948.51	68	70	<0.5	<0.5	28	<0.5	21	12	390	missing	3.5	<0.5	missing	missing	missing	SB-19S	611.6	GW GP sep 09

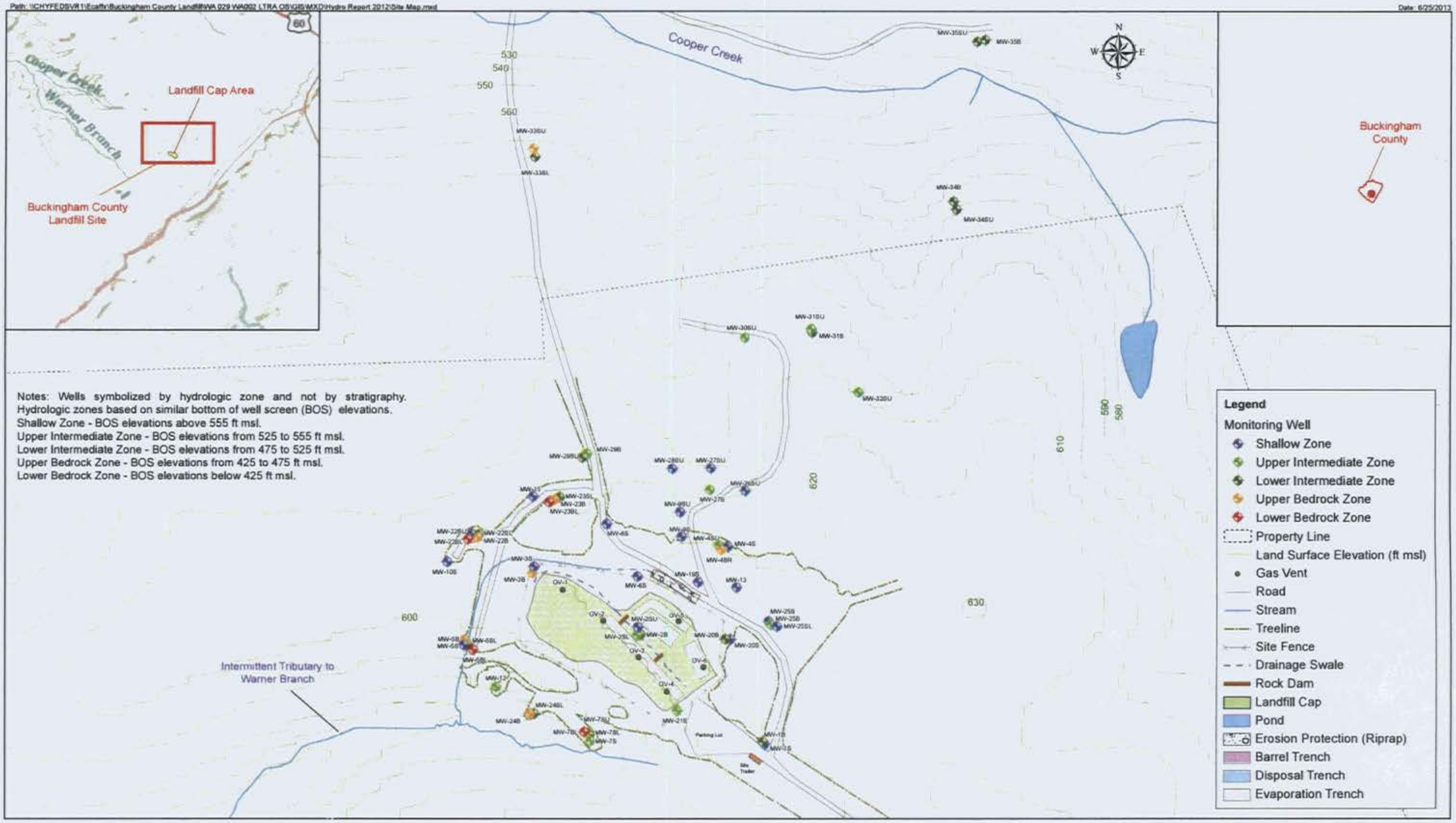
Note: ug/l = micrograms per liter

ORIGINAL

Figures

Path: \\CHYFEDSVR1\Ecaffn\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Hydro Report 2012\Site Map.mxd

Date: 6/25/2013



Notes: Wells symbolized by hydrologic zone and not by stratigraphy. Hydrologic zones based on similar bottom of well screen (BOS) elevations.
Shallow Zone - BOS elevations above 555 ft msl.
Upper Intermediate Zone - BOS elevations from 525 to 555 ft msl.
Lower Intermediate Zone - BOS elevations from 475 to 525 ft msl.
Upper Bedrock Zone - BOS elevations from 425 to 475 ft msl.
Lower Bedrock Zone - BOS elevations below 425 ft msl.

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Buckingham County Landfill Site
Buckingham County, Virginia

Figure 2-1
Site Map

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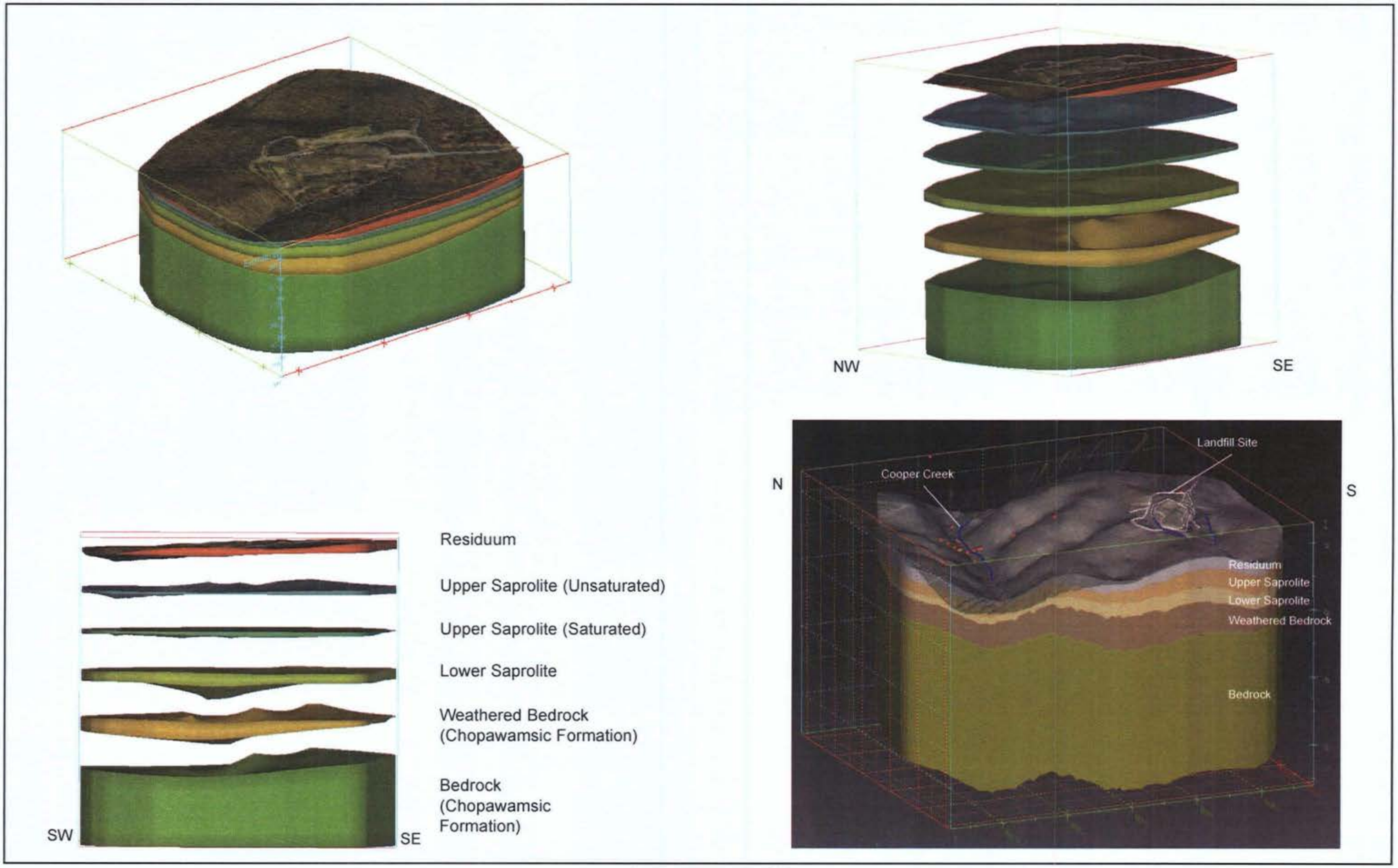
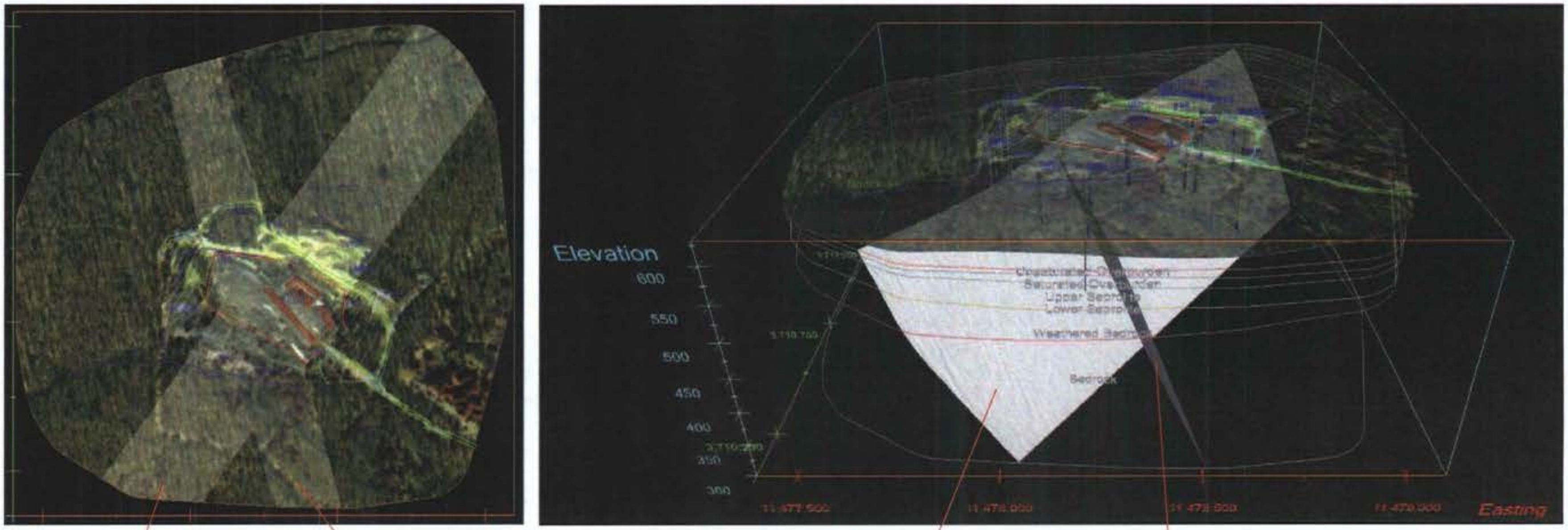


Buckingham County Landfill
Buckingham County, Virginia

Figure 2-2
Site Stratigraphy



Predominant Fracture Plane in Well Clusters 5 and 7

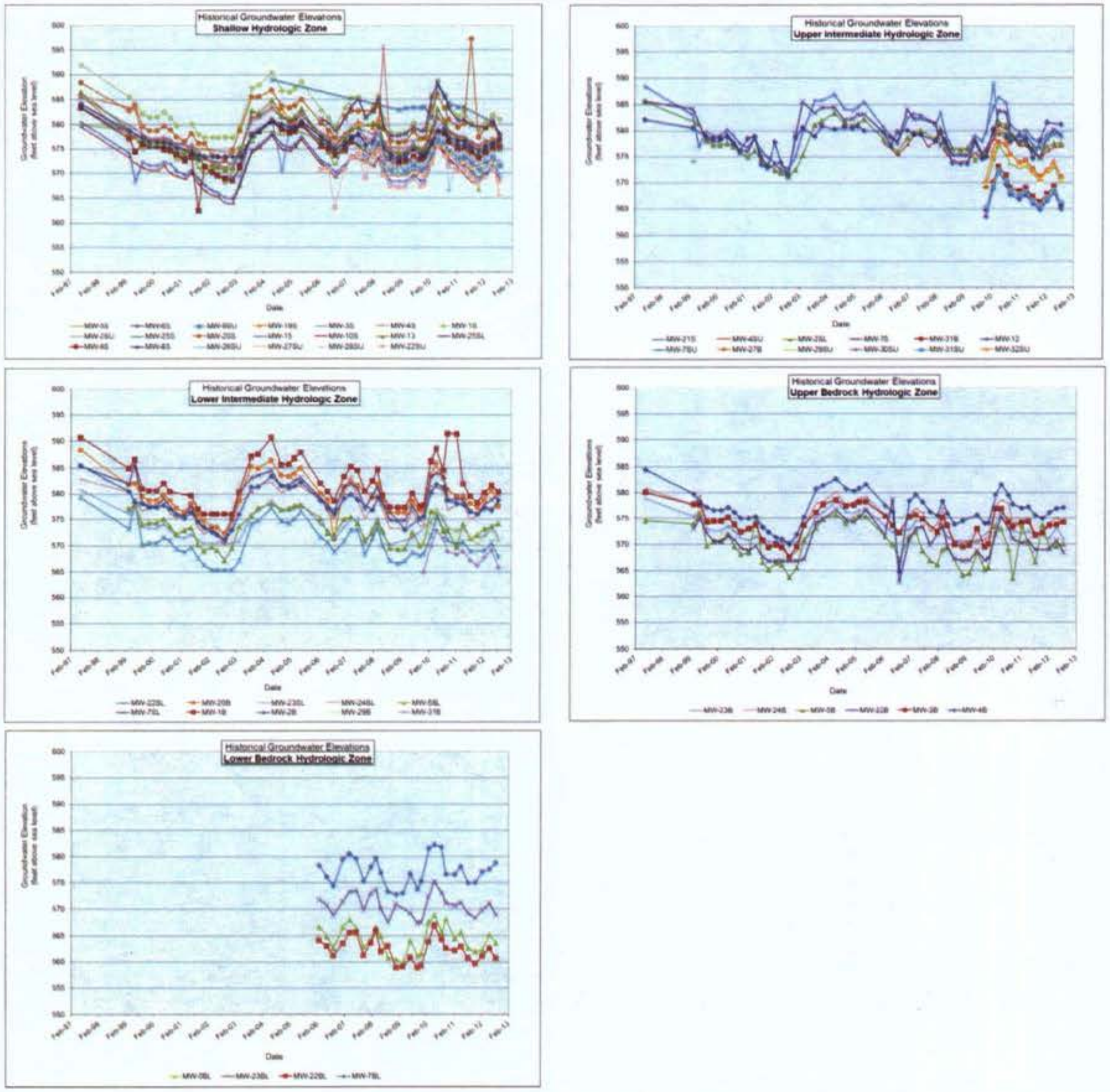
Predominant Fracture Plane in Well Clusters 22 and 23

Predominant Fracture Plane in Well Clusters 5 and 7

Predominant Fracture Plane in Well Clusters 22 and 23

Buckingham County Landfill
Buckingham County, Virginia

Figure 2-3
3D Fracture Plane Diagram



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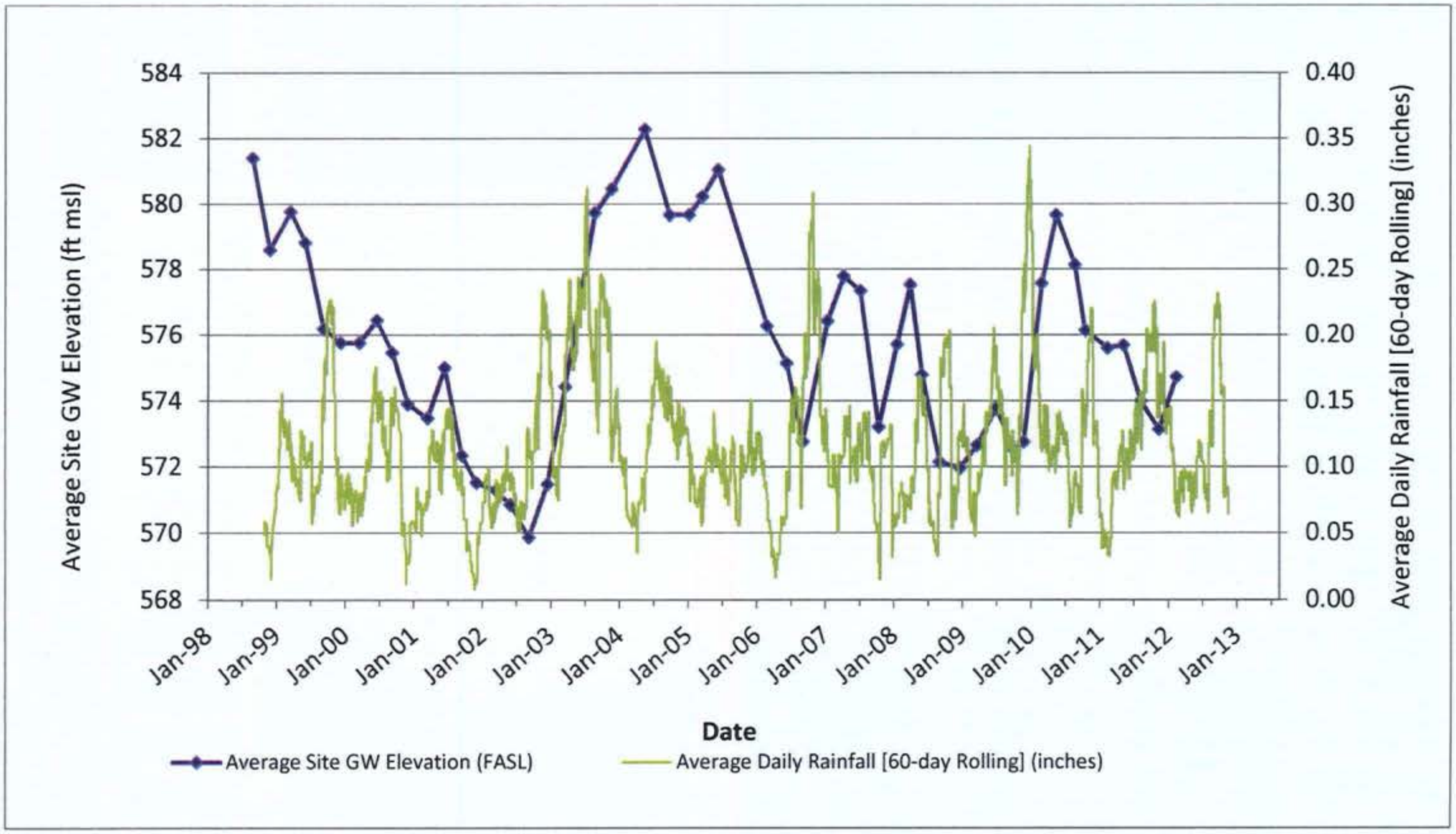
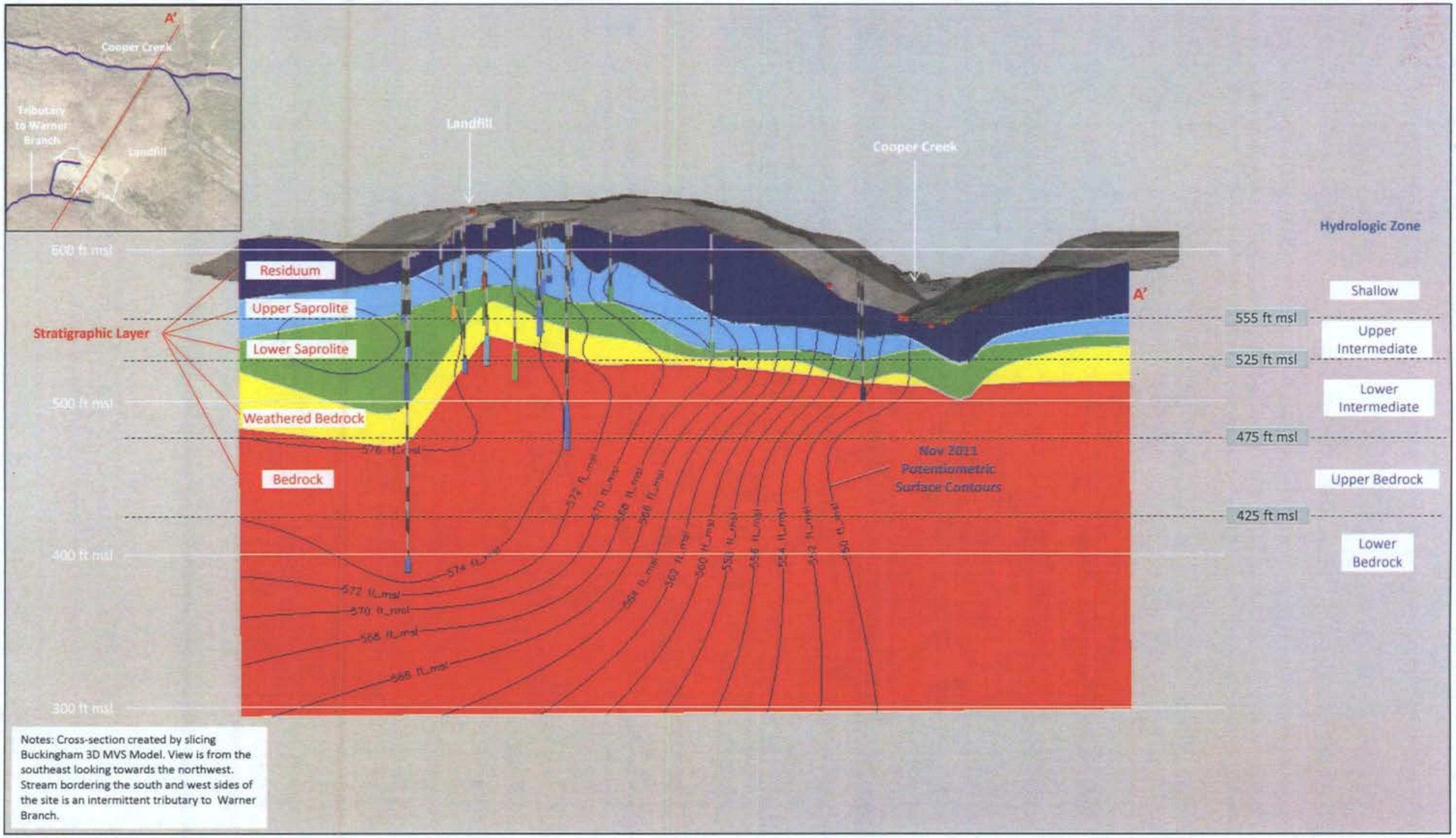
Buckingham County, Virginia

Figure 2-4
Historical Groundwater Elevations by Hydrologic Zone

Figure 2-5
Average Site Groundwater Elevation vs. Daily Average Rainfall



ORIGINAL



Notes: Cross-section created by slicing Buckingham 3D MVS Model. View is from the southeast looking towards the northwest. Stream bordering the south and west sides of the site is an intermittent tributary to Warner Branch.

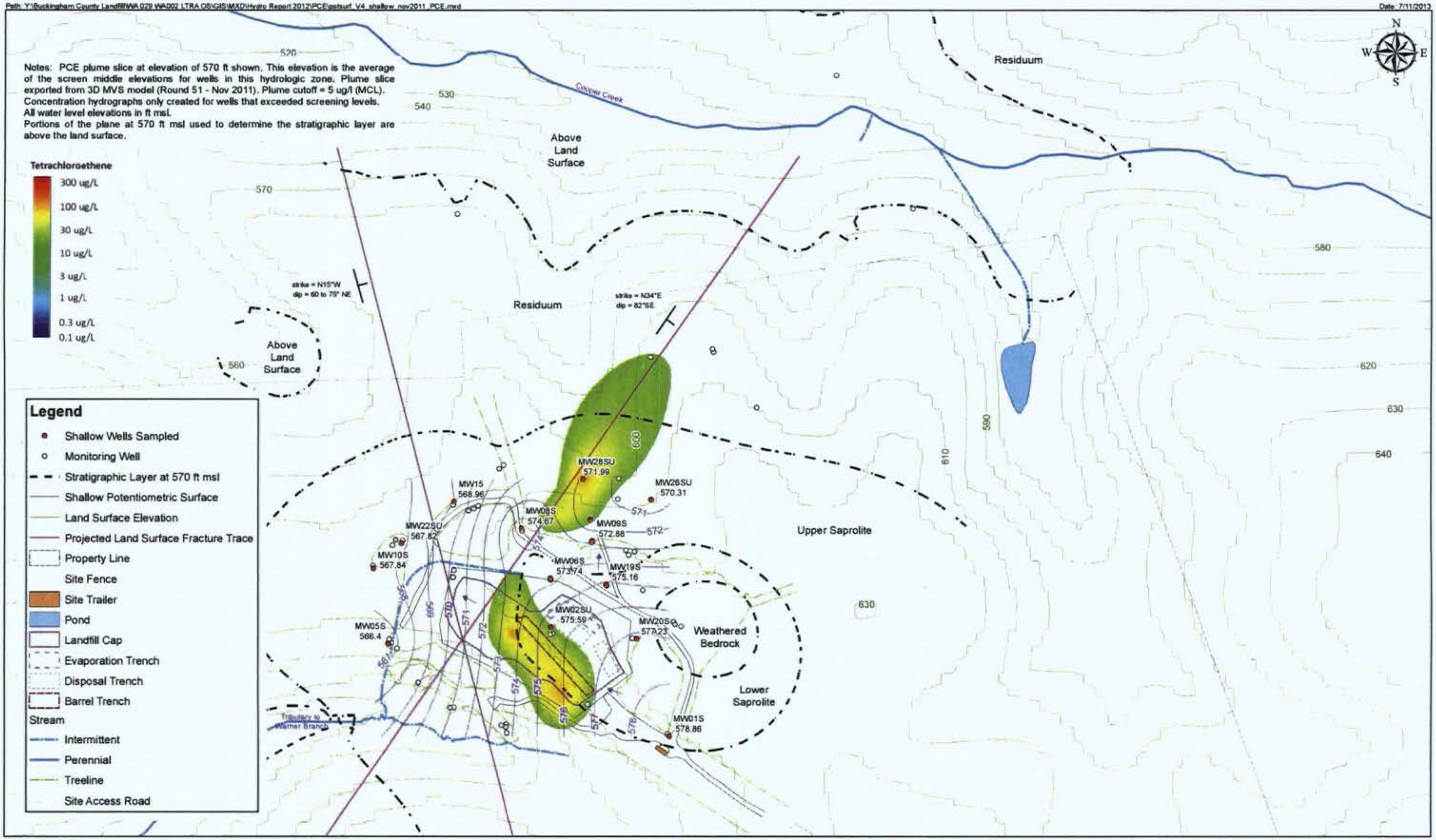
CDM Smith

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 2-6
Hydrologic Zone Versus Stratigraphic Layer

Path: Y:\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Hydro Report 2012\PCE\potsurf_V4_shallow_nov2011_PCE.mxd

Date: 7/11/2013



Notes: PCE plume slice at elevation of 570 ft shown. This elevation is the average of the screen middle elevations for wells in this hydrologic zone. Plume slice exported from 3D MVS model (Round 51 - Nov 2011). Plume cutoff = 5 ug/l (MCL). Concentration hydrographs only created for wells that exceeded screening levels. All water level elevations in ft msl.

Portions of the plane at 570 ft msl used to determine the stratigraphic layer are above the land surface.

CDM Smith

0 200 400 Feet

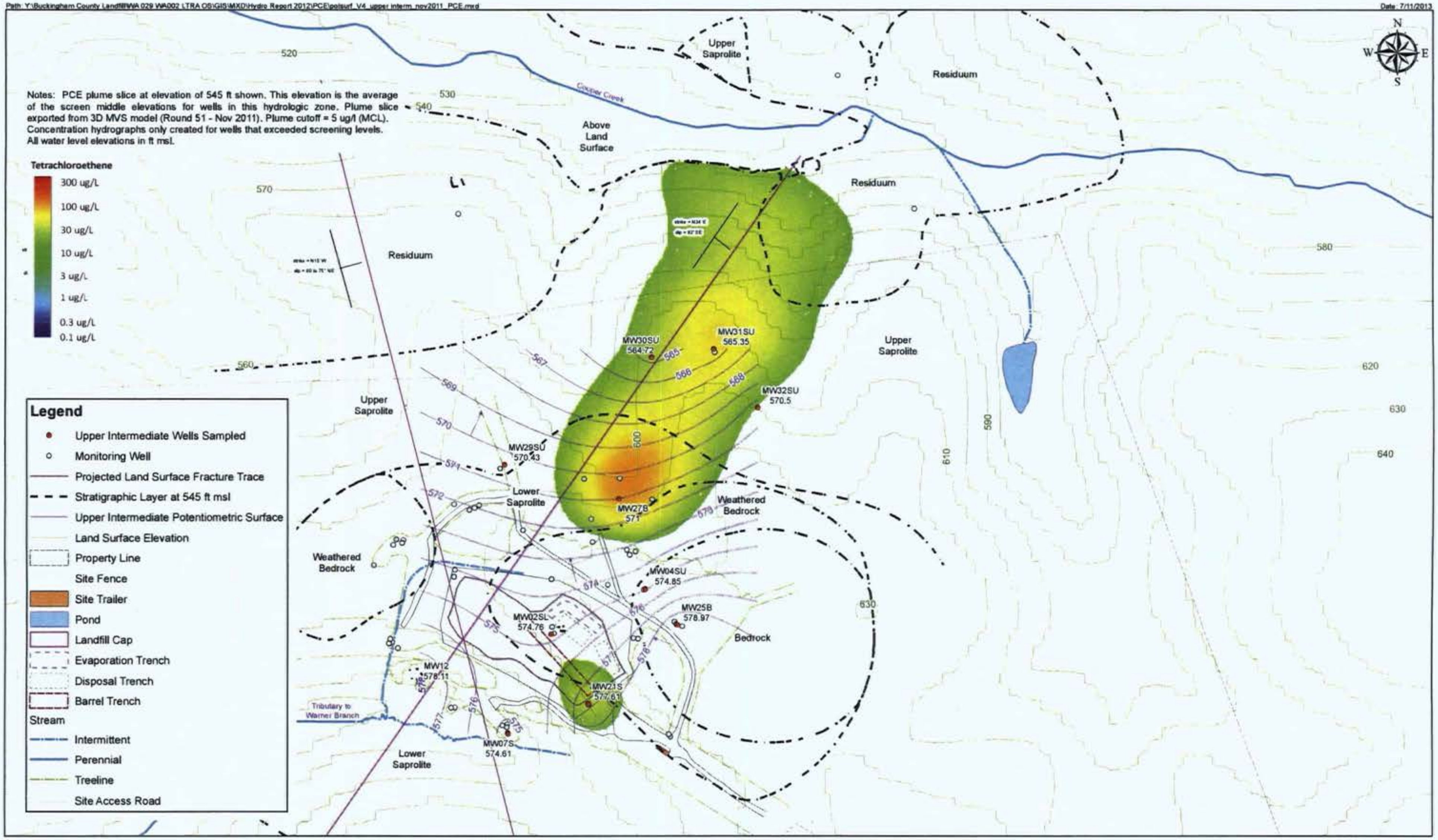
Buckingham County Landfill Site
Buckingham County, Virginia

Figure 3-1
Potentiometric Surface (Water Table) with PCE Plume Slice and Concentration Trends
Shallow Hydrologic Zone
November 2011

ORIGINAL

Path: Y:\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Hydro Report 2012\PCE\polsurf_V4_upper interm_nov2011_PCE.mxd

Date: 7/11/2013



Notes: PCE plume slice at elevation of 545 ft shown. This elevation is the average of the screen middle elevations for wells in this hydrologic zone. Plume slice exported from 3D MVS model (Round 51 - Nov 2011). Plume cutoff = 5 ug/l (MCL). Concentration hydrographs only created for wells that exceeded screening levels. All water level elevations in ft msl.

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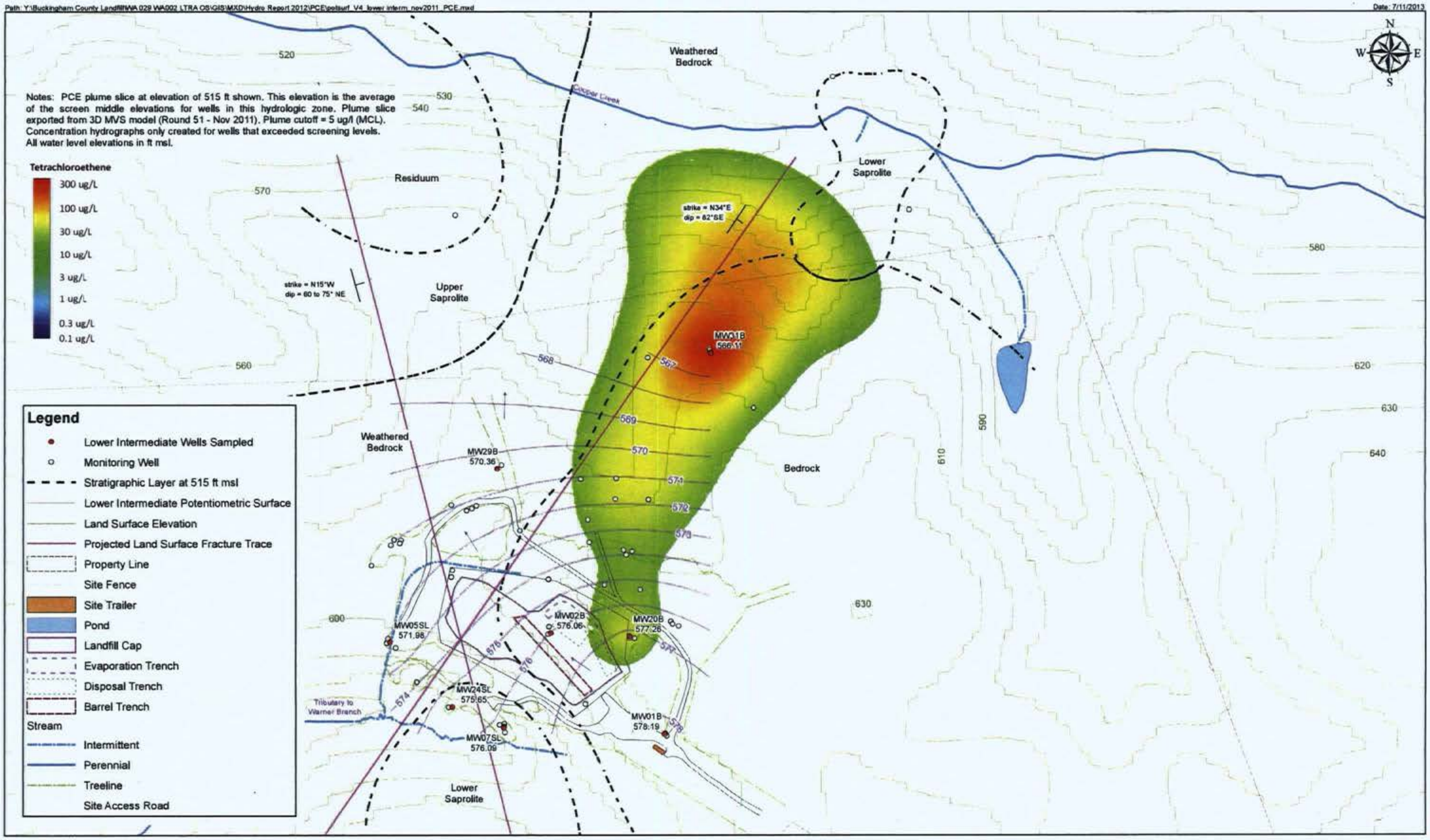
Buckingham County Landfill Site
Buckingham County, Virginia

Figure 3-2
Potentiometric Surface with PCE Plume Slice and Concentration Trends
Upper Intermediate Hydrologic Zone
November 2011

Path: Y:\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Hydro Report 2012\PCE\potsurf_V4_lower interm_nov2011_PCE.mxd

Date: 7/11/2013



Notes: PCE plume slice at elevation of 515 ft shown. This elevation is the average of the screen middle elevations for wells in this hydrologic zone. Plume slice exported from 3D MVS model (Round 51 - Nov 2011). Plume cutoff = 5 ug/l (MCL). Concentration hydrographs only created for wells that exceeded screening levels. All water level elevations in ft msl.

CDM Smith

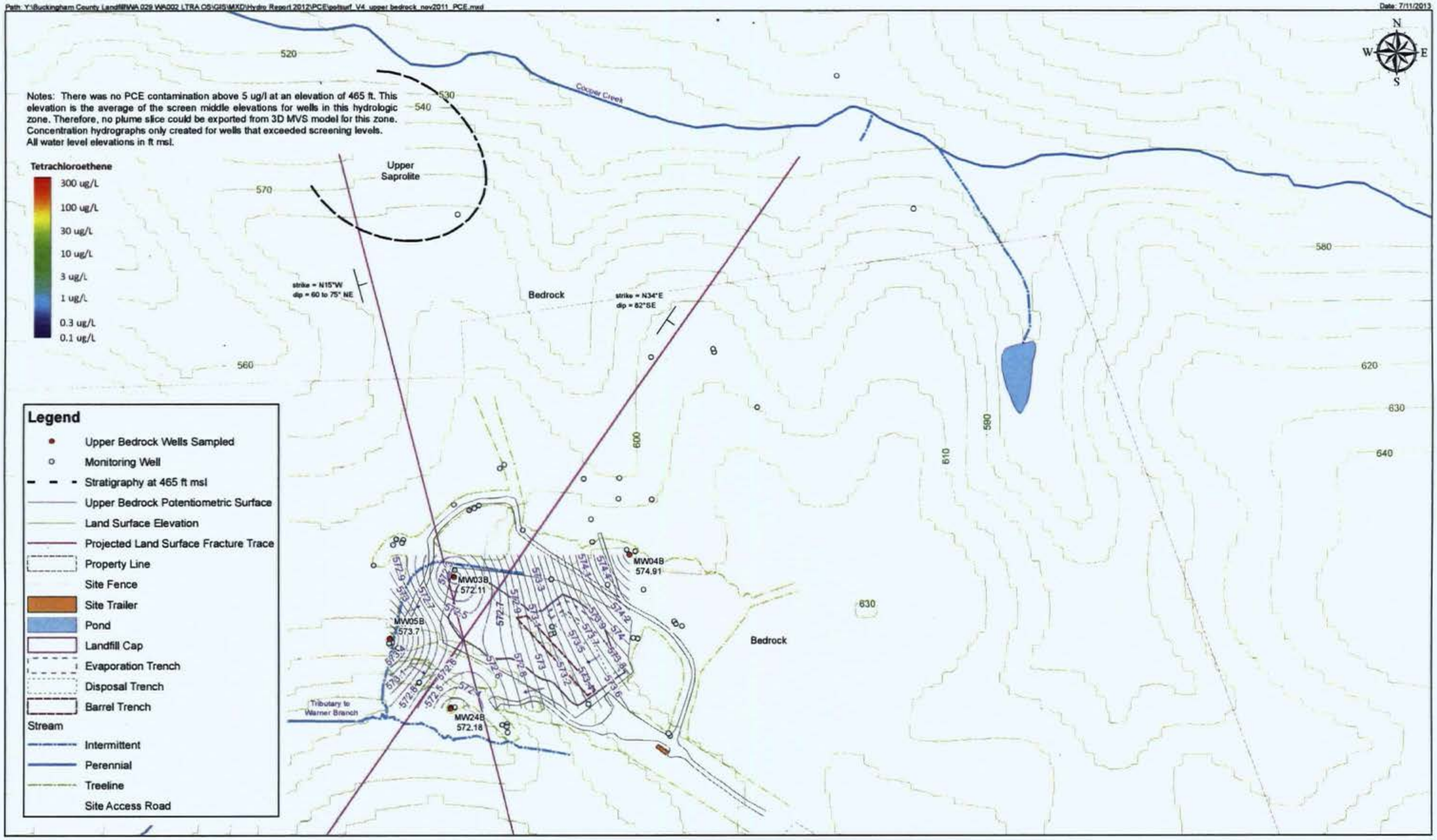
Buckingham County Landfill Site
Buckingham County, Virginia

Figure 3-3
Potentiometric Surface with PCE Plume Slice and Concentration Trends
Lower Intermediate Hydrologic Zone
November 2011

ORIGINAL

Path: Y:\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Hydro Report 2012\PCE\potsurf_V4_upper bedrock_nov2011_PCE.mxd

Date: 7/11/2013



Notes: There was no PCE contamination above 5 ug/l at an elevation of 465 ft. This elevation is the average of the screen middle elevations for wells in this hydrologic zone. Therefore, no plume slice could be exported from 3D MVS model for this zone. Concentration hydrographs only created for wells that exceeded screening levels. All water level elevations in ft msl.

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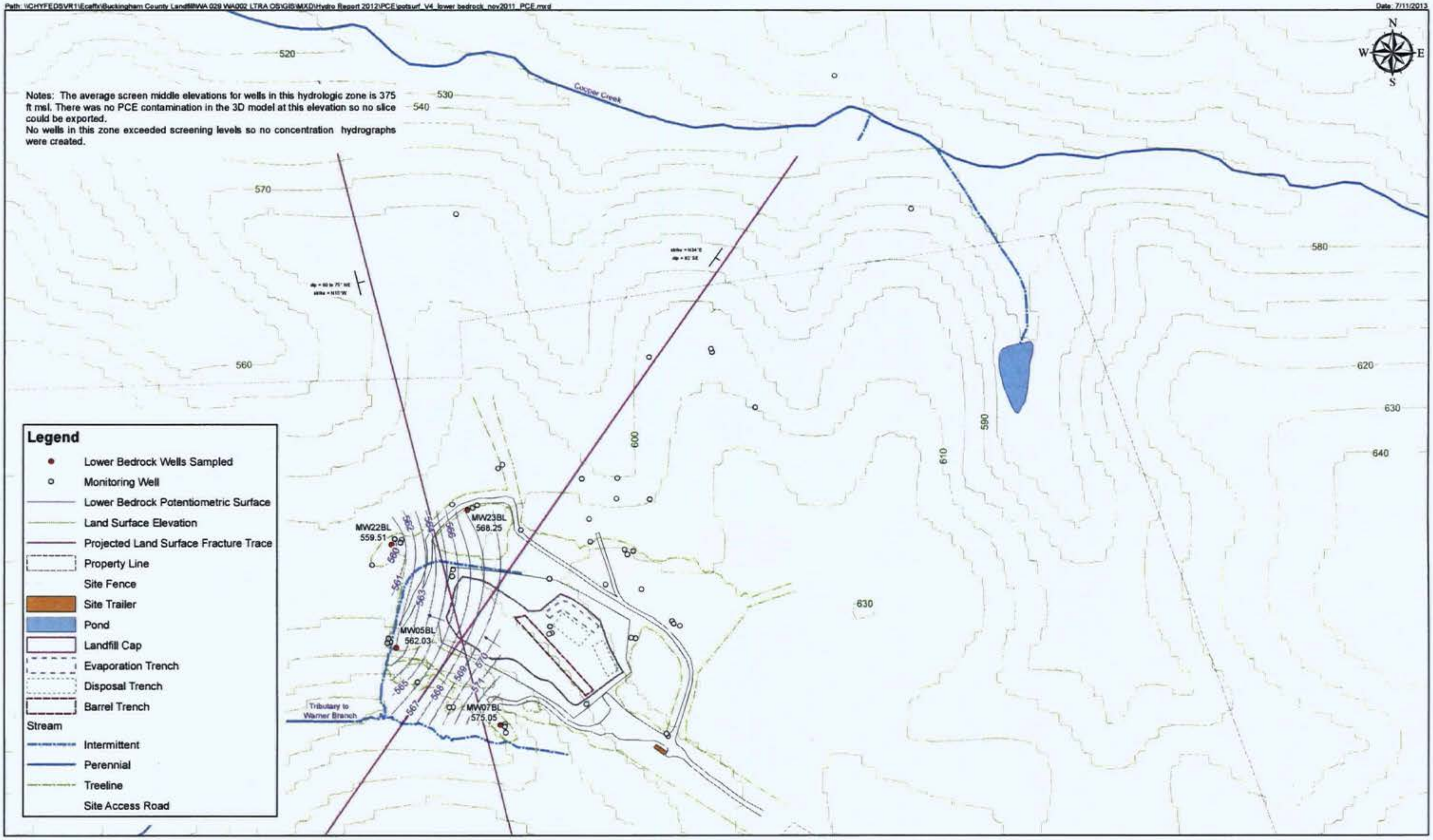
Buckingham County Landfill Site
Buckingham County, Virginia

Figure 3-4
Potentiometric Surface with PCE Plume Slice and Concentration Trends
Upper Bedrock Hydrologic Zone
November 2011

Path: \\CHYFEDSVR1\Ecaffx\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Hydro Report 2012\PCE\potsurf_V4_lower bedrock_nov2011_PCE.mxd

Date: 7/11/2013

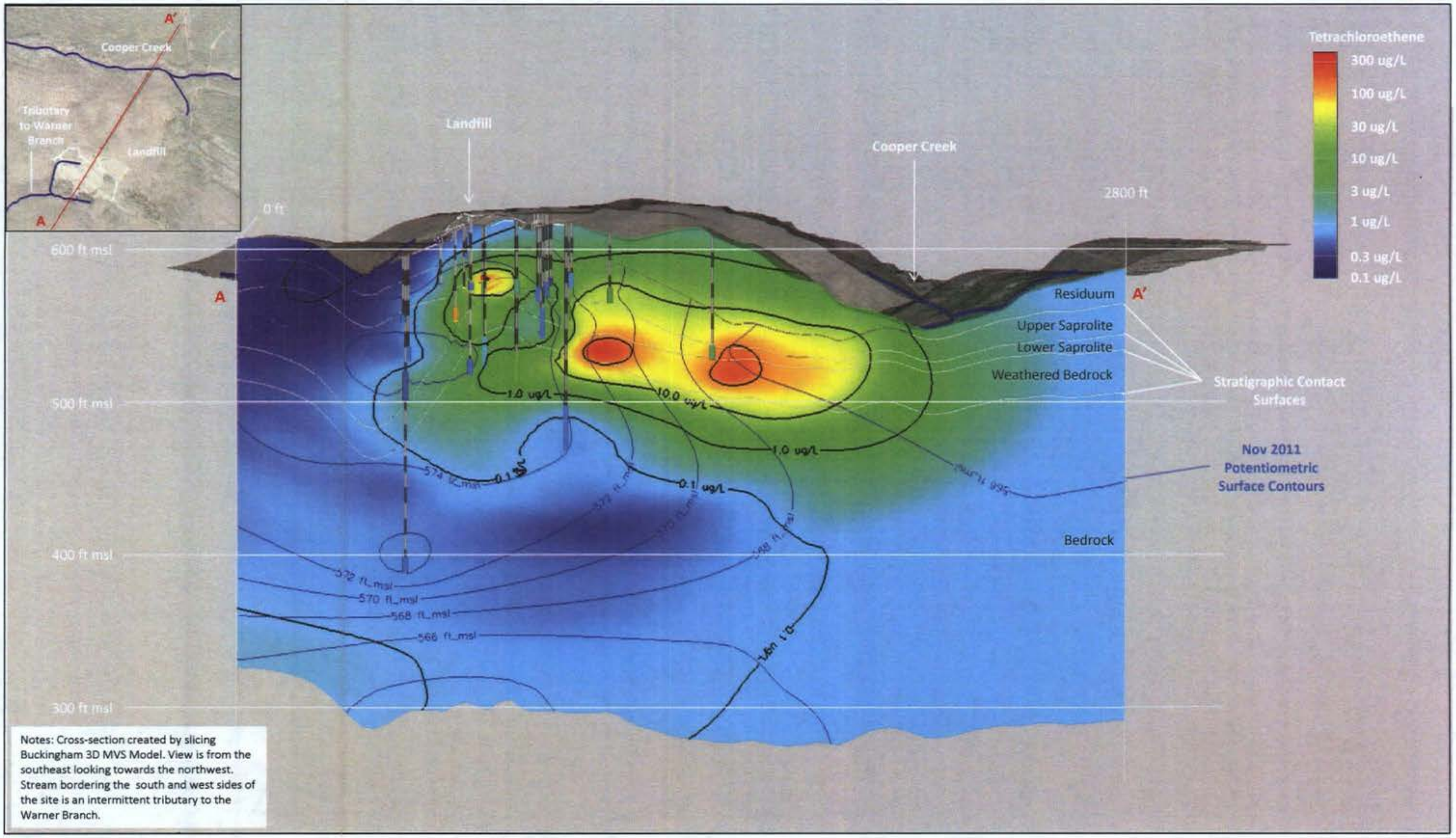


Notes: The average screen middle elevations for wells in this hydrologic zone is 375 ft msl. There was no PCE contamination in the 3D model at this elevation so no slice could be exported.
No wells in this zone exceeded screening levels so no concentration hydrographs were created.

CDM Smith

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 3-5
Potentiometric Surface with PCE Plume Slice and Concentration Trends
Lower Bedrock Hydrologic Zone
November 2011

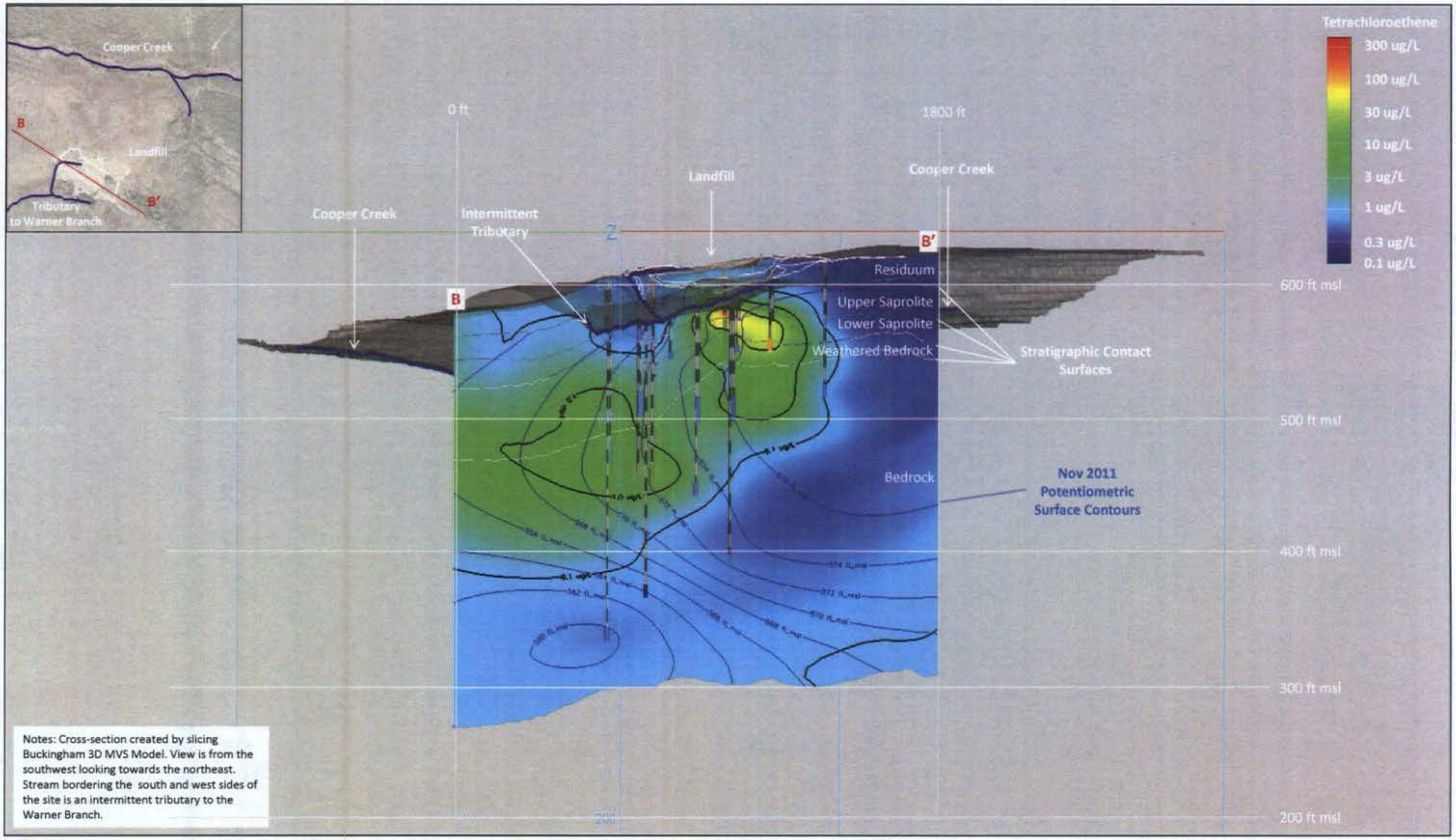


Notes: Cross-section created by slicing Buckingham 3D MVS Model. View is from the southeast looking towards the northwest. Stream bordering the south and west sides of the site is an intermittent tributary to the Warner Branch.

CDM Smith

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 3-6
Hydrogeochemical Cross-Section A-A'



Notes: Cross-section created by slicing Buckingham 3D MVS Model. View is from the southwest looking towards the northeast. Stream bordering the south and west sides of the site is an intermittent tributary to the Warner Branch.

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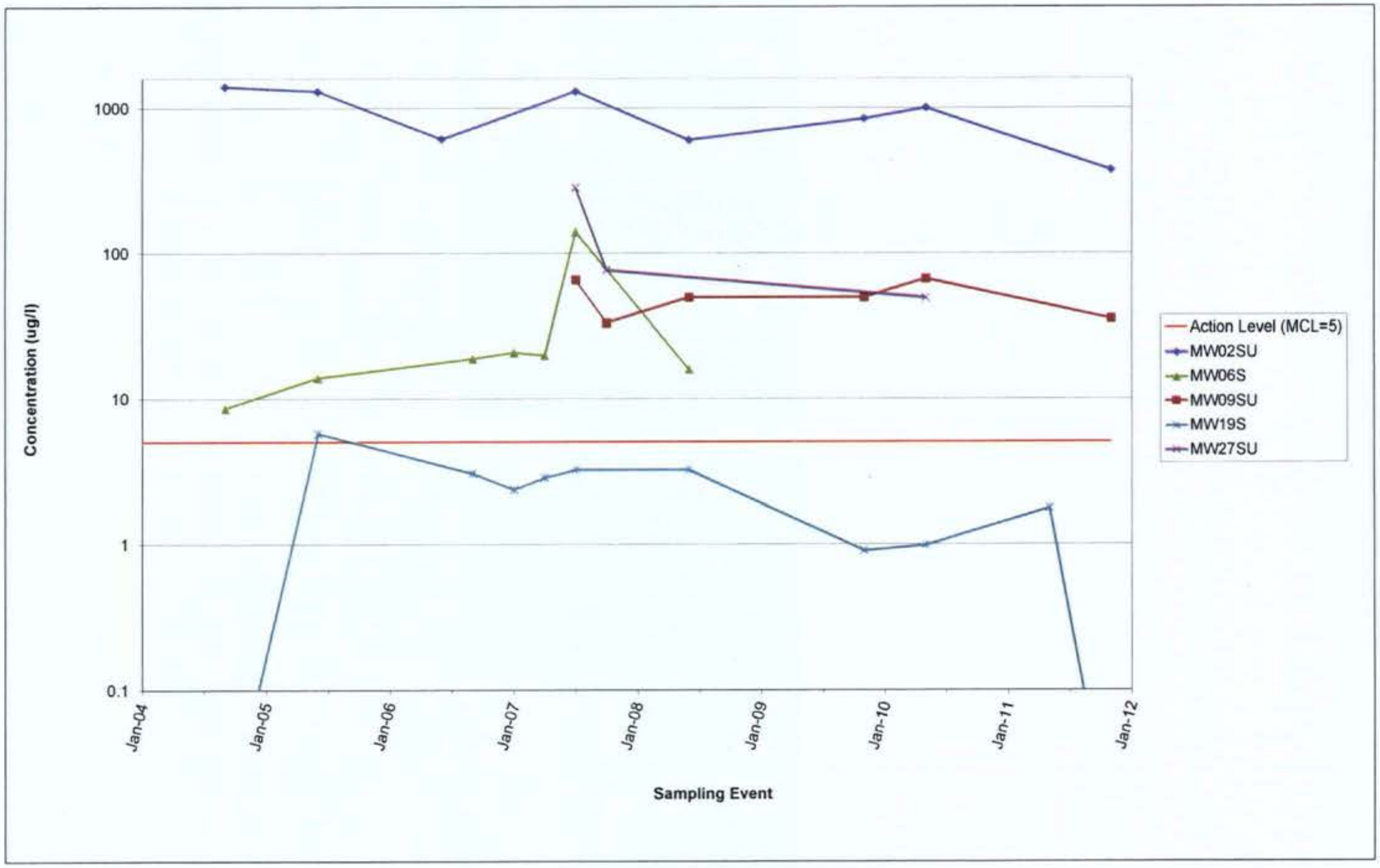
Buckingham County Landfill Site
Buckingham County, Virginia

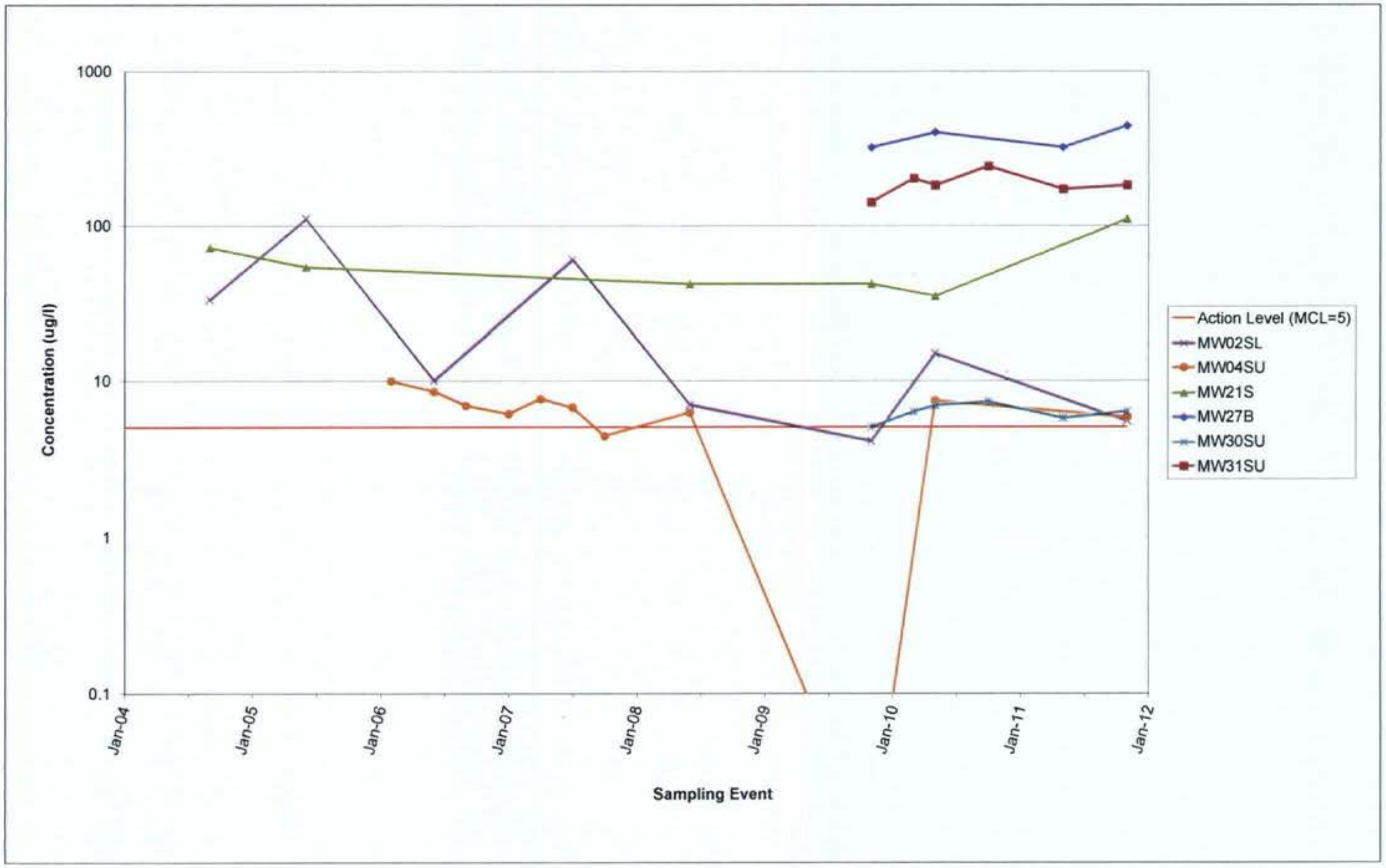
Figure 3-7
Hydrogeochemical Cross-Section B-B'

Figure 4-1
Tetrachloroethene Concentration Trends
Shallow Hydrologic Zone



Notes: Data points shown below 0.1 ug/l indicate nondetect results.

Figure 4-2
Tetrachloroethene Concentration Trends
Upper Intermediate Hydrologic Zone



Notes: Data points shown below 0.1 ug/l indicate nondetect results.

CDM Smith

Figure 4-3
Tetrachloroethene Concentration Trends
Lower Intermediate Hydrologic Zone

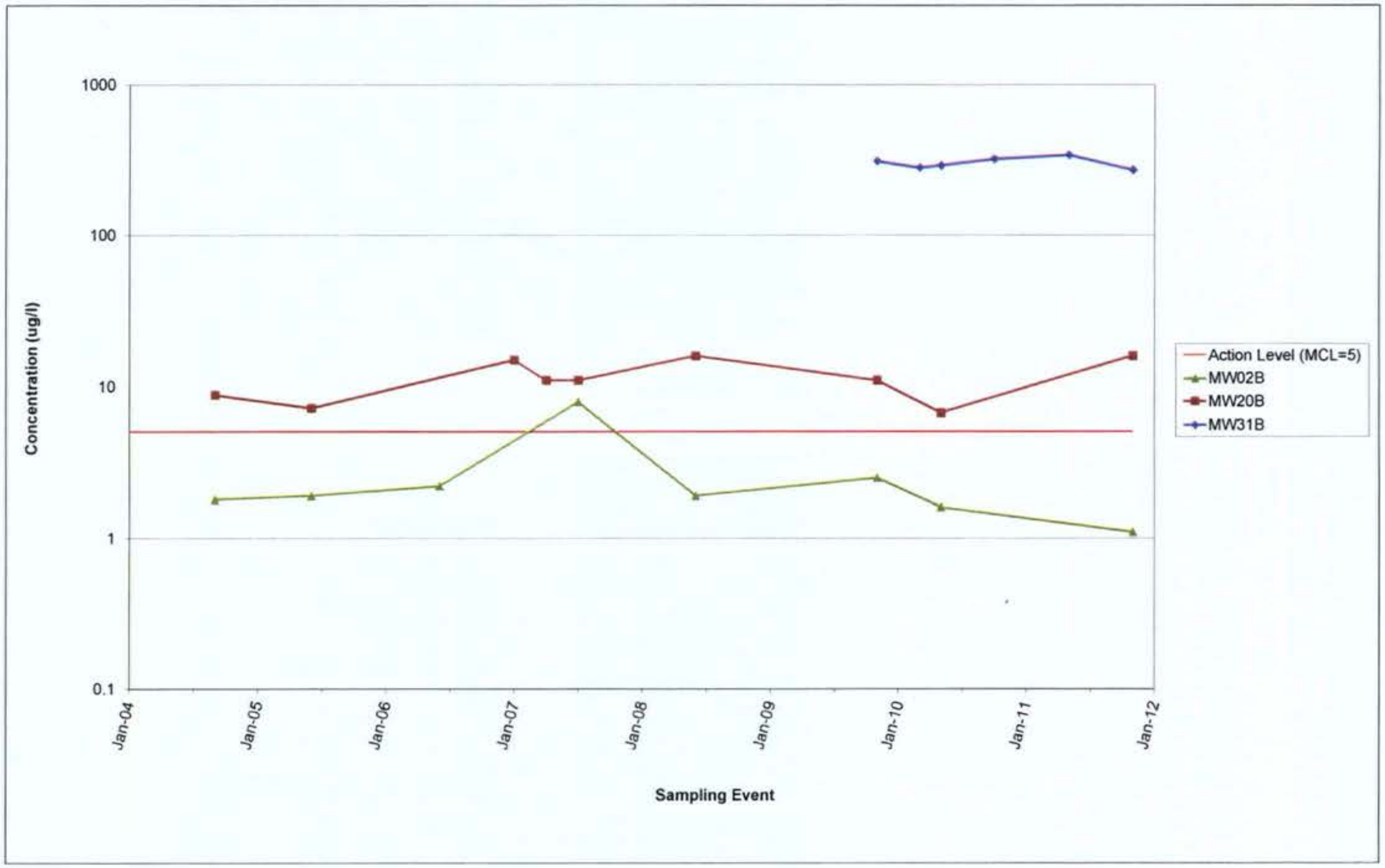


Figure 4-4
Tetrachloroethene Concentration Trends
Upper Bedrock Hydrologic Zone

ORIGINAL

Figure 4-5
Trichloroethene Concentration Trends
Shallow Hydrologic Zone

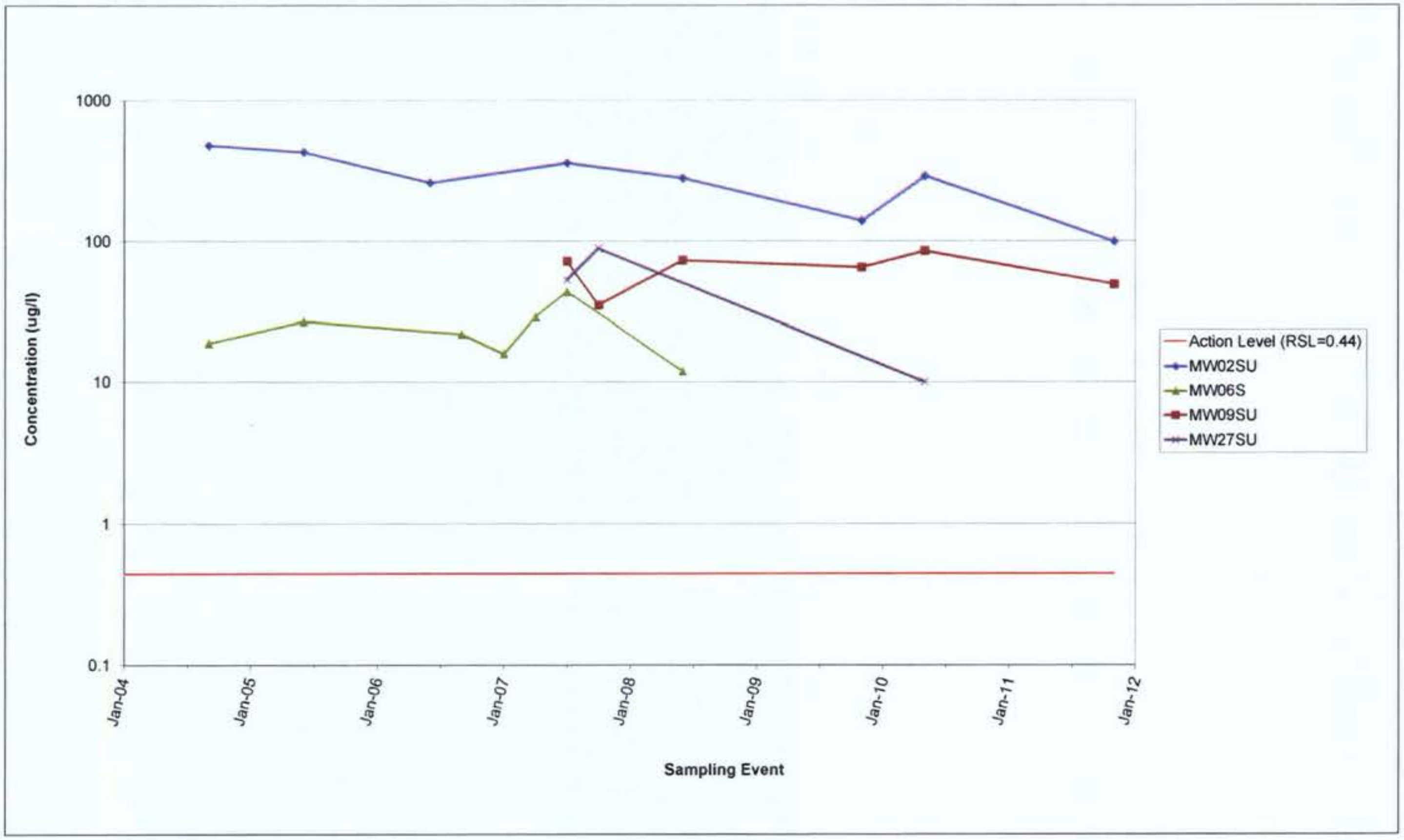
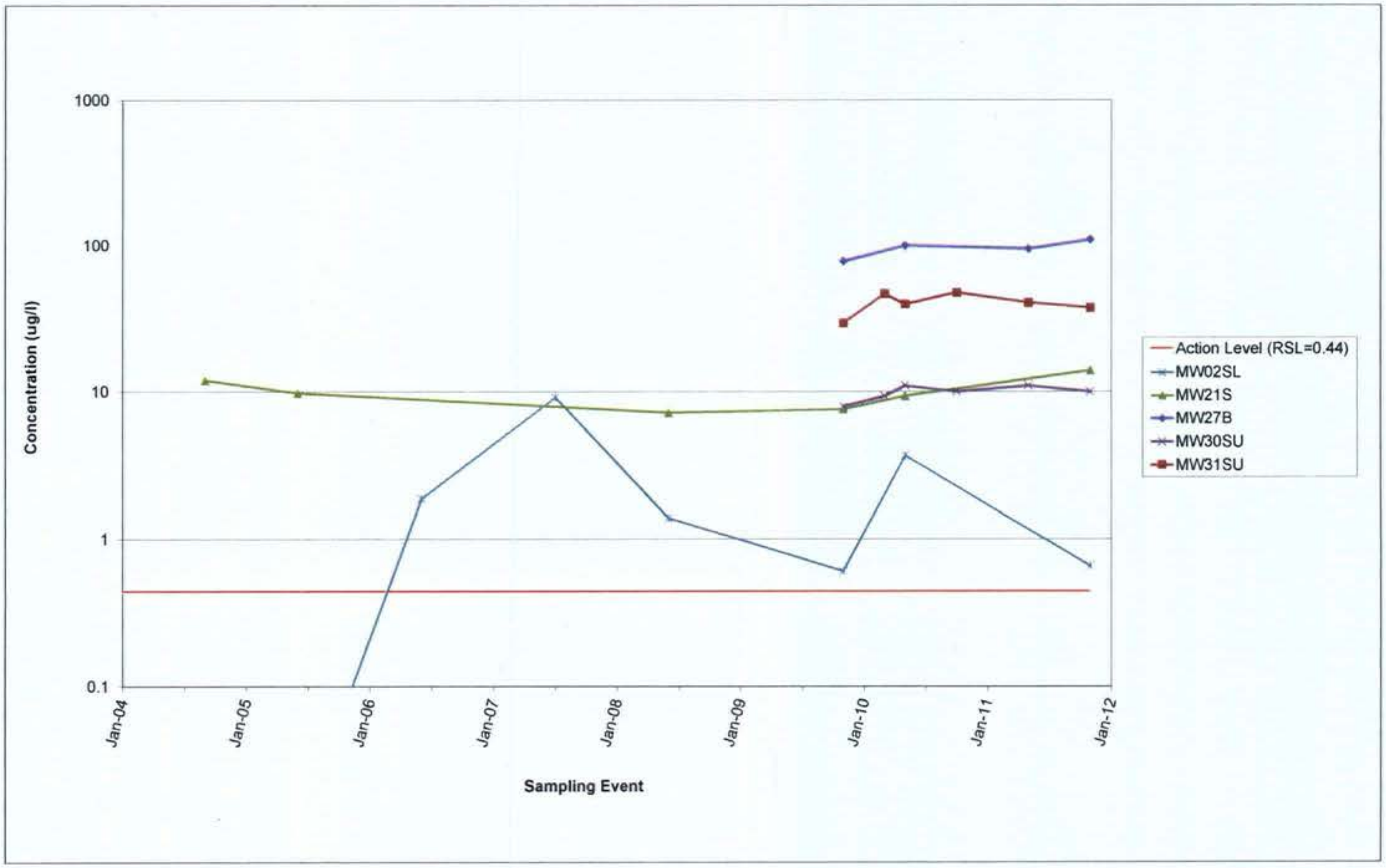


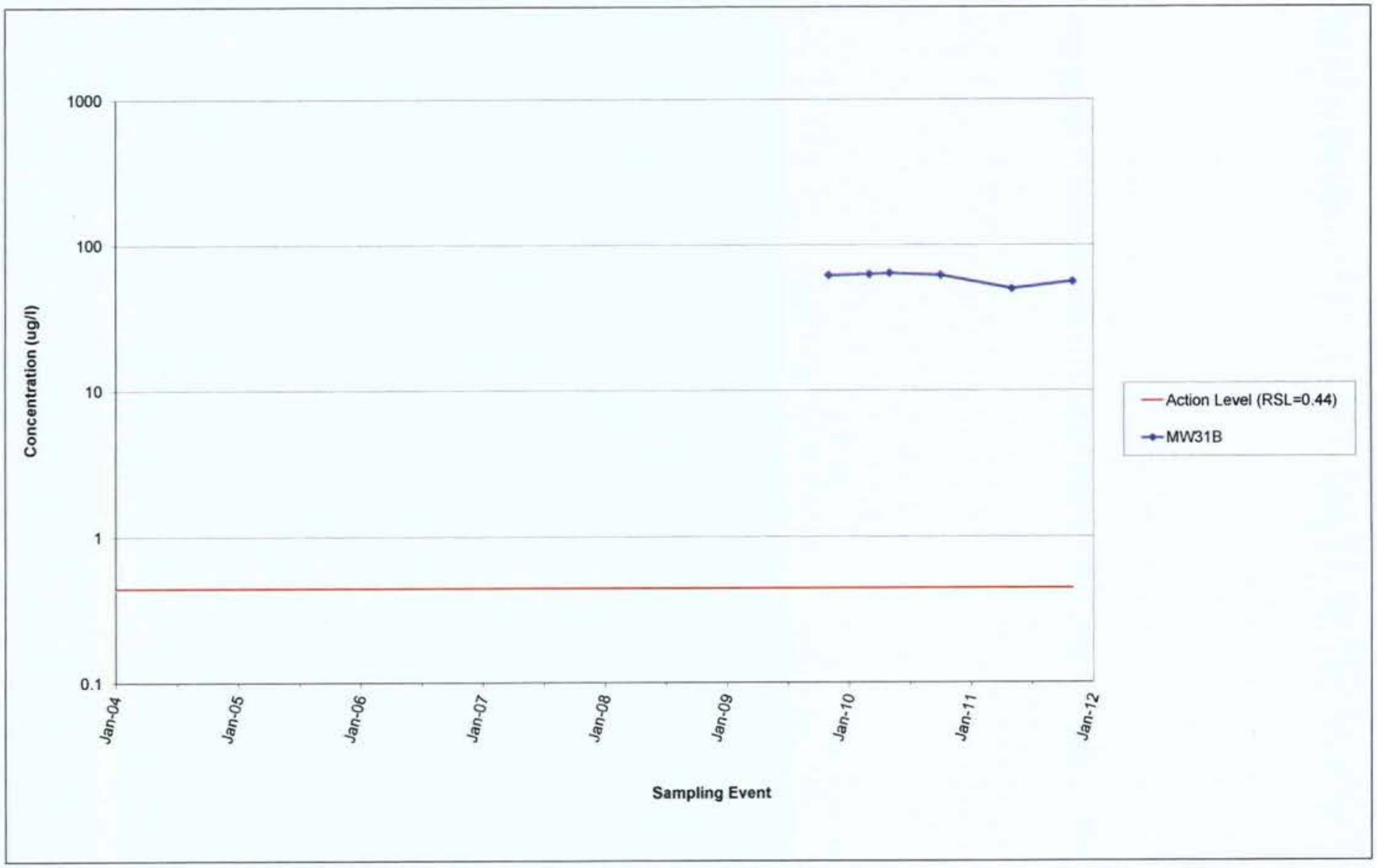
Figure 4-6
Trichloroethene Concentration Trends
Upper Intermediate Hydrologic Zone



Notes: Data points shown below 0.1 ug/l indicate nondetect results.

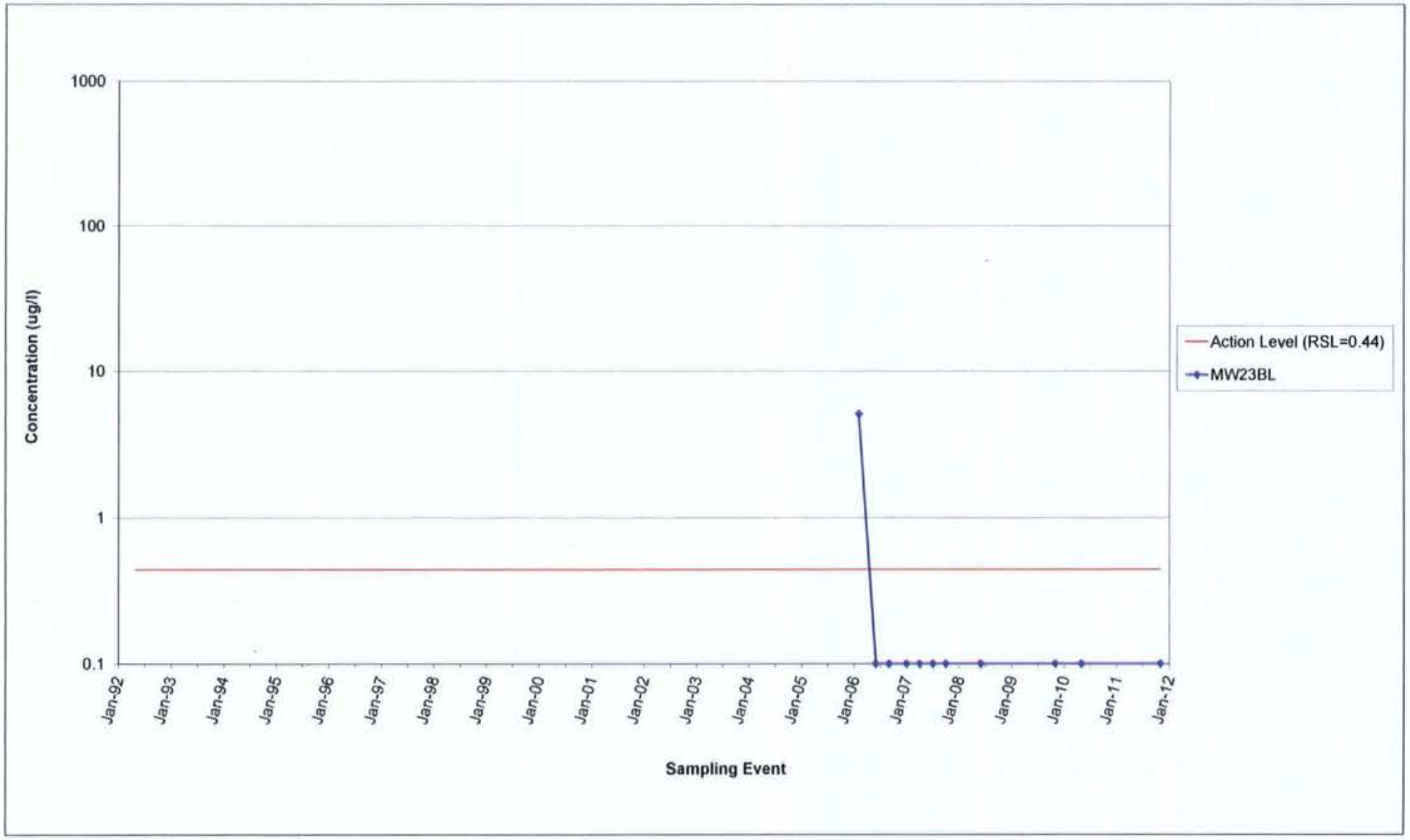
ORIGINAL

Figure 4-7
Trichloroethene Concentration Trends
Lower Intermediate Hydrologic Zone



CDM Smith

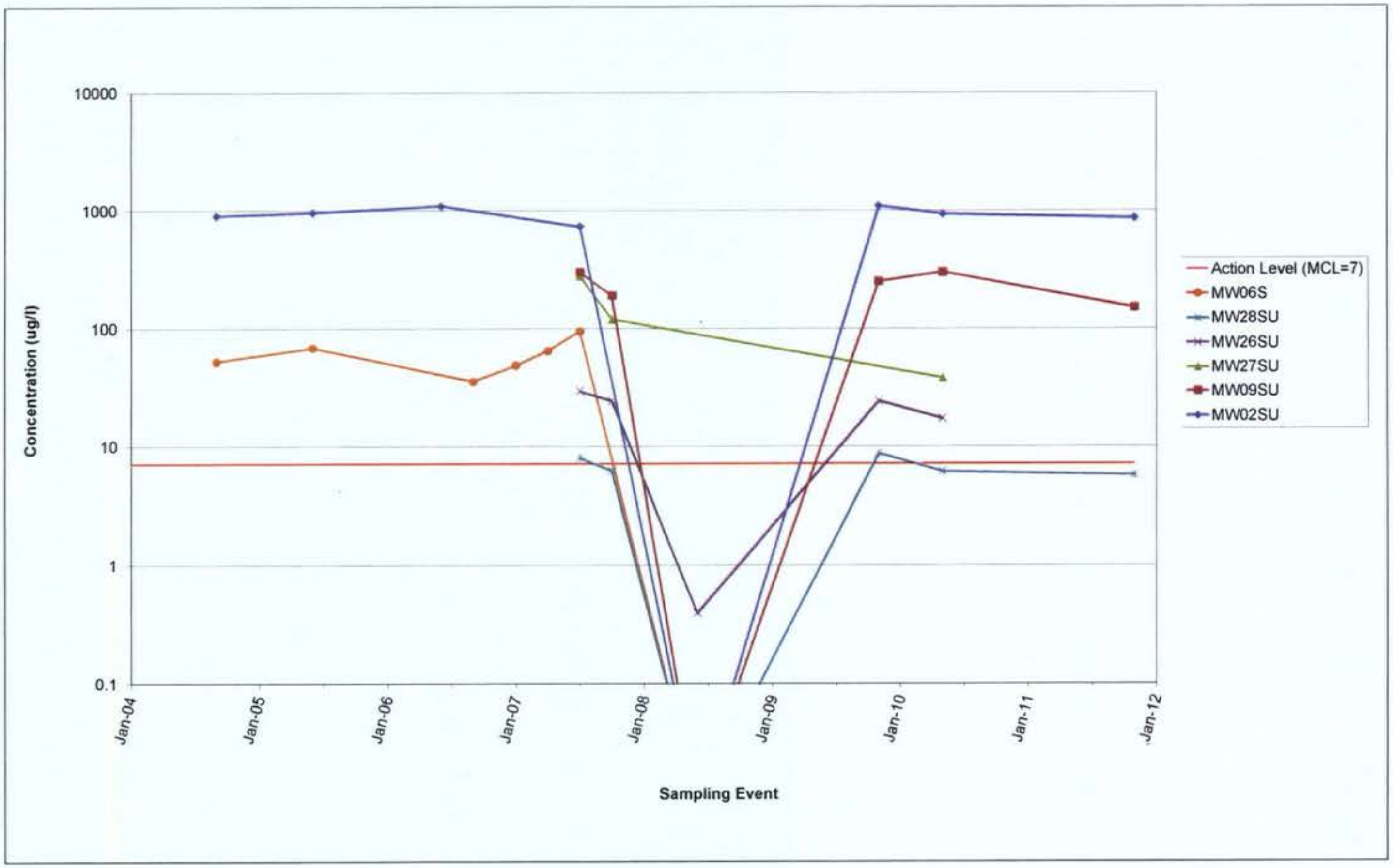
Figure 4-8
Trichloroethene Concentration Trends
Lower Bedrock Hydrologic Zone



Notes: Data points shown below 0.1 ug/l indicate nondetect results.

ORIGINAL

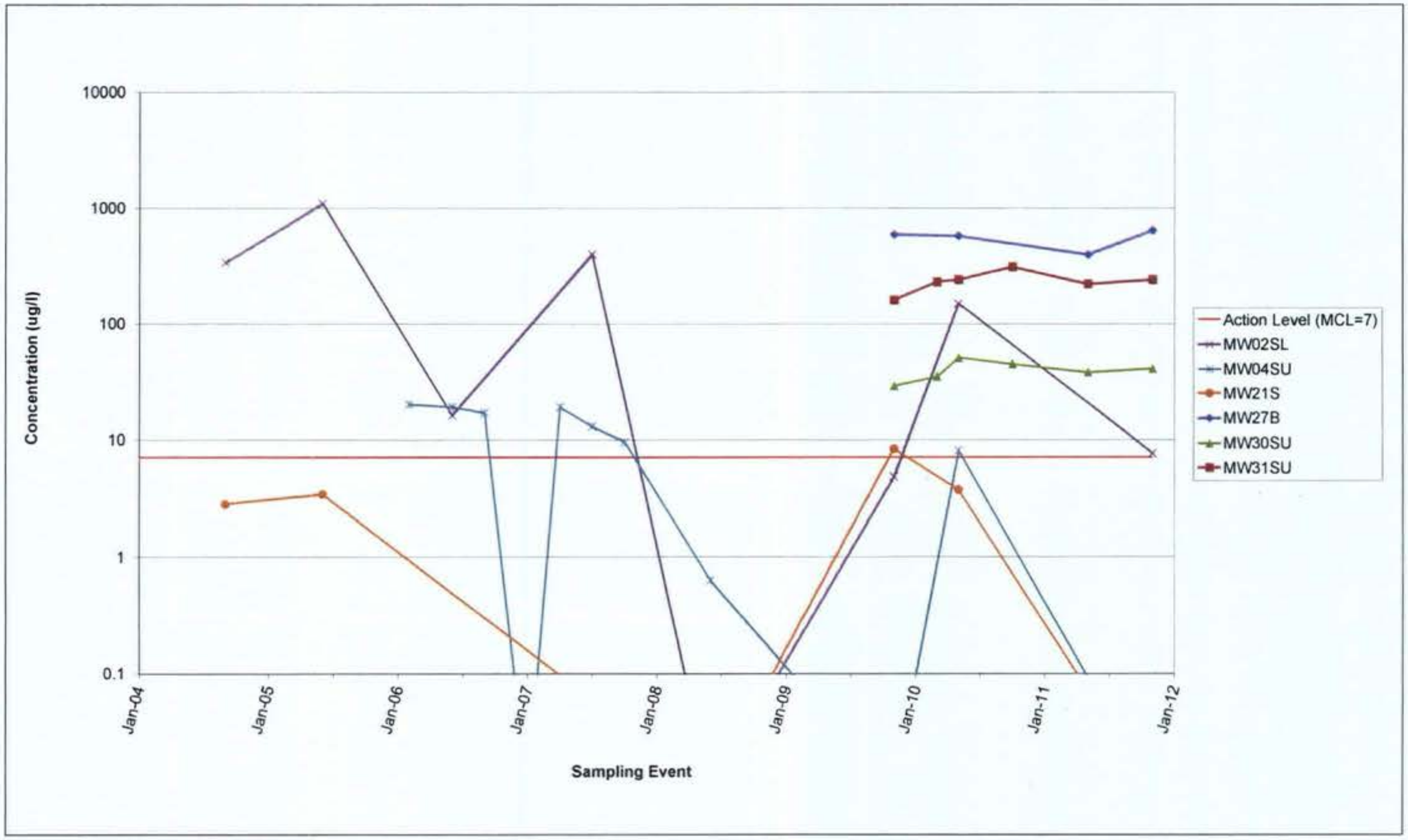
Figure 4-9
1,1-Dichloroethene Concentration Trends
Shallow Hydrologic Zone



Notes: Data points shown below 0.1 ug/l indicate nondetect results.

CDM Smith

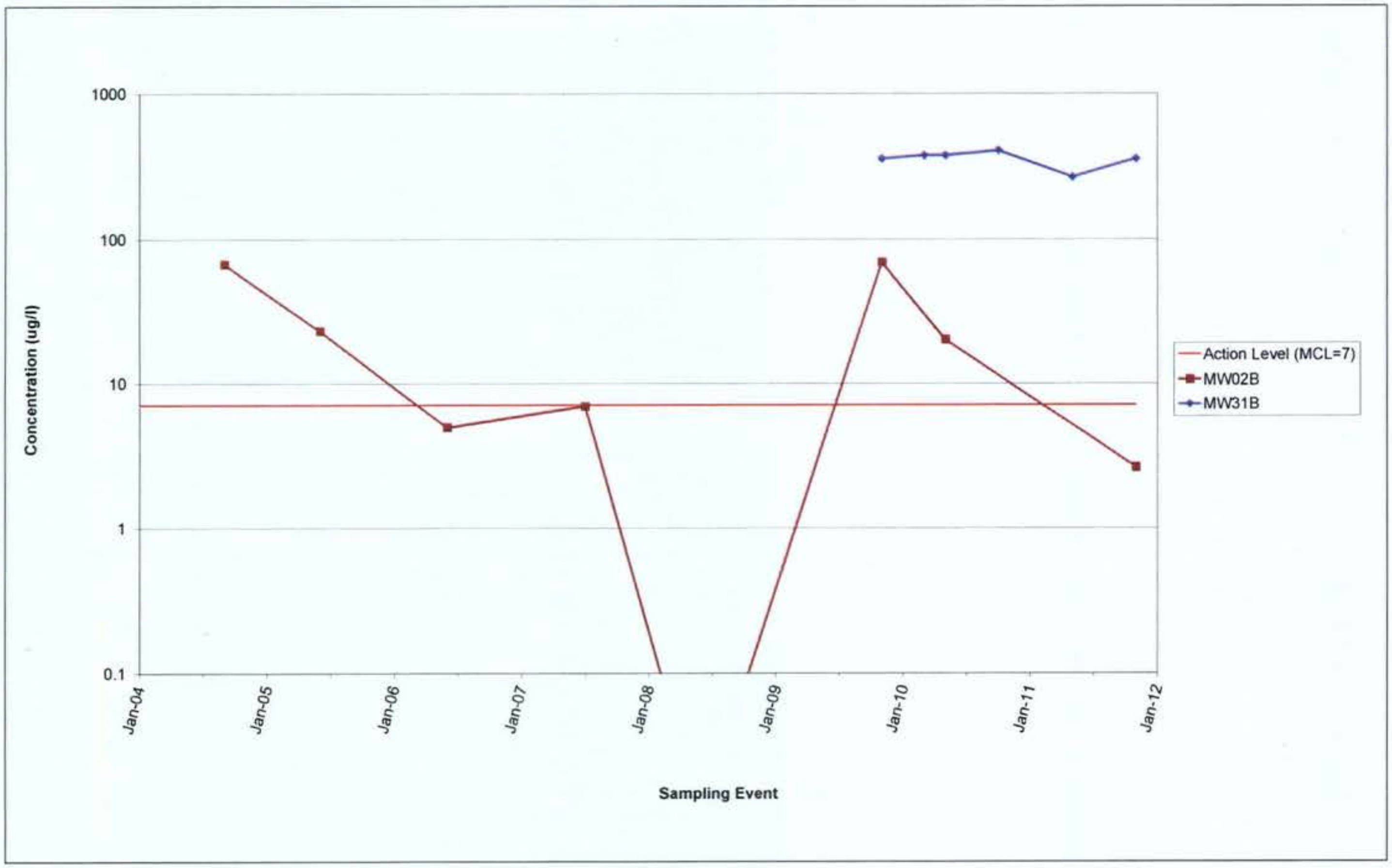
Figure 4-10
1,1-Dichloroethene Concentration Trends
Upper Intermediate Hydrologic Zone



Notes: Data points shown below 0.1 ug/l indicate nondetect results.

ORIGINAL

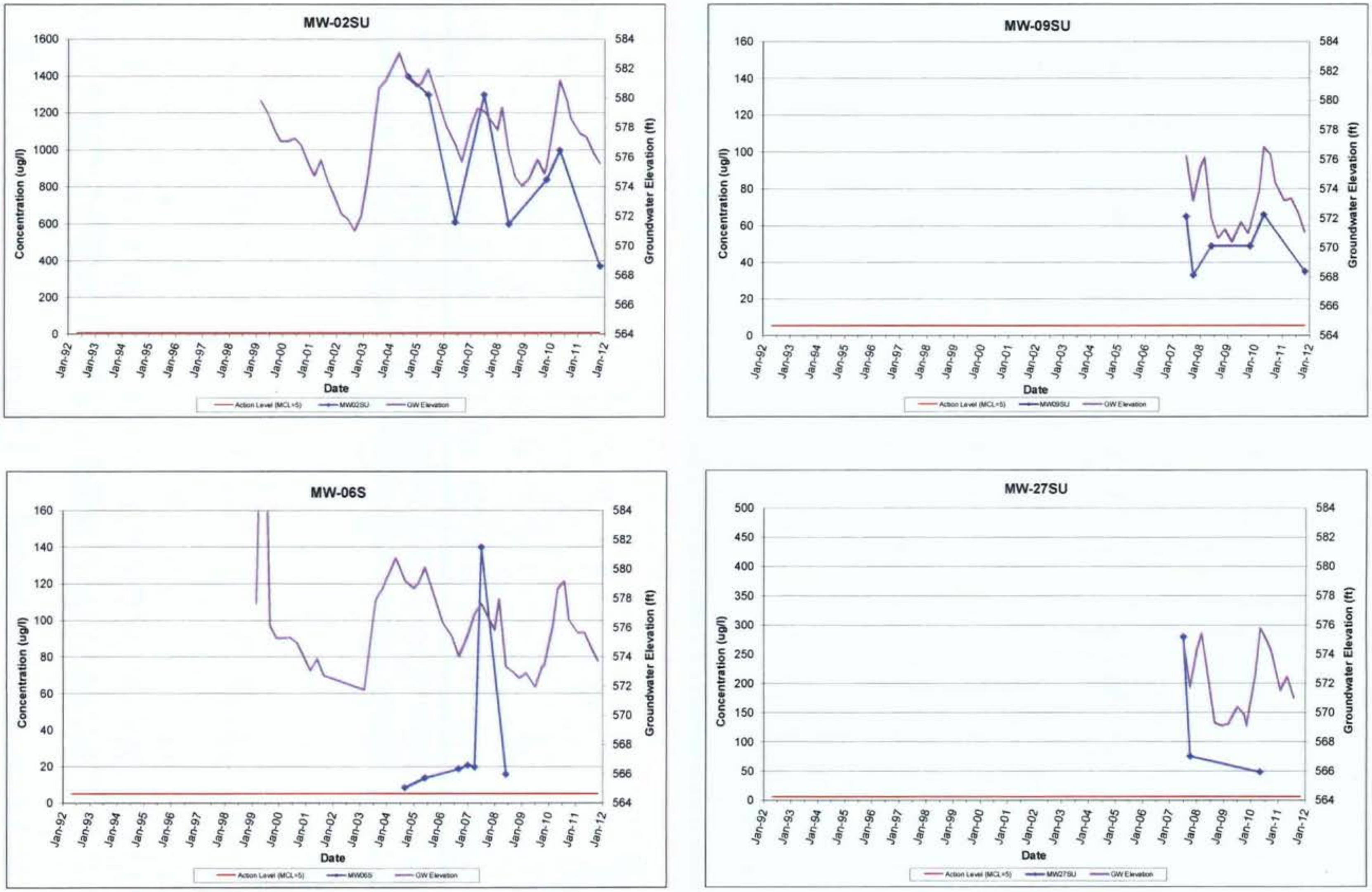
Figure 4-11
1,1-Dichloroethene Concentration Trends
Lower Intermediate Hydrologic Zone



Notes: Data points shown below 0.1 ug/l indicate nondetect results.

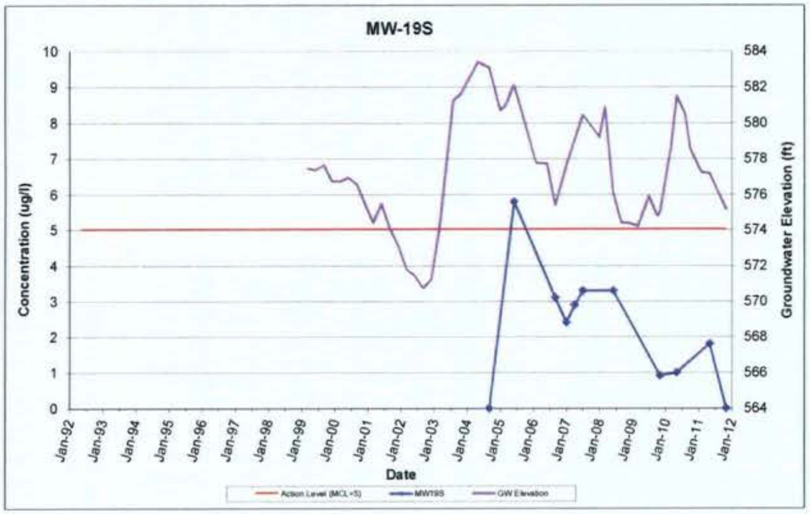
CDM Smith

Figure 4-12
PCE Concentration vs. Groundwater Elevation
Shallow Hydrologic Zone



CDM Smith

Figure 4-12
PCE Concentration vs. Groundwater Elevation
Shallow Hydrologic Zone



Note: Graphs arranged by highest concentration to lowest.

Figure 4-13
PCE Concentration vs. Groundwater Elevation
Upper Intermediate Hydrologic Zone

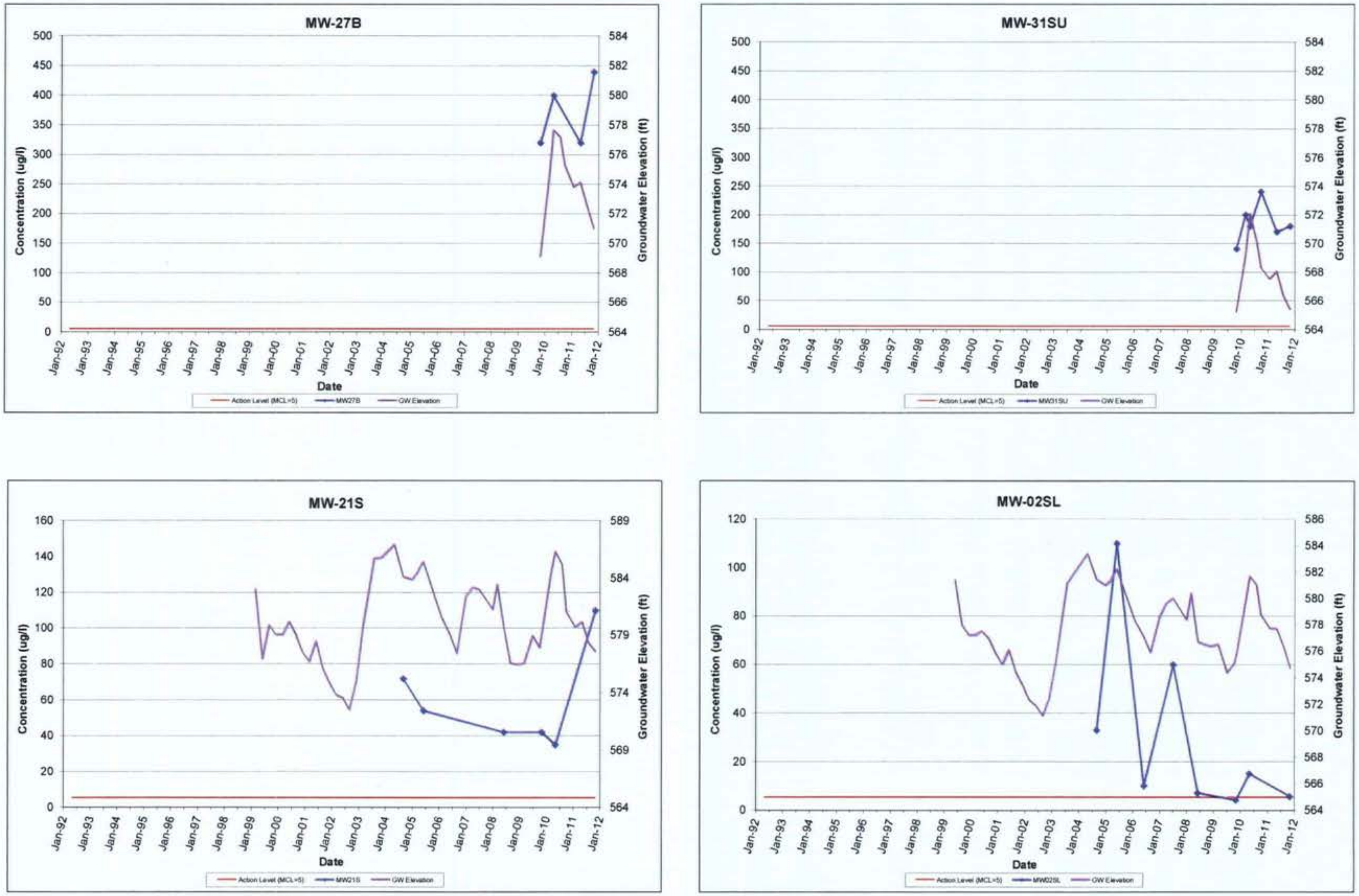
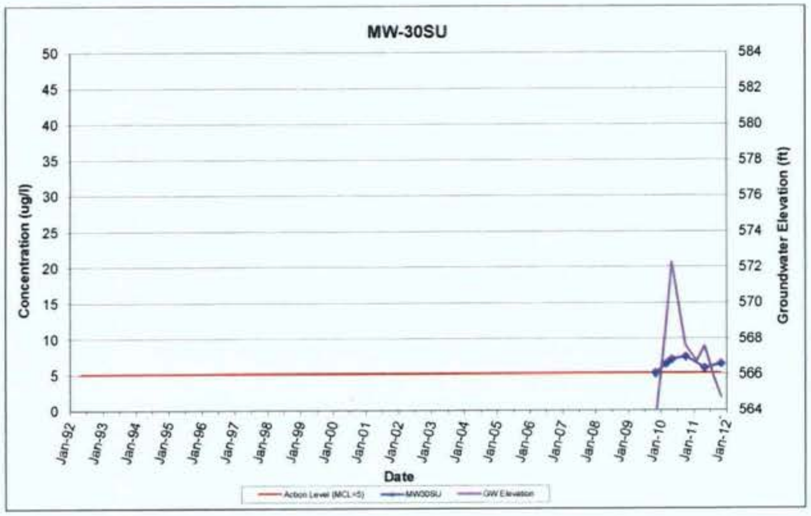
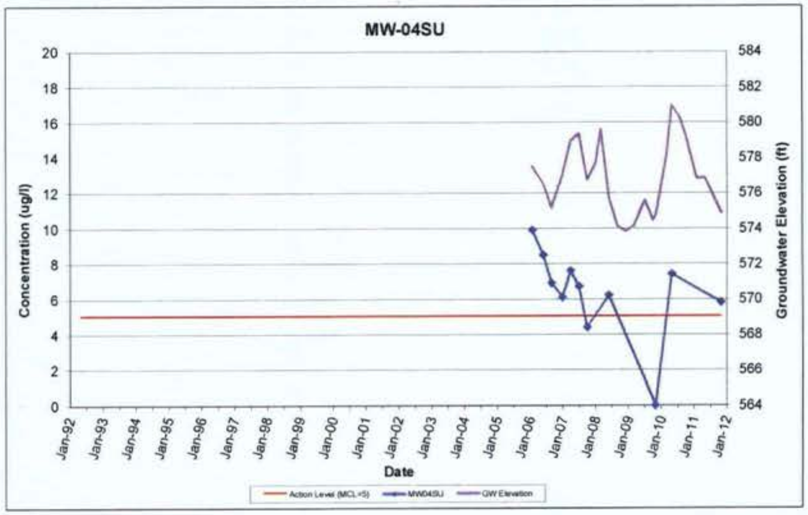


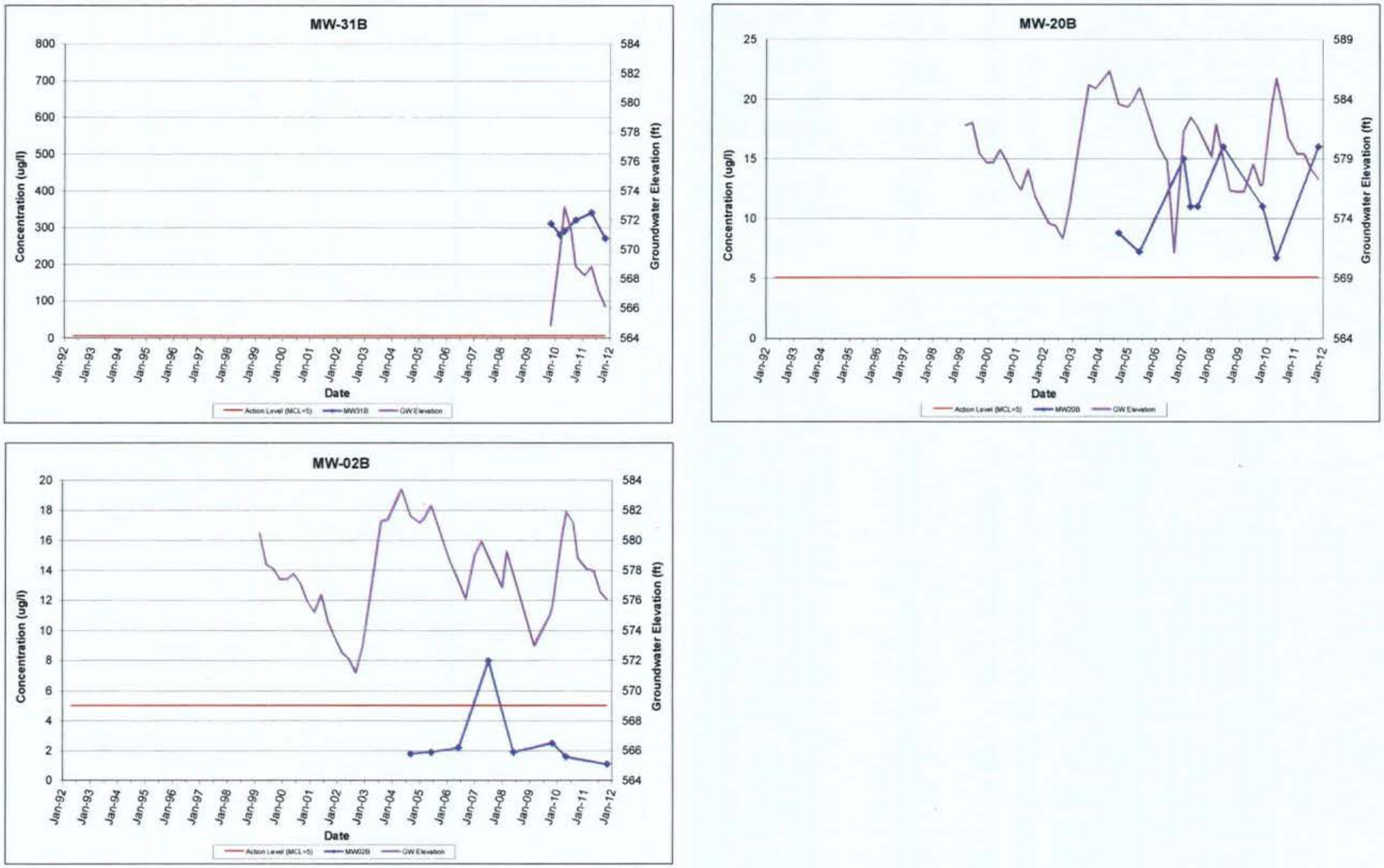
Figure 4-13
PCE Concentration vs. Groundwater Elevation
Upper Intermediate Hydrologic Zone





Note: Graphs arranged by highest concentration to lowest.

Figure 4-14
PCE Concentration vs. Groundwater Elevation
Lower Intermediate Hydrologic Zone



Note: Graphs arranged by highest concentration to lowest.

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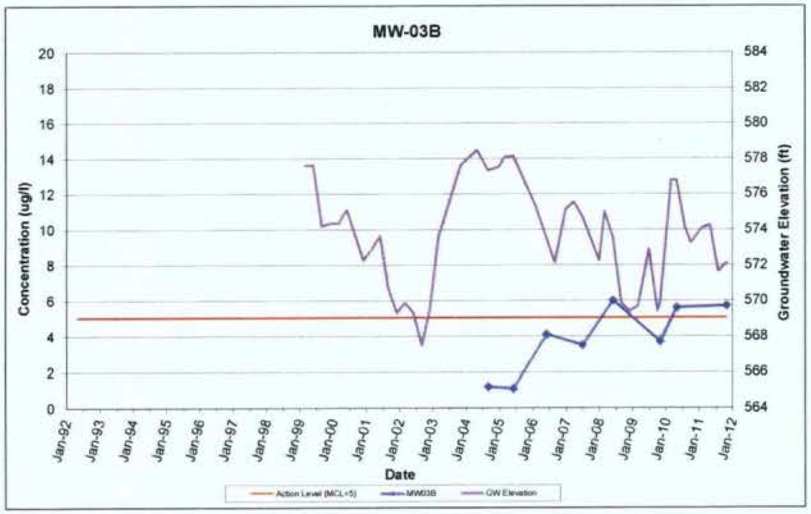
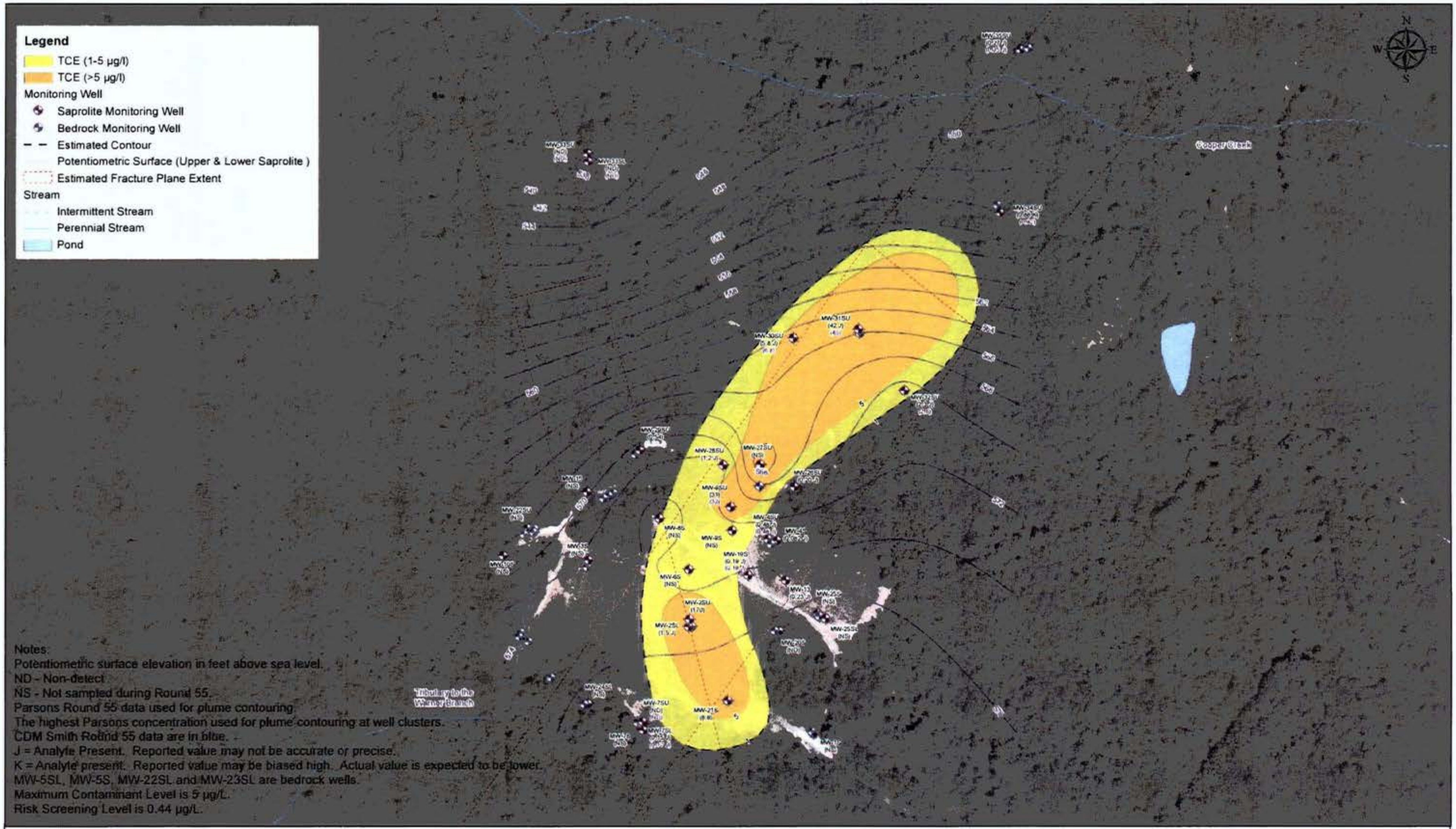
Figure 4-15
PCE Concentration vs. Groundwater Elevation
Upper Bedrock Hydrologic Zone



CDM Smith



Notes:
Potentiometric surface elevation in feet above sea level.
ND - Non-detect
NS - Not sampled during Round 55.
Parsons Round 55 data used for plume contouring.
The highest Parsons concentration used for plume contouring at well clusters.
CDM Smith Round 55 data are in blue.
J = Analyte Present. Reported value may not be accurate or precise.
K = Analyte present. Reported value may be biased high. Actual value is expected to be lower.
MW-5SL, MW-5S, MW-22SL and MW-23SL are bedrock wells.
Maximum Contaminant Level is 5 µg/L.
Risk Screening Level is 0.44 µg/L.

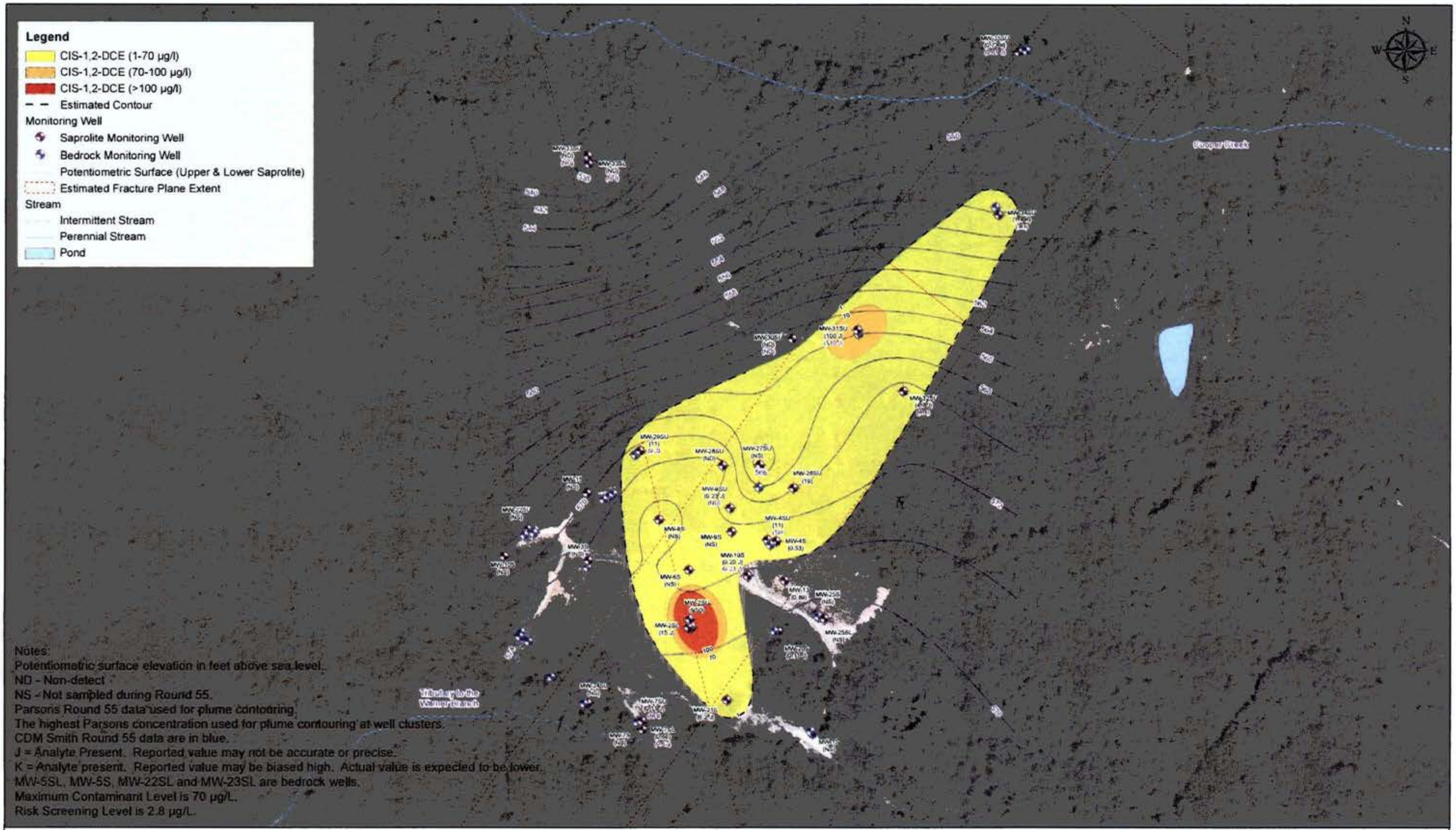
CDM Smith

0 200 400 Feet

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 4-16
Trichloroethene in Upper and Lower Saprolite Groundwater
Round 55 (November and December 2012)

\\Chyfedsvr1\Ecaffx\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Round 55 Oversight Report\Manganese_Shallow.mxd



Notes:
Potentiometric surface elevation in feet above sea level.
ND - Non-detect
NS - Not sampled during Round 55.
Parsons Round 55 data used for plume contouring.
The highest Parsons concentration used for plume contouring at well clusters.
CDM Smith Round 55 data are in blue.
J = Analyte Present. Reported value may not be accurate or precise.
K = Analyte present. Reported value may be biased high. Actual value is expected to be lower.
MW-5SL, MW-5S, MW-22SL and MW-23SL are bedrock wells.
Maximum Contaminant Level is 70 µg/L.
Risk Screening Level is 2.8 µg/L.

CDM Smith

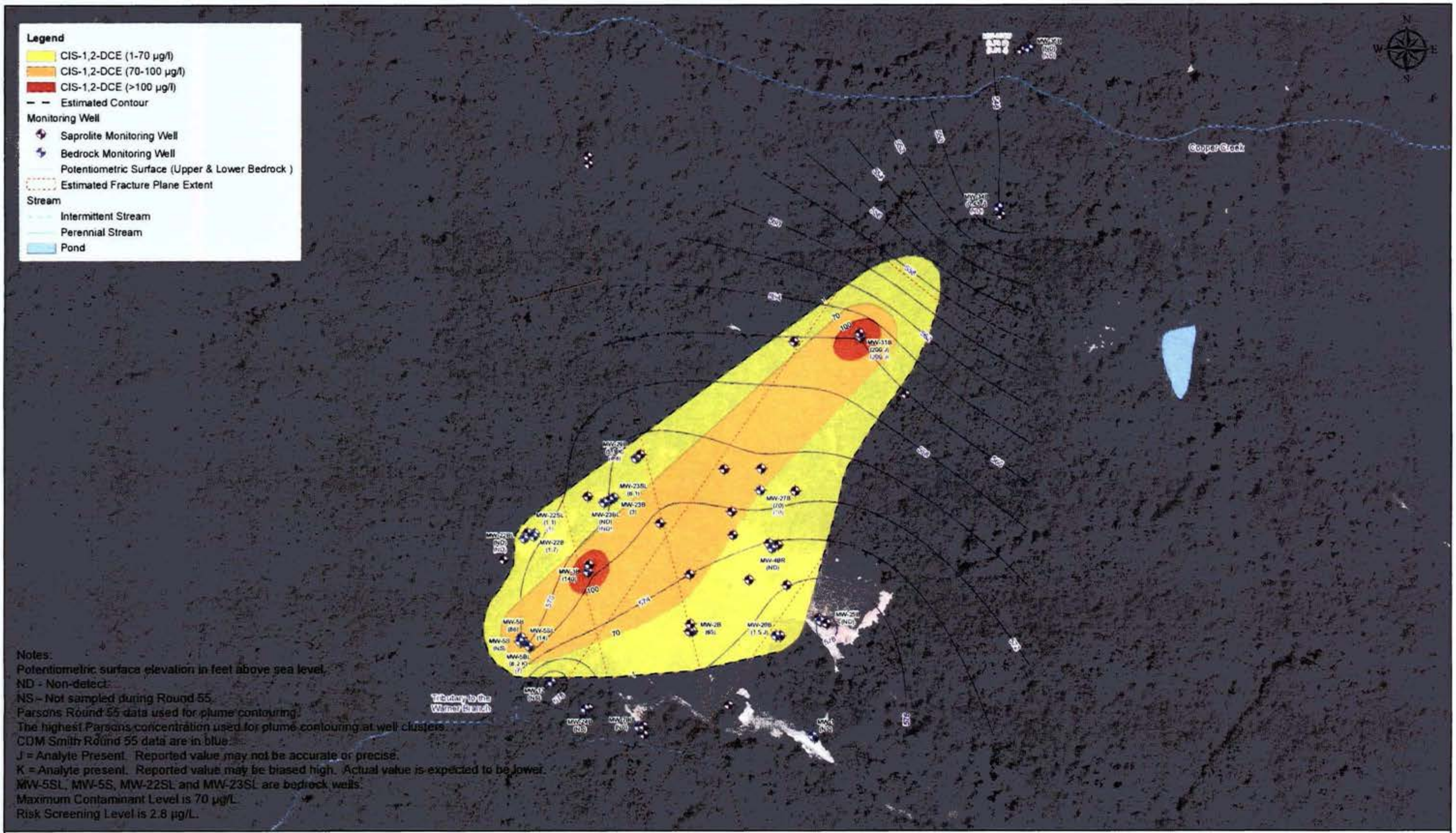
0 200 400 Feet

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 4-18
Cis-1,2-Dichloroethene in Upper and Lower Saprolite Groundwater
Round 55 (November and December 2012)

\\Chyfedsvr1\Ecaffx\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Round 55 Oversight Report\Manganese_Shallow.mxd

ORIGINAL



Notes:
Potentiometric surface elevation in feet above sea level.
ND - Non-detect.
NS – Not sampled during Round 55.
Parsons Round 55 data used for plume contouring.
The highest Parsons concentration used for plume contouring at well clusters.
CDM Smith Round 55 data are in blue.
J = Analyte Present. Reported value may not be accurate or precise.
K = Analyte present. Reported value may be biased high. Actual value is expected to be lower.
MW-5SL, MW-5S, MW-22SL and MW-23SL are bedrock wells.
Maximum Contaminant Level is 70 µg/L.
Risk Screening Level is 2.8 µg/L.

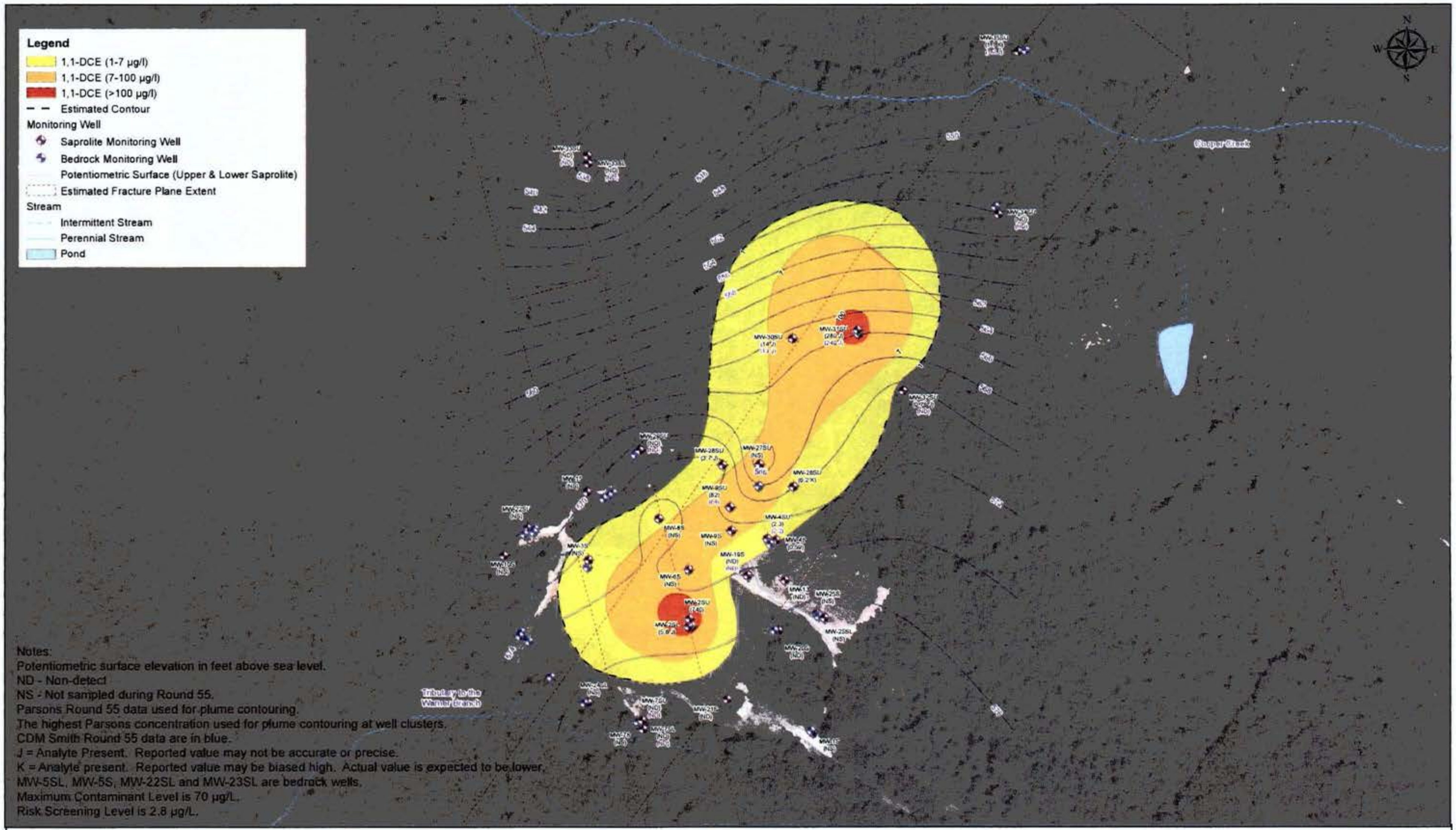
CDM Smith

0 200 400 Feet

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 4-19
Cis-1,2-Dichloroethene in Upper and Lower Bedrock Groundwater
Round 55 (November and December 2012)

\\Chyfedsvr1\Ecaffx\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Round 55 Oversight Report\Manganese_Shallow.mxd



Notes:
Potentiometric surface elevation in feet above sea level.
ND - Non-detect
NS - Not sampled during Round 55.
Parsons Round 55 data used for plume contouring.
The highest Parsons concentration used for plume contouring at well clusters.
CDM Smith Round 55 data are in blue.
J = Analyte Present. Reported value may not be accurate or precise.
K = Analyte present. Reported value may be biased high. Actual value is expected to be lower.
MW-5SL, MW-5S, MW-22SL and MW-23SL are bedrock wells.
Maximum Contaminant Level is 70 µg/L.
Risk Screening Level is 2.8 µg/L.

CDM Smith

0 200 400 Feet

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 4-20
1,1-Dichloroethene in Upper and Lower Saprolite Groundwater
Round 55 (November and December 2012)

\\Chyfedsvr1\Ecafts\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Round 55 Oversight Report\Manganese_Shallow.mxd

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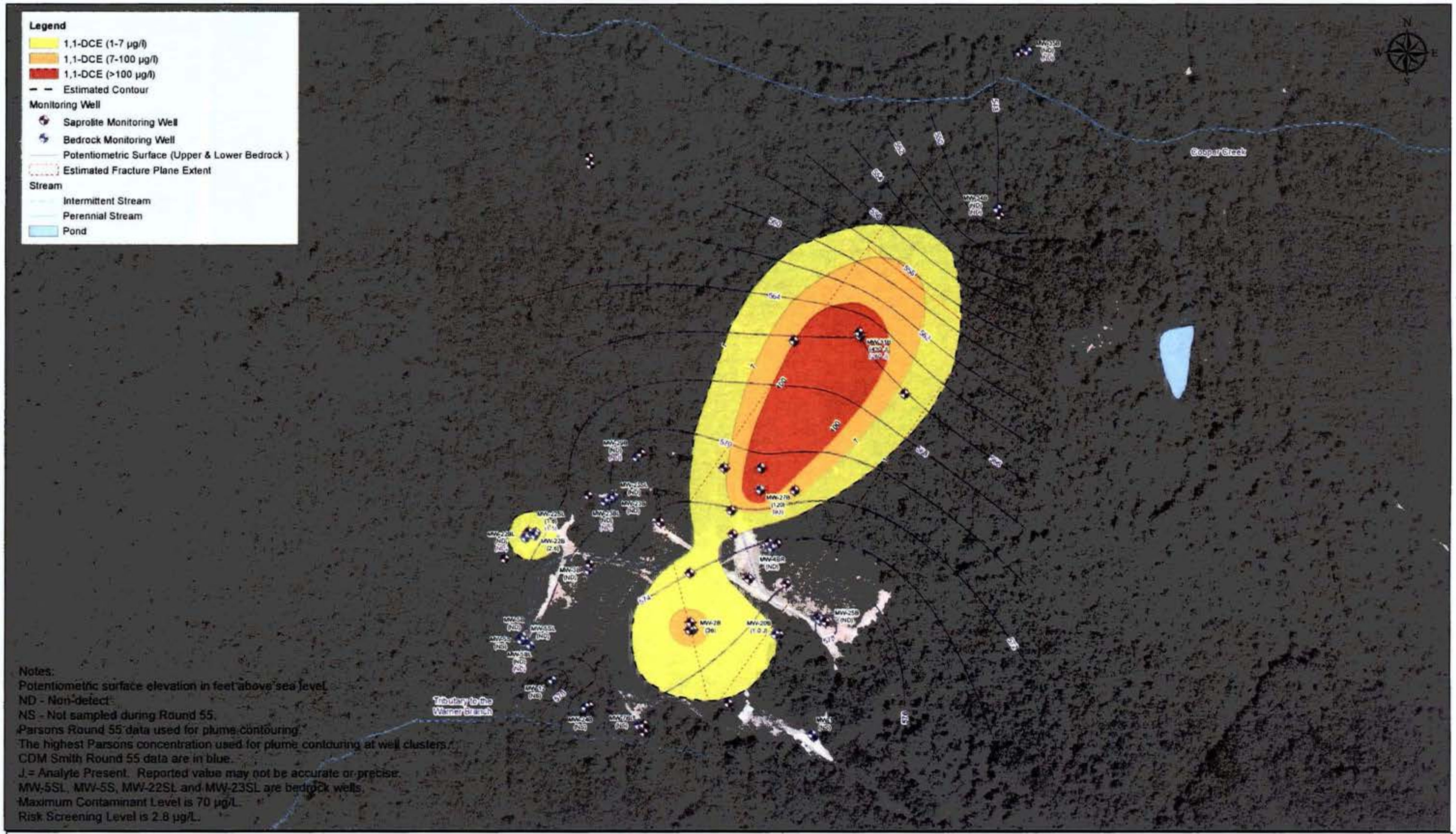


Notes:
Potentiometric surface elevation in feet above sea level.
ND - Non-detect.
NS - Not sampled during Round 55.
Parsons Round 55 data used for plume contouring.
The highest Parsons concentration used for plume contouring at well clusters.
CDM Smith Round 55 data are in blue.
J = Analyte Present. Reported value may not be accurate or precise.
MW-5SL, MW-5S, MW-22SL and MW-23SL are bedrock wells.
Maximum Contaminant Level is 70 µg/L.
Risk Screening Level is 2.8 µg/L.

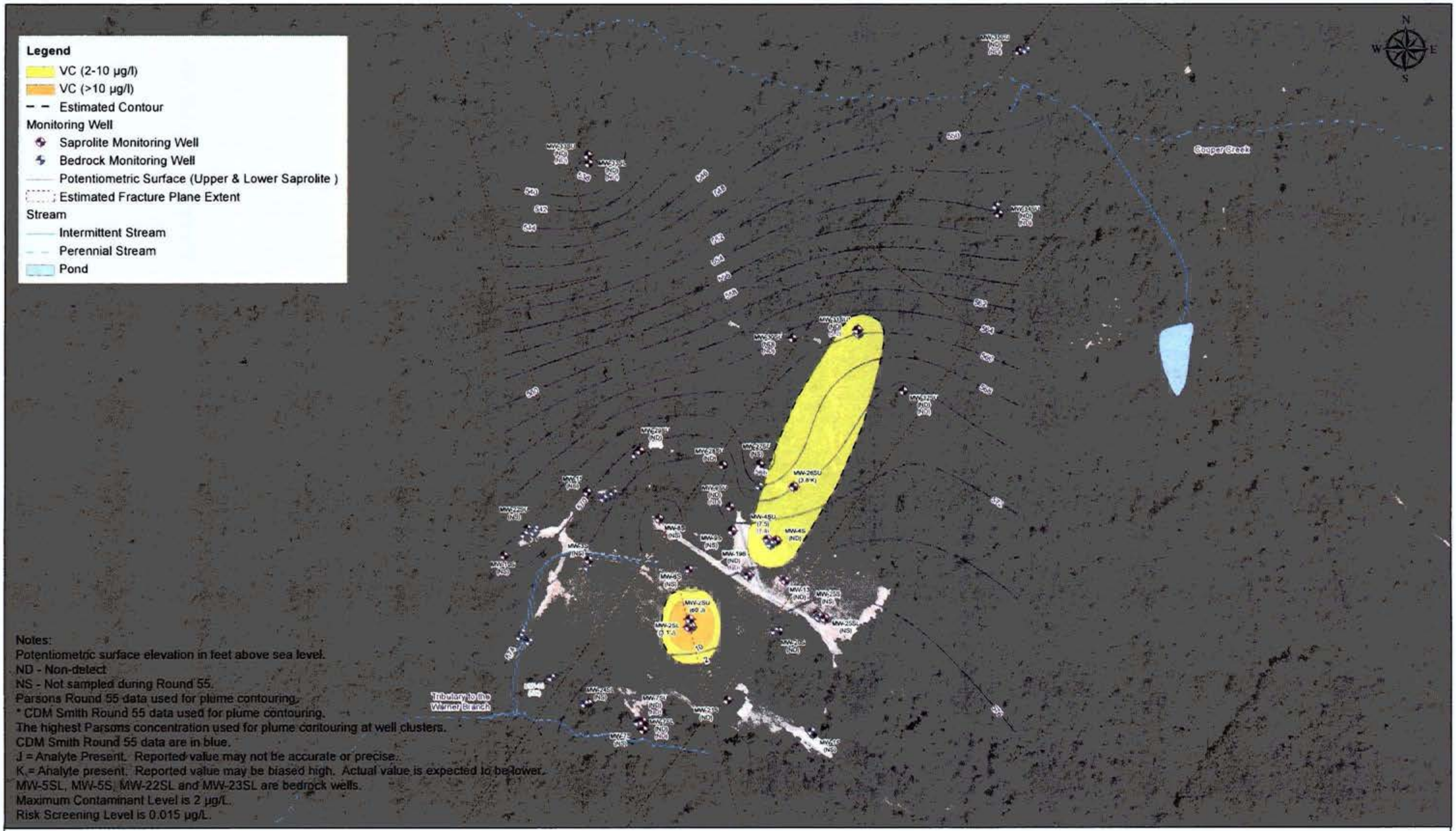
CDM Smith

0 200 400 Feet

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 4-21
1,1-Dichloroethene in Upper and Lower Bedrock Groundwater
Round 55 (November and December 2012)

\\Chyfedsvr1\Ecaffx\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Round 55 Oversight Report\Manganese_Shallow.mxd



Notes:
Potentiometric surface elevation in feet above sea level.
ND - Non-detect
NS - Not sampled during Round 55.
Parsons Round 55 data used for plume contouring.
* CDM Smith Round 55 data used for plume contouring.
The highest Parsons concentration used for plume contouring at well clusters.
CDM Smith Round 55 data are in blue.
J = Analyte Present. Reported value may not be accurate or precise.
K = Analyte present. Reported value may be biased high. Actual value is expected to be lower.
MW-5SL, MW-5S, MW-22SL and MW-23SL are bedrock wells.
Maximum Contaminant Level is 2 µg/L.
Risk Screening Level is 0.015 µg/L.

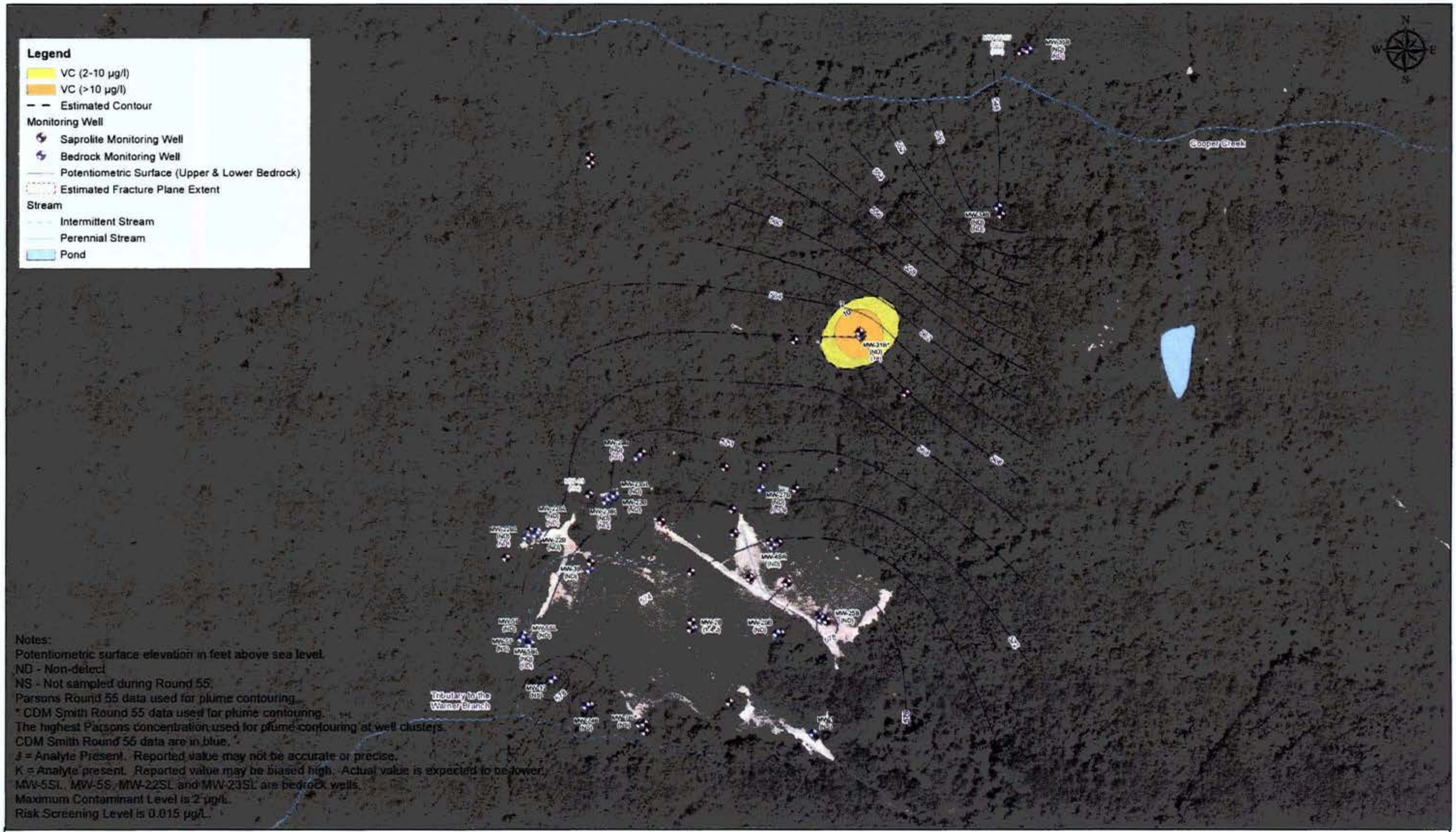
CDM Smith

0 200 400 Feet

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 4-22
Vinyl Chloride in Upper and Lower Saprolite Groundwater
Round 55 (November and December 2012)

\\Chyfedsvr1\Ecaffx\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Round 55 Oversight Report\Manganese_Shallow.mxd



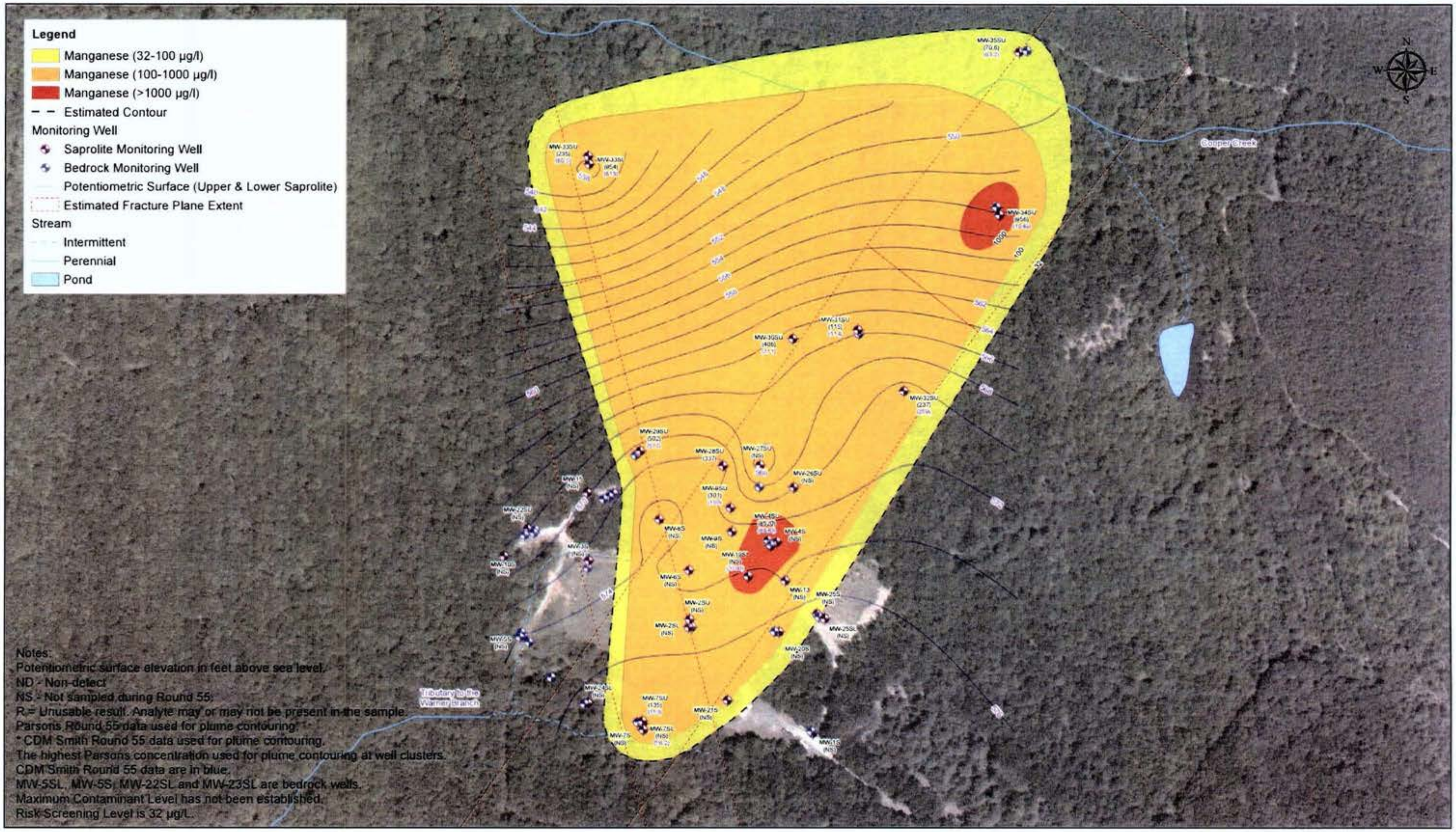
Notes:
Potentiometric surface elevation in feet above sea level.
ND - Non-detect
NS - Not sampled during Round 55.
Parsons Round 55 data used for plume contouring.
* CDM Smith Round 55 data used for plume contouring.
The highest Parsons concentration used for plume contouring at well clusters.
CDM Smith Round 55 data are in blue.
J = Analyte Present. Reported value may not be accurate or precise.
K = Analyte present. Reported value may be biased high. Actual value is expected to be lower.
MW-5SL, MW-5S, MW-22SL and MW-23SL are bedrock wells.
Maximum Contaminant Level is 2 µg/L.
Risk Screening Level is 0.015 µg/L.

CDM Smith

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 4-23
Vinyl Chloride in Upper and Lower Bedrock Groundwater
Round 55 (November and December 2012)

\\Chyfedsvr1\Ecaffx\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Round 55 Oversight Report\Manganese_Shallow.mxd



Legend

- 🟨 Manganese (32-100 µg/l)
- 🟧 Manganese (100-1000 µg/l)
- 🟥 Manganese (>1000 µg/l)
- – – Estimated Contour

Monitoring Well

- ● Saprolite Monitoring Well
- ● Bedrock Monitoring Well
- — Potentiometric Surface (Upper & Lower Saprolite)
- ⬚ Estimated Fracture Plane Extent

Stream

- - - Intermittent
- — Perennial
- ▭ Pond

Notes:
Potentiometric surface elevation in feet above sea level.
ND - Non-detect
NS - Not sampled during Round 55.
R = Unusable result. Analyte may or may not be present in the sample.
Parsons Round 55 data used for plume contouring.
* CDM Smith Round 55 data used for plume contouring.
The highest Parsons concentration used for plume contouring at well clusters.
CDM Smith Round 55 data are in blue.
MW-5SL, MW-5S, MW-22SL and MW-23SL are bedrock wells.
Maximum Contaminant Level has not been established.
Risk Screening Level is 32 µg/L.

CDM Smith

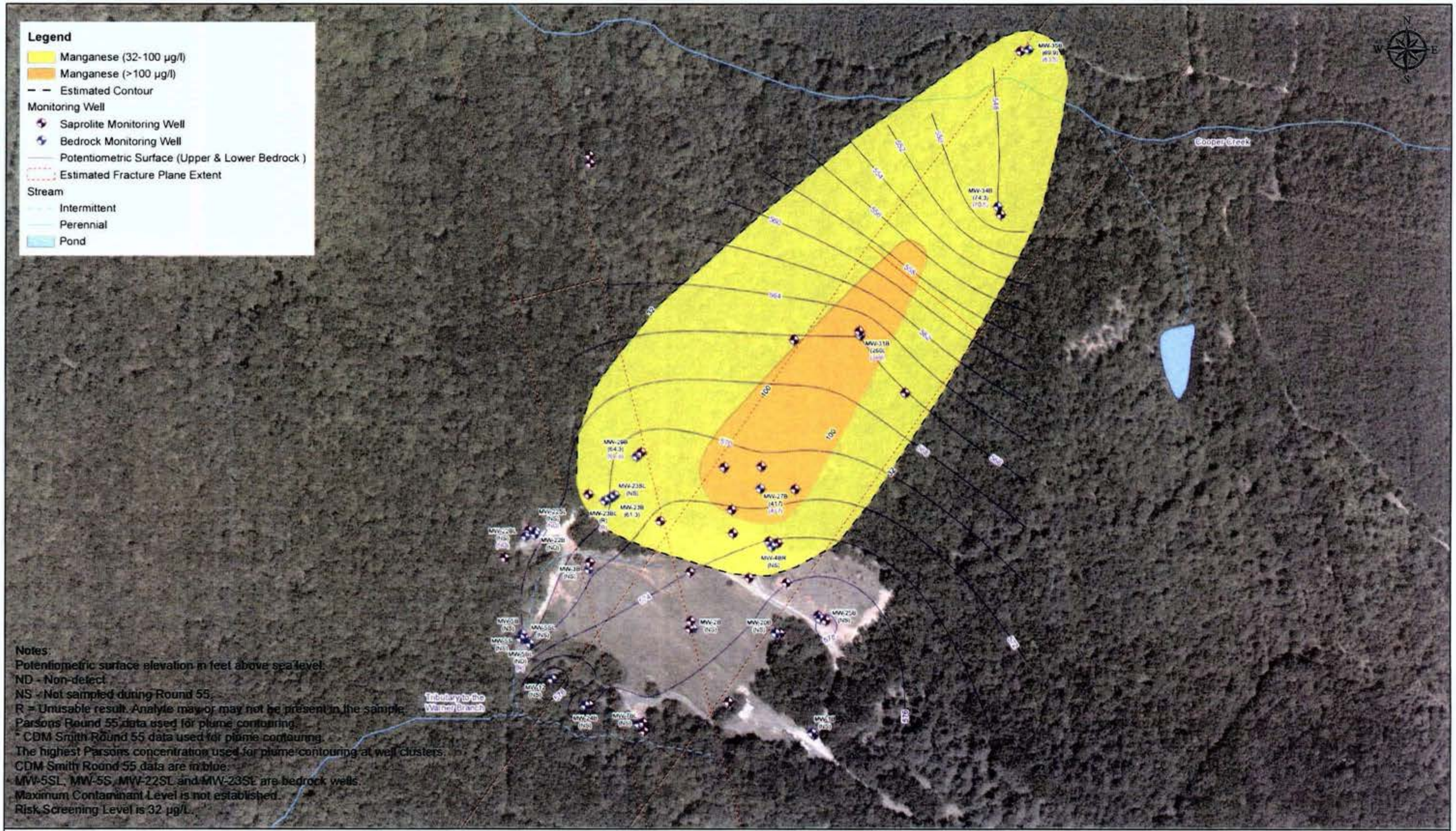
0 200 400 Feet

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 4-24
Total Manganese in Upper and Lower Saprolite Groundwater
Round 55 (November and December 2012)

\\Chyfedsvr1\Ecaftx\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Round 55 Oversight Report\Manganese_Shallow.mxd

ORIGINAL



Notes:
Potentiometric surface elevation in feet above sea level.
ND - Non-detect
NS - Not sampled during Round 55.
R = Unusable result. Analyte may or may not be present in the sample.
Parsons Round 55 data used for plume contouring.
* CDM Smith Round 55 data used for plume contouring.
The highest Parsons concentration used for plume contouring at well clusters.
CDM Smith Round 55 data are in blue.
MW-5SL, MW-5S, MW-22SL and MW-23SL are bedrock wells.
Maximum Contaminant Level is not established.
Risk Screening Level is 32 µg/L.

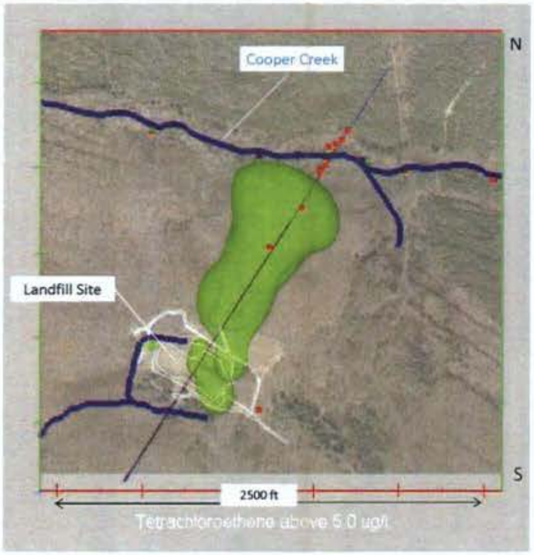
CDM Smith

0 200 400 Feet

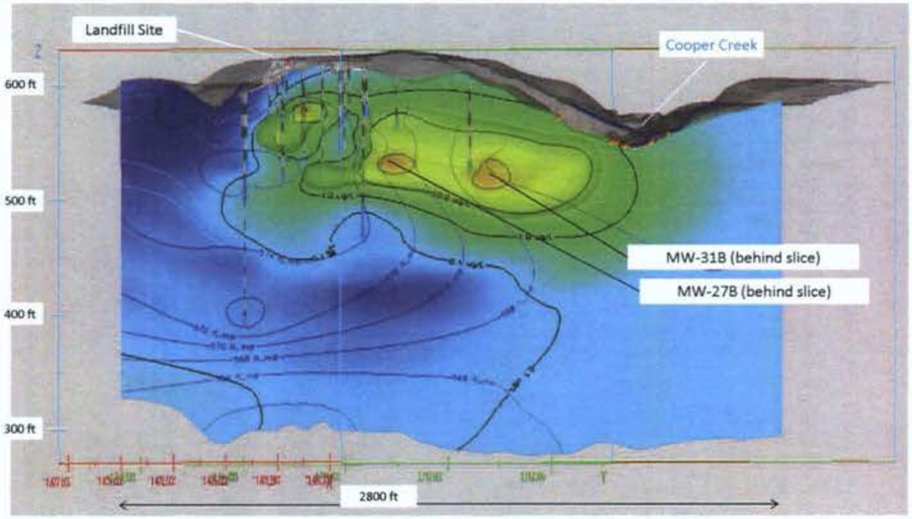
Buckingham County Landfill Site
Buckingham County, Virginia

Figure 4-25
Total Manganese in Upper and Lower Bedrock Groundwater
Round 55 (November and December 2012)

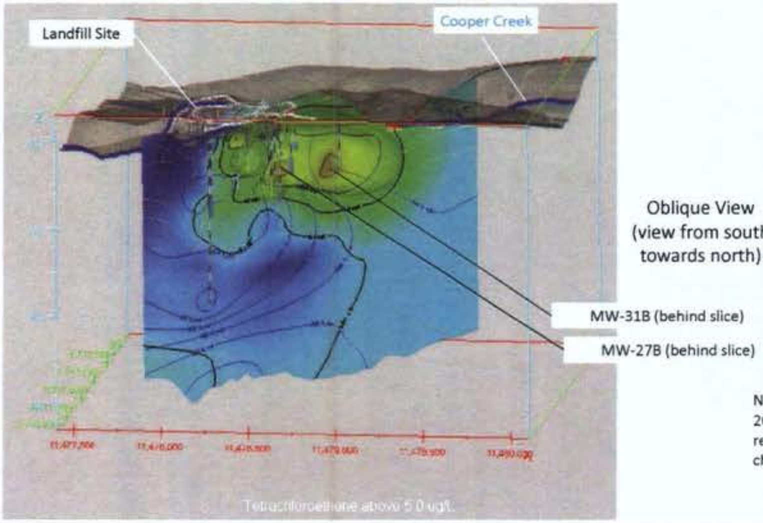
\\Chyfedsvr1\Ecafx\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Round 55 Oversight Report\Manganese_Shallow.mxd



Aerial View



Side View
(view from southeast towards
northwest)



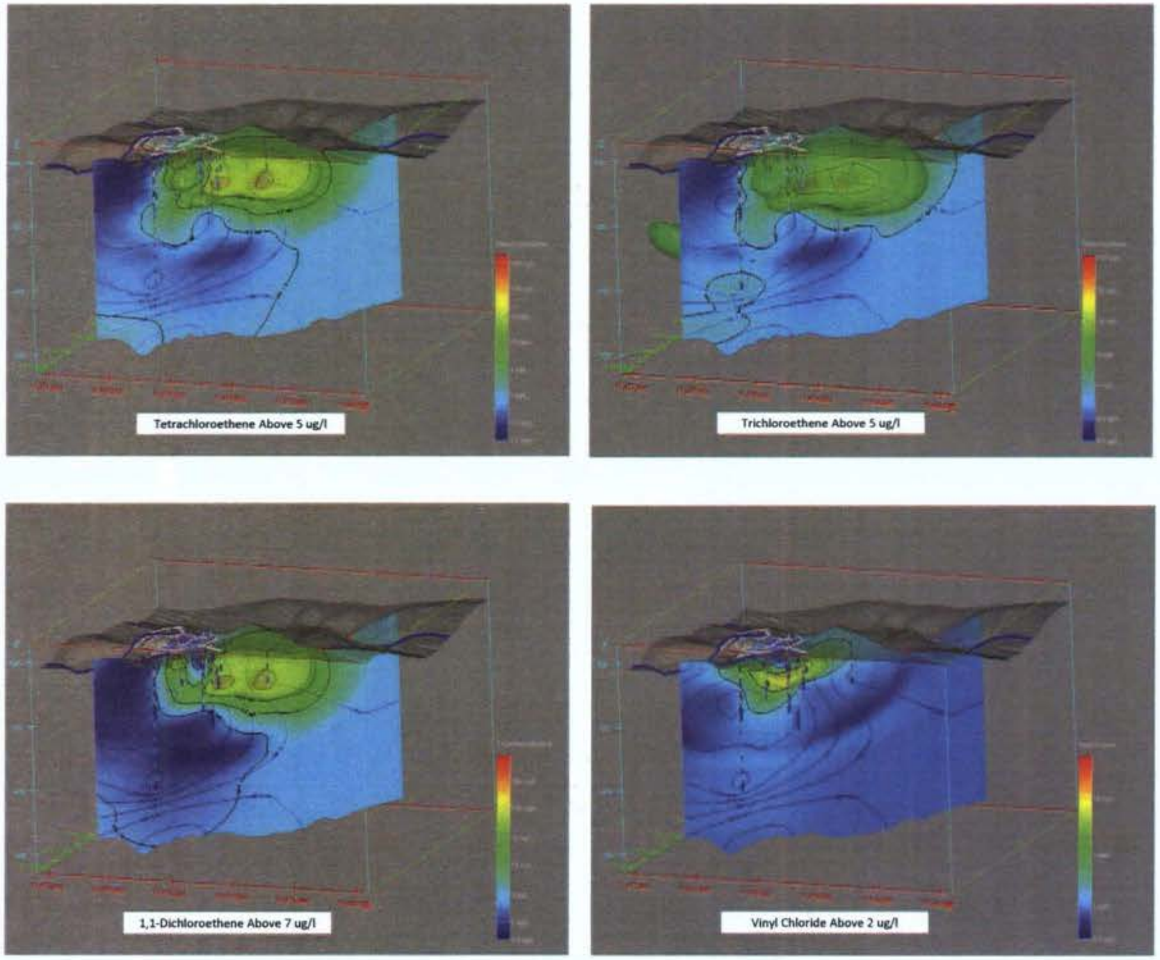
Oblique View
(view from south
towards north)

Notes: 3D model created in MVS using data from Round 51 (Nov 2011) where available. For wells not sampled in Round 51, the most recent analytical result was used to ensure the model fully characterized the site.

CDM
Smith

Buckingham County Landfill
Buckingham County, Virginia

Figure 4-26
3D Model of PCE Groundwater Plume
Round 51 – November 2011



Tetrachloroethene Above 5 ug/l

Trichloroethene Above 5 ug/l

Cis-1,2-dichloroethene Above 2.8 ug/l

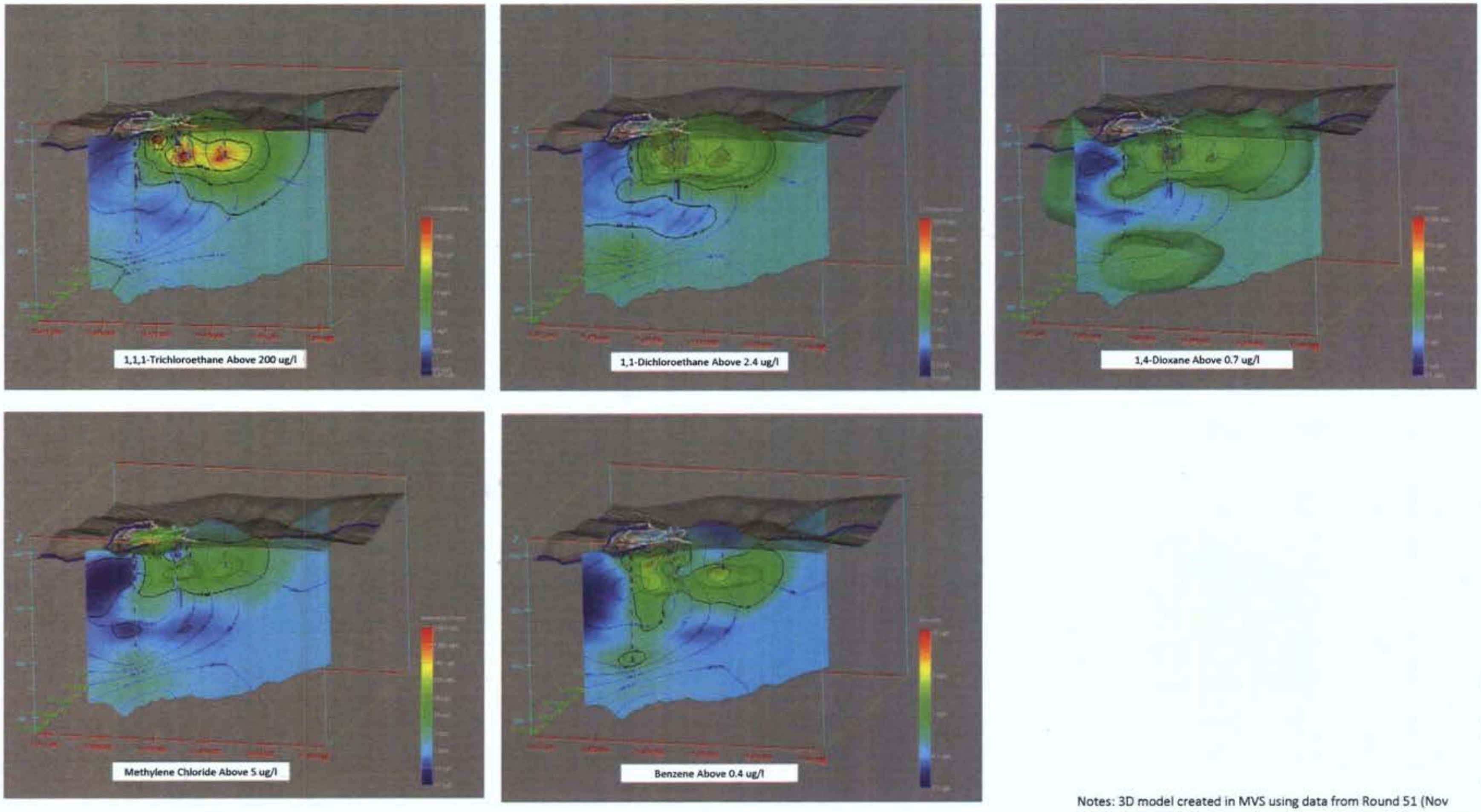
1,1-Dichloroethene Above 7 ug/l

Vinyl Chloride Above 2 ug/l

Notes: 3D model created in MVS using data from Round 51 (Nov 2011) where available. For wells not sampled in Round 51, the most recent analytical result was used to ensure the model fully characterized the site. Transparent plumes shown at cutoff level equal to screening level (MCL or RSL). Vinyl chloride is shown at a cutoff of 2 ug/l (MCL) due to a low RSL of 0.015 ug/l that resulted in a poor visualization. Models shown with oblique view from southeast to northwest.

Buckingham County Landfill
Buckingham County, Virginia

Figure 4-27
3D Model Groundwater Plumes - PCE and Breakdown Products
Round 51 – November 2011



Notes: 3D model created in MVS using data from Round 51 (Nov 2011) where available. For wells not sampled in Round 51, the most recent analytical result was used to ensure the model fully characterized the site. Transparent plumes shown at cutoff level equal to screening level (MCL or RSL). . Models shown with oblique view from southeast to northwest.

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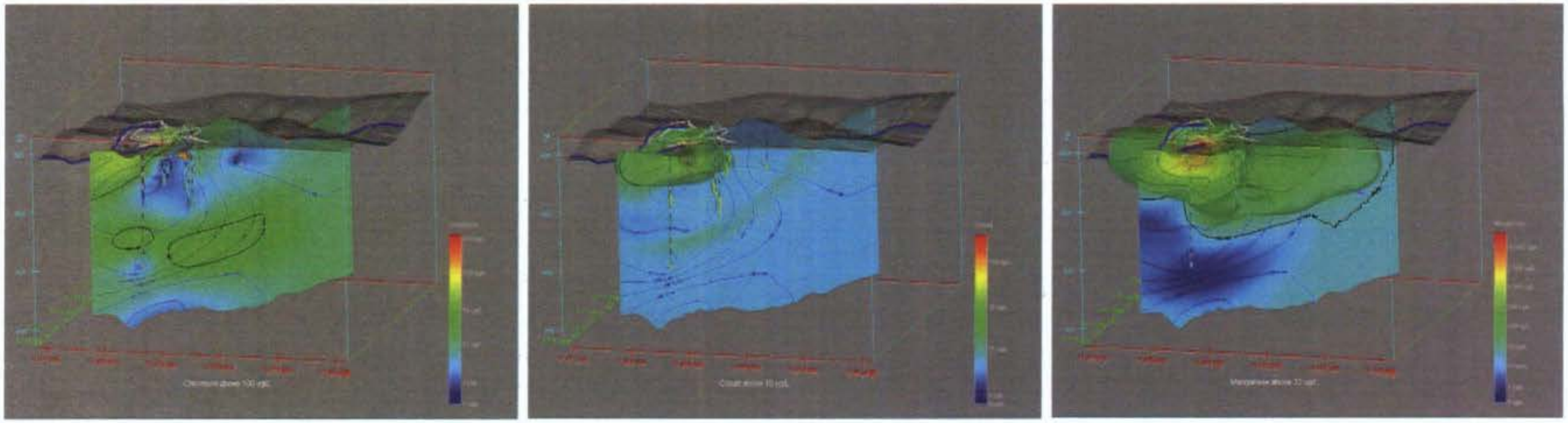
Buckingham County Landfill
Buckingham County, Virginia

Figure 4-28
3D Model Groundwater Plumes – Other COCs – VOCs and 1,4-Dioxane
Round 51 – November 2011

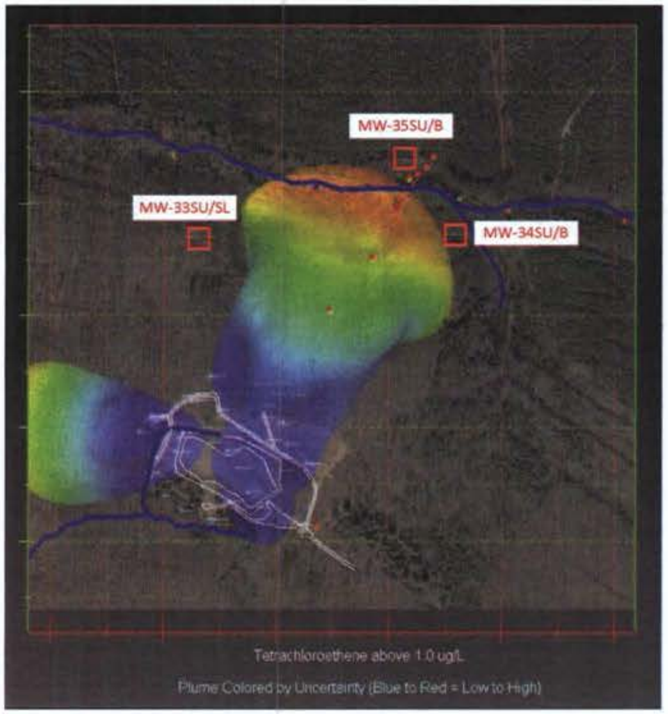


Notes: 3D model created in MVS using data from Round 51 (Nov 2011) where available. For wells not sampled in Round 51, the most recent analytical result was used to ensure the model fully characterized the site. Transparent plumes shown at cutoff level equal to screening level (MCL or RSL) except cobalt which is shown at a cutoff of 10 ug/l due to a low RSL of 0.47 ug/l that resulted in a poor visualization.

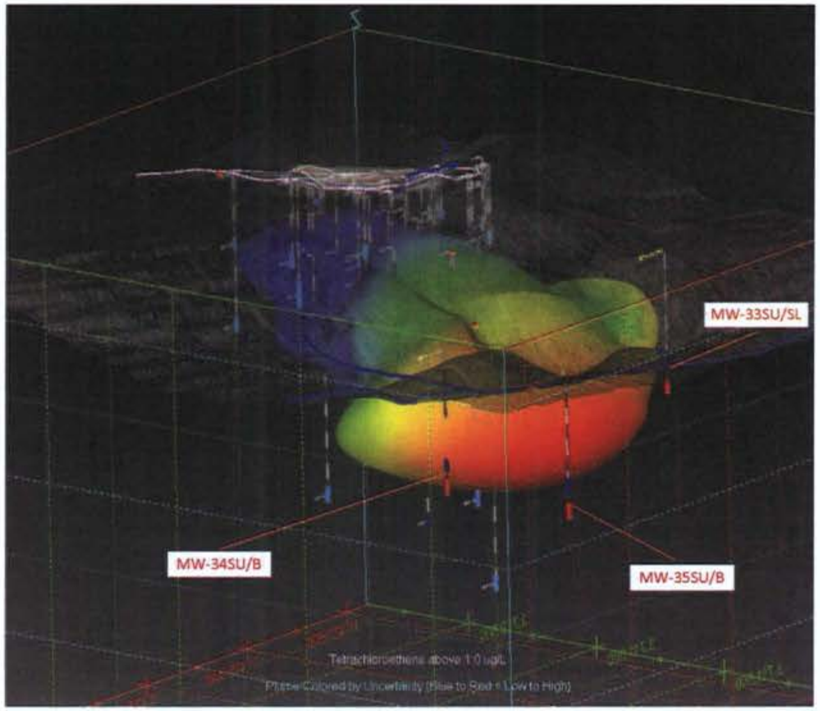
CDM Smith

Buckingham County Landfill
Buckingham County, Virginia

Figure 4-29
3D Model Groundwater Plumes – Other COCs – Metals
Round 51 – November 2011



Aerial View



Oblique View
(view from Cooper Creek
looking to the southeast)

Notes: Uncertainty calculated based on density of well spacing
and magnitude of PCE detection in groundwater wells.

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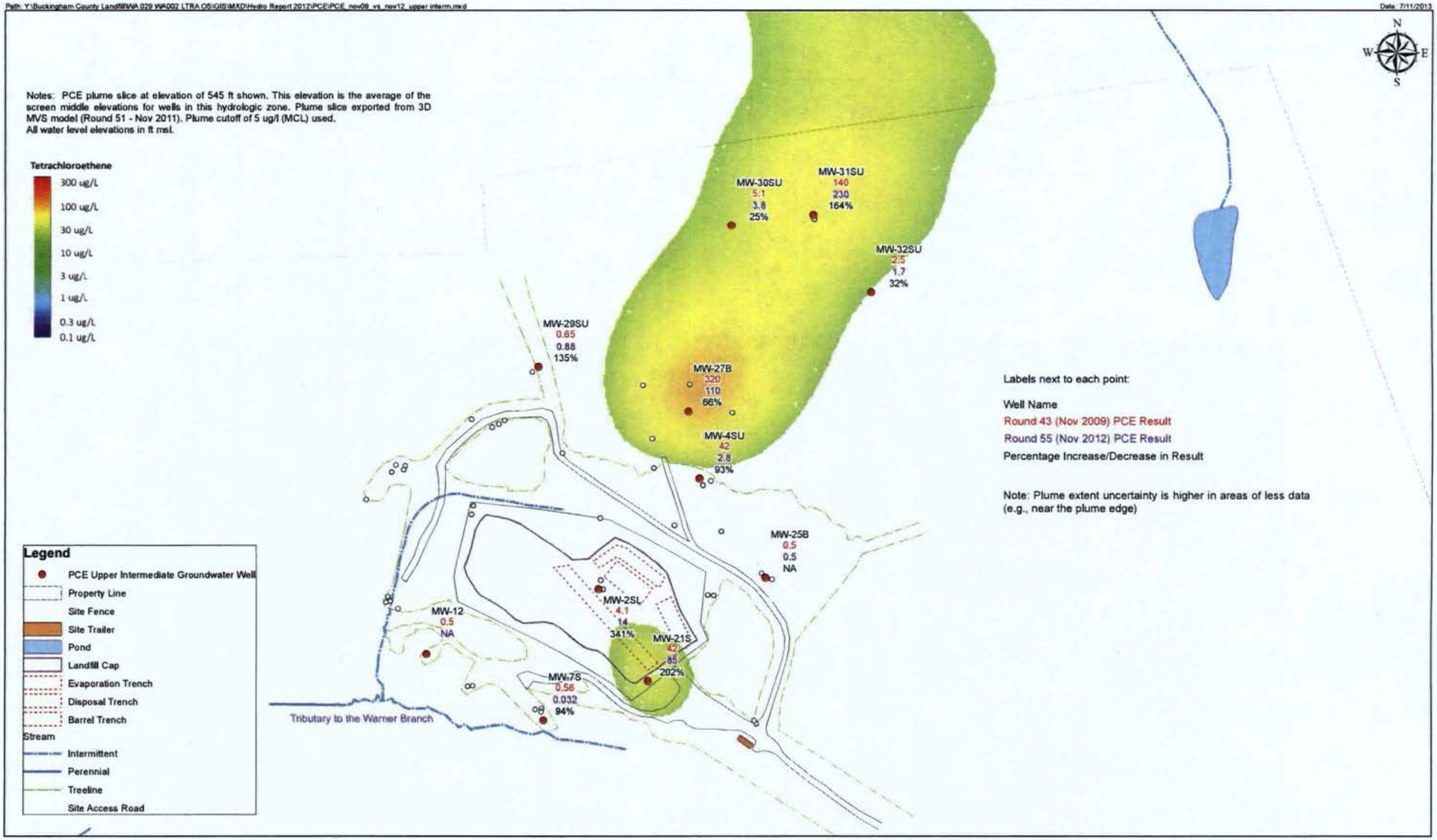
Buckingham County Landfill
Buckingham County, Virginia

Figure 4-30
New Monitoring Wells and PCE Uncertainty Model

ORIGINAL

Path: Y:\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\Hydro Report 2012\PCE\PCE_nov09_vs_nov12_upper interm.mxd

Date: 7/11/2013



Notes: PCE plume slice at elevation of 545 ft shown. This elevation is the average of the screen middle elevations for wells in this hydrologic zone. Plume slice exported from 3D MVS model (Round 51 - Nov 2011). Plume cutoff of 5 ug/l (MCL) used.
All water level elevations in ft msl.

Labels next to each point:

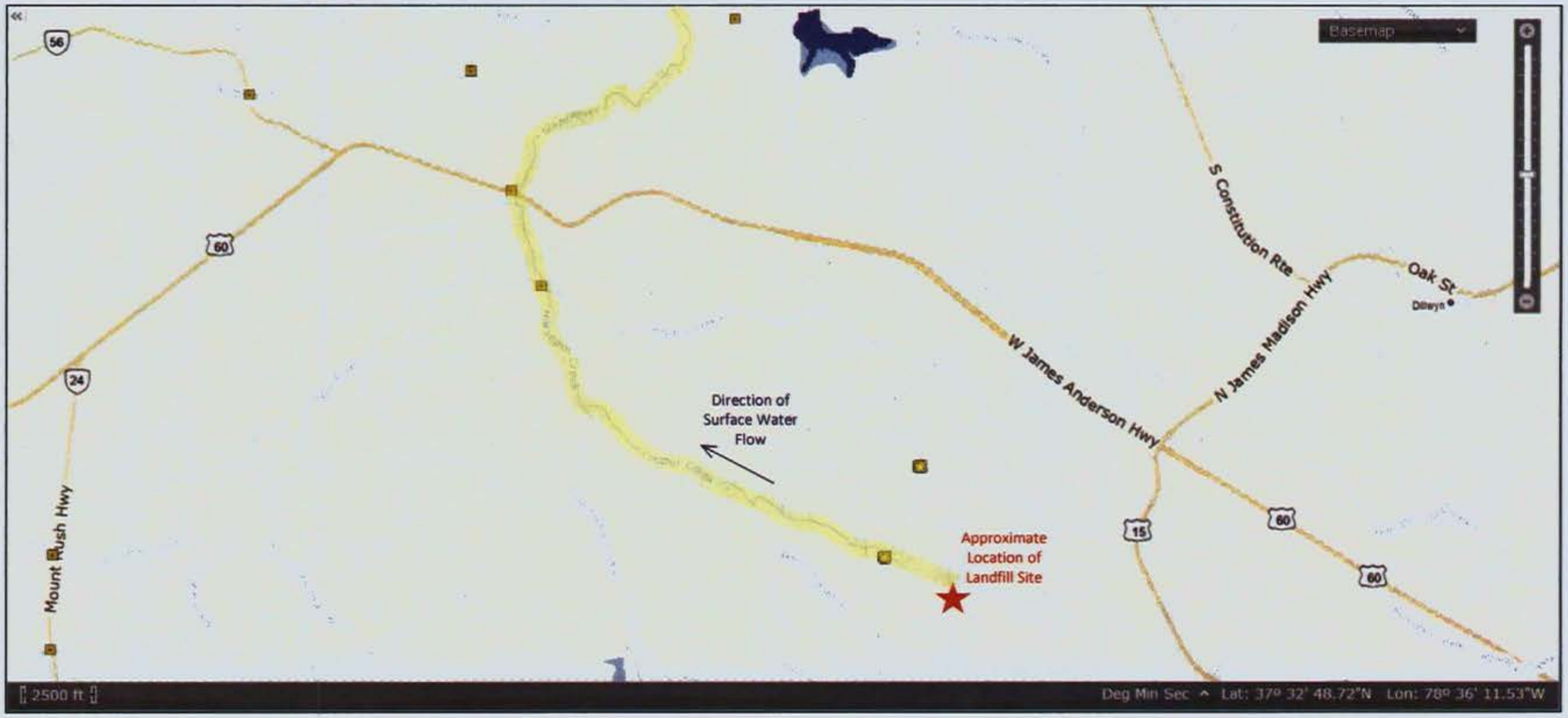
Well Name
Round 43 (Nov 2009) PCE Result
Round 55 (Nov 2012) PCE Result
Percentage Increase/Decrease in Result

Note: Plume extent uncertainty is higher in areas of less data (e.g., near the plume edge)

CDM Smith

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 4-31
PCE in Upper Intermediate Groundwater Concentration Comparison
Nov 2009 to Nov 2012



Source of Map:
Virginia Department of Environmental Quality Web Mapper
http://www.deq.virginia.gov/mapper_ext/default.aspx?service=public/wimby#

CDM Smith

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 5-1
Drainage Basin and Receiving Waters for Cooper Creek

List of Documents Reviewed

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Parsons. 2009c. *Round 40 (March 2009) Long-Term Monitoring Report, Buckingham County Landfill, Buckingham County, Virginia.* Parsons. May 2009.

Parsons. 2009d. *Round 41 (July 2009) Long-Term Monitoring Report, Buckingham County Landfill, Buckingham County, Virginia.* Parsons. September 2009.

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Parsons. 2010c. *Round 44 (March 2010) Long-Term Monitoring Report, Buckingham County Landfill, Buckingham County, Virginia*. Parsons. May 2010.

Parsons. 2010d. *Round 45 (May 2010) Long-Term Monitoring Report, Buckingham County Landfill, Buckingham County, Virginia*. Parsons. August 2010.

Parsons. 2010e. *Round 46 (August 2010) Long-Term Monitoring Report, Buckingham County Landfill, Buckingham County, Virginia*. Parsons. October 2010.

Parsons. 2010f. *Round 47 (October 2010) Long-Term Monitoring Report, Buckingham County Landfill, Buckingham County, Virginia*. Parsons. December 2010.

Parsons. 2011a. *Round 48 (February 2011) Long-Term Monitoring Report, Buckingham County Landfill, Buckingham County, Virginia*. Parsons. March 2011.

Parsons. 2011b. *Round 49 (May 2011) Long-Term Monitoring Report, Buckingham County Landfill, Buckingham County, Virginia*. Parsons. July 2011.

Parsons. 2011c. *Round 50 (August 2011) Long-Term Monitoring Report, Buckingham County Landfill, Buckingham County, Virginia*. Parsons. October 2011.

Parsons. 2011d. *Stream and Tree Sampling Work Plan, Buckingham County Landfill, Buckingham County, Virginia*. Parsons. September 2011.

Parsons. 2012a. Rationale and Scope for Chemical Oxidation Bench-scale Treatability Testing, *Buckingham County Landfill Superfund Site*. Letter to USEPA Region III. January 30, 2012.

Parsons. 2012b. *Round 51 (November 2011) Long-Term Monitoring Report, Buckingham County Landfill, Buckingham County, Virginia*. Parsons. February 2012.

Parsons. 2012c. *Stream and Tree Sampling Report, Buckingham County Landfill, Buckingham County, Virginia*. Parsons. February 2012.

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ORIGINAL

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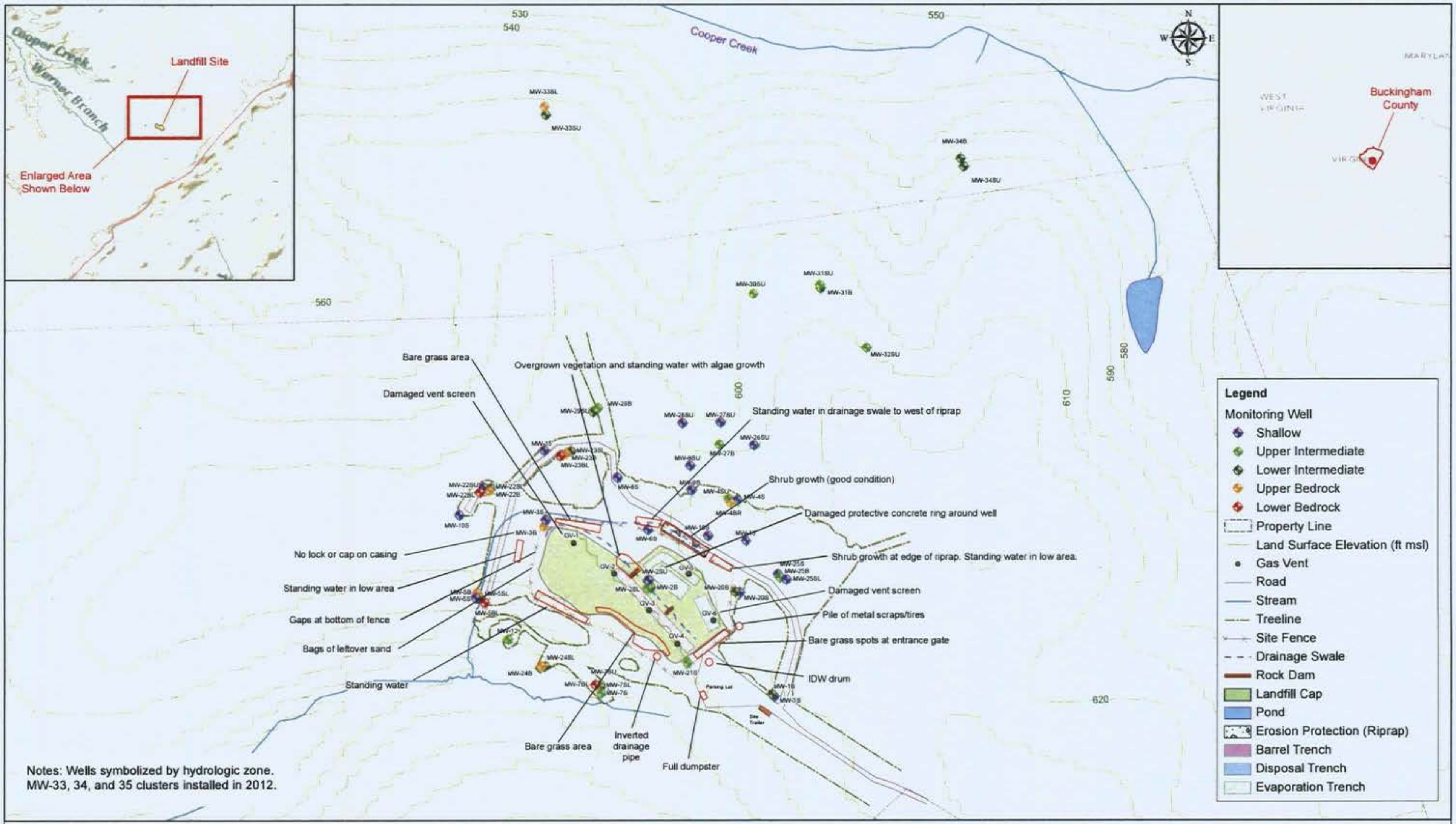
Appendix C

Site Inspection Map



CDM Smith

Buckingham County Landfill Site
Buckingham County, Virginia

Figure 1
Site Inspection Map
February 28, 2013

Path: Y:\Buckingham County Landfill\WA 029 WA002 LTRA OS\GIS\MXD\5-yr 2013 update\Site Map w markups.mxd

Appendix D

Site Inspection Checklist

ORIGINAL

Please note that "O&M" is referred to throughout this checklist. At sites where Long-Term Response Actions are in progress, O&M activities may be referred to as "system operations" since these sites are not considered to be in the O&M phase while being remediated under the Superfund program.

Five-Year Review Site Inspection Checklist (Template)

(Working document for site inspection. Information may be completed by hand and attached to the Five-Year Review report as supporting documentation of site status. "N/A" refers to "not applicable.")

I. SITE INFORMATION

Site name: BUCKINGHAM COUNTY LANDFILL	**Date of inspection:** FEBRUARY 28, 2013
Location and Region: BUCKINGHAM Co., VA / REGION 3	**EPA ID:** VAD089027973
Agency, office, or company leading the five-year review: CDM SMITH / USEPA	**Weather/temperature:** SUNNY, 34°F

Remedy Includes: (Check all that apply)

[✓ Landfill cover/containment]
Access controls
Institutional controls
Groundwater pump and treatment
Surface water collection and treatment
Other LONG-TERM GROUNDWATER MONITORING

Monitored natural attenuation
Groundwater containment
Vertical barrier walls

Attachments: Inspection team roster attached Site map attached

II. INTERVIEWS (Check all that apply)

1. **O&M site manager** TOMMY RANSON
Name
COUNTY GROUNDS & BUILDING INSPECTOR
Title
2/28/2013
Date
Interviewed at site [✓ at office] by phone Phone no. (434) 969-4242
Problems, suggestions; Report attached

2. **O&M staff**
Name Title Date
Interviewed at site at office by phone Phone no.
Problems, suggestions; Report attached

3. **Local regulatory authorities and response agencies** (i.e., State and Tribal offices, emergency response office, police department, office of public health or environmental health, zoning office, recorder of deeds, or other city and county offices, etc.) Fill in all that apply.

Agency VIRGINIA DEQ
Contact KEVIN GREENE SUPERFUND & VOLUNTARY REMEDIATION PROGRAM 2/28/2013 (804) 698-4236
Name Title MANAGER Date Phone no.
Problems; suggestions; Report attached

Agency VIRGINIA DEQ
Contact THOMAS MODENA REMEDIAL PROJECT 2/28/2013 (804) 698-4183
Name Title MANAGER Date Phone no.
Problems; suggestions; Report attached

Agency VIRGINIA DEQ
Contact BOB NICHOLAS REMEDIAL PROJECT 2/28/2013 (804) 698-4000
Name Title MANAGER Date Phone no.
Problems; suggestions; Report attached

Agency
Contact
Name Title Date Phone no.
Problems; suggestions; Report attached

4. **Other interviews** (optional) Report attached.

ORIGINAL

III. ON-SITE DOCUMENTS & RECORDS VERIFIED (Check all that apply)

1. **O&M Documents**
    - O&M manual Readily available Up to date [✓ N/A]
    - As-built drawings Readily available Up to date [✓ N/A]
    - Maintenance logs Readily available Up to date [✓ N/A]

    Remarks____

2. **Site-Specific Health and Safety Plan** Readily available Up to date [✓ N/A]
    - Contingency plan/emergency response plan Readily available Up to date [✓ N/A]

    Remarks____

3. **O&M and OSHA Training Records** Readily available Up to date [✓ N/A]

    Remarks____

4. **Permits and Service Agreements**
    - Air discharge permit Readily available Up to date [✓ N/A]
    - Effluent discharge Readily available Up to date [✓ N/A]
    - Waste disposal, POTW Readily available Up to date [✓ N/A]
    - Other permits________________ Readily available Up to date [✓ N/A]

    Remarks____

5. **Gas Generation Records** Readily available Up to date [✓ N/A]

    Remarks____

6. **Settlement Monument Records** Readily available Up to date [✓ N/A]

    Remarks____

7. **Groundwater Monitoring Records** [✓ Readily available] Up to date N/A

    Remarks____

8. **Leachate Extraction Records** Readily available Up to date [✓ N/A]

    Remarks____

9. **Discharge Compliance Records**
    - Air Readily available Up to date [✓ N/A]
    - Water (effluent) Readily available Up to date [✓ N/A]

    Remarks____

10. **Daily Access/Security Logs** Readily available Up to date [✓ N/A]

    Remarks____

IV. O&M COSTS

1. **O&M Organization**

State in-house   Contractor for State
✓ PRP in-house   Contractor for PRP
Federal Facility in-house   Contractor for Federal Facility
Other______________________________

2. **O&M Cost Records** N/A

Readily available   Up to date
Funding mechanism/agreement in place
Original O&M cost estimate____________   Breakdown attached

Total annual cost by year for review period if available

From______ To______ __________ Breakdown attached
Date   Date   Total cost
From______ To______ __________ Breakdown attached
Date   Date   Total cost
From______ To______ __________ Breakdown attached
Date   Date   Total cost
From______ To______ __________ Breakdown attached
Date   Date   Total cost
From______ To______ __________ Breakdown attached
Date   Date   Total cost

3. **Unanticipated or Unusually High O&M Costs During Review Period**

Describe costs and reasons: N/A

V. ACCESS AND INSTITUTIONAL CONTROLS   Applicable   N/A

A. Fencing

1. **Fencing damaged**   Location shown on site map   Gates secured   N/A

Remarks SEVERAL GAPS BETWEEN FENCE BOTTOM AND GROUND SURFACE.
BACK GATE NOT LOCKED – CURRENT LOCK NEEDS TO BE REPLACED

B. Other Access Restrictions

1. **Signs and other security measures**   ✓ Location shown on site map   N/A

Remarks______________________________

ORIGINAL

C. Institutional Controls (ICs)

1. **Implementation and enforcement**

Site conditions imply ICs not properly implemented Yes No N/A
Site conditions imply ICs not being fully enforced Yes No N/A

Type of monitoring (*e.g.*, self-reporting, drive by) ______
Frequency ______
Responsible party/agency ______
Contact ______ Name ______ Title ______ Date ______ Phone no.

Reporting is up-to-date Yes No N/A
Reports are verified by the lead agency Yes No N/A

Specific requirements in deed or decision documents have been met Yes No N/A
Violations have been reported Yes No N/A
Other problems or suggestions: Report attached
COUNTY-OWNED PROPERTY. SITE ACCESS RESTRICTED BY GATE AT ROAD.

2. **Adequacy** ICs are adequate ICs are inadequate N/A
Remarks ______

D. General

1. **Vandalism/trespassing** Location shown on site map [✓ No vandalism evident]
Remarks ______

2. **Land use changes on site** N/A
Remarks NONE

3. **Land use changes off site** N/A
Remarks NONE

VI. GENERAL SITE CONDITIONS

A. Roads Applicable N/A

1. **Roads damaged** Location shown on site map [✓ Roads adequate] N/A
Remarks ______

B. Other Site Conditions

Remarks EVIDENCE OF STANDING WATER IN VARIOUS LOCATIONS; BARE GRASS SPOTS IN VARIOUS LOCATIONS; PRESENCE OF 55-GALLON IDW DRUM ON SITE; TRASH-FILLED DUMPSTER IN NEED OF EMPTYING.

VII. LANDFILL COVERS Applicable N/A

A. Landfill Surface

1. **Settlement** (Low spots) Location shown on site map [✓ Settlement not evident]
Areal extent________ Depth________
Remarks GOOD CONDITION

2. **Cracks** Location shown on site map [✓ Cracking not evident]
Lengths________ Widths________ Depths________
Remarks________

3. **Erosion** [✓ Location shown on site map] Erosion not evident
Areal extent________ Depth________
Remarks SEVERAL SCATTERED BARE SPOTS THAT WILL REQUIRE RESEEDING SEE PHOTOLOG.

4. **Holes** Location shown on site map [✓ Holes not evident]
Areal extent________ Depth________
Remarks________

5. **Vegetative Cover** [✓ Grass] Cover properly established No signs of stress
Trees/Shrubs (indicate size and locations on a diagram)
Remarks BARE SPOTS THAT WILL REQUIRE RESEEDING. SEE PHOTOLOG

6. **Alternative Cover (armored rock, concrete, etc.)** [✓ N/A]
Remarks________

7. **Bulges** Location shown on site map [✓ Bulges not evident]
Areal extent________ Height________
Remarks________

8. **Wet Areas/Water Damage** Wet areas/water damage not evident
Wet areas [✓ Location shown on site map] Areal extent______
Ponding [✓ Location shown on site map] Areal extent______
Seeps Location shown on site map Areal extent______
Soft subgrade Location shown on site map Areal extent______
Remarks WET AREAS/PONDING PERSISTENT DURING WINTER AND SPRING

9. **Slope Instability** Slides Location shown on site map [✓ No evidence of slope instability]
Areal extent______
Remarks______

B. Benches Applicable [✓ N/A]
(Horizontally constructed mounds of earth placed across a steep landfill side slope to interrupt the slope in order to slow down the velocity of surface runoff and intercept and convey the runoff to a lined channel.)

1. **Flows Bypass Bench** Location shown on site map N/A or okay
Remarks______

2. **Bench Breached** Location shown on site map N/A or okay
Remarks______

3. **Bench Overtopped** Location shown on site map N/A or okay
Remarks______

C. Letdown Channels [✓ Applicable] N/A
(Channel lined with erosion control mats, riprap, grout bags, or gabions that descend down the steep side slope of the cover and will allow the runoff water collected by the benches to move off of the landfill cover without creating erosion gullies.)

1. **Settlement** Location shown on site map [✓ No evidence of settlement]
Areal extent______ Depth______
Remarks______

2. **Material Degradation** Location shown on site map [✓ No evidence of degradation]
Material type______ Areal extent______
Remarks______

3. **Erosion** Location shown on site map [✓ No evidence of erosion]
Areal extent______ Depth______
Remarks______

4. **Undercutting** Location shown on site map [✓ No evidence of undercutting]
Areal extent________ Depth________
Remarks________

5. **Obstructions** Type________ [✓ No obstructions]
Location shown on site map Areal extent________
Size________
Remarks________

6. **Excessive Vegetative Growth** Type BRUSHES & SHRUBS
No evidence of excessive growth
Vegetation in channels does not obstruct flow
[✓ Location shown on site map] Areal extent________
Remarks________

D. Cover Penetrations [✓ Applicable] N/A

1. **Gas Vents** Active [✓ Passive]
Properly secured/locked Functioning Routinely sampled Good condition
Evidence of leakage at penetration Needs Maintenance
N/A
Remarks GAS VENT SCREENS DAMAGED AT — GV-1, GV-4 & GV-6

2. **Gas Monitoring Probes**
Properly secured/locked Functioning Routinely sampled Good condition
Evidence of leakage at penetration Needs Maintenance [✓ N/A]
Remarks________

3. **Monitoring Wells** (within surface area of landfill)
Properly secured/locked Functioning Routinely sampled Good condition
Evidence of leakage at penetration [✓ Needs Maintenance] N/A
Remarks MW-25U HAS CRACKED CONCRETE RING AROUND WELL.
MW-3B HAS NO LOCK & NO CAP

4. **Leachate Extraction Wells**
Properly secured/locked Functioning Routinely sampled Good condition
Evidence of leakage at penetration Needs Maintenance [✓ N/A]
Remarks________

5. **Settlement Monuments** Located Routinely surveyed [✓ N/A]
Remarks________

E. Gas Collection and Treatment Applicable [✓ N/A]

1. **Gas Treatment Facilities**
Flaring Thermal destruction Collection for reuse
Good condition Needs Maintenance
Remarks____________________

2. **Gas Collection Wells, Manifolds and Piping**
Good condition Needs Maintenance
Remarks____________________

3. **Gas Monitoring Facilities** (*e.g.*, gas monitoring of adjacent homes or buildings)
Good condition Needs Maintenance N/A
Remarks____________________

F. Cover Drainage Layer [✓ Applicable] N/A

1. **Outlet Pipes Inspected** Functioning N/A
Remarks SOUTH EASTERN DRAINAGE PIPE INVERTED AT OUTLET & NOT DRAINING; NORTHEASTERN DRAINAGE PIPE DAMAGED; NORTHWESTERN DRAINAGE PIPE CLOGGED.

2. **Outlet Rock Inspected** Functioning [✓ N/A]
Remarks____________________

G. Detention/Sedimentation Ponds Applicable [✓ N/A]

1. **Siltation** Areal extent________ Depth________ N/A
Siltation not evident
Remarks____________________

2. **Erosion** Areal extent________ Depth________
Erosion not evident
Remarks____________________

3. **Outlet Works** Functioning N/A
Remarks____________________

4. **Dam** Functioning N/A
Remarks____________________

H. Retaining Walls Applicable [✓ N/A]

1. **Deformations** Location shown on site map Deformation not evident
Horizontal displacement____________ Vertical displacement______________
Rotational displacement____________
Remarks____

2. **Degradation** Location shown on site map Degradation not evident
Remarks____

I. Perimeter Ditches/Off-Site Discharge [✓ Applicable] N/A

1. **Siltation** Location shown on site map [✓ Siltation not evident]
Areal extent____________ Depth____________
Remarks____

2. **Vegetative Growth** [✓ Location shown on site map] N/A
Vegetation does not impede flow
Areal extent____________ Type____________
Remarks OVERGROWN VEGETATION IMPEDING WATER MOVEMENT, ALGAE GROWTH IS EVIDENT IN DRAINAGE SWALE. SEE PHOTOLOG.

3. **Erosion** Location shown on site map [✓ Erosion not evident]
Areal extent____________ Depth____________
Remarks____

4. **Discharge Structure** Functioning [✓ N/A]
Remarks____

VIII. VERTICAL BARRIER WALLS

Applicable [✓ N/A]

1. **Settlement** Location shown on site map Settlement not evident
Areal extent____________ Depth____________
Remarks____

2. **Performance Monitoring** Type of monitoring____________________
Performance not monitored
Frequency__________________________ Evidence of breaching
Head differential__________________________
Remarks____

IX. GROUNDWATER/SURFACE WATER REMEDIES Applicable [✓ N/A]

A. Groundwater Extraction Wells, Pumps, and Pipelines Applicable [✓ N/A]

1. **Pumps, Wellhead Plumbing, and Electrical**
Good condition All required wells properly operating Needs Maintenance N/A
Remarks____

2. **Extraction System Pipelines, Valves, Valve Boxes, and Other Appurtenances**
Good condition Needs Maintenance
Remarks____

3. **Spare Parts and Equipment**
Readily available Good condition Requires upgrade Needs to be provided
Remarks____

B. Surface Water Collection Structures, Pumps, and Pipelines Applicable [✓ N/A]

1. **Collection Structures, Pumps, and Electrical**
Good condition Needs Maintenance
Remarks____

2. **Surface Water Collection System Pipelines, Valves, Valve Boxes, and Other Appurtenances**
Good condition Needs Maintenance
Remarks____

3. **Spare Parts and Equipment**
Readily available Good condition Requires upgrade Needs to be provided
Remarks____

C. Treatment System Applicable [✓ N/A]

1. **Treatment Train** (Check components that apply)
   Metals removal Oil/water separation Bioremediation
   Air stripping Carbon adsorbers
   Filters____________________
   Additive (*e.g.*, chelation agent, flocculent)____________________
   Others____________________
   Good condition Needs Maintenance
   Sampling ports properly marked and functional
   Sampling/maintenance log displayed and up to date
   Equipment properly identified
   Quantity of groundwater treated annually____________
   Quantity of surface water treated annually____________
   Remarks____________________

2. **Electrical Enclosures and Panels** (properly rated and functional)
   N/A Good condition Needs Maintenance
   Remarks____________________

3. **Tanks, Vaults, Storage Vessels**
   N/A Good condition Proper secondary containment Needs Maintenance
   Remarks____________________

4. **Discharge Structure and Appurtenances**
   N/A Good condition Needs Maintenance
   Remarks____________________

5. **Treatment Building(s)**
   N/A Good condition (esp. roof and doorways) Needs repair
   Chemicals and equipment properly stored
   Remarks____________________

6. **Monitoring Wells** (pump and treatment remedy)
   Properly secured/locked Functioning Routinely sampled Good condition
   All required wells located Needs Maintenance N/A
   Remarks____________________

D. Monitoring Data

1. Monitoring Data
   ✓ Is routinely submitted on time ✓ Is of acceptable quality

2. Monitoring data suggests: INCONCLUSIVE
   Groundwater plume is effectively contained NO Contaminant concentrations are declining

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D. Monitored Natural Attenuation

1. **Monitoring Wells** (natural attenuation remedy)
Properly secured/locked Functioning Routinely sampled Good condition
All required wells located Needs Maintenance [✓ N/A]
Remarks

X. OTHER REMEDIES

If there are remedies applied at the site which are not covered above, attach an inspection sheet describing the physical nature and condition of any facility associated with the remedy. An example would be soil vapor extraction.

XI. OVERALL OBSERVATIONS

A. Implementation of the Remedy

Describe issues and observations relating to whether the remedy is effective and functioning as designed. Begin with a brief statement of what the remedy is to accomplish (i.e., to contain contaminant plume, minimize infiltration and gas emission, etc.).

LANDFILL RCRA CAP DESIGNED TO MINIMIZE INFILTRATION. LOWER GROUNDWATER LEVELS UNDER THE CAP AT MW-25U INDICATE THAT THE CAP IS LIMITING RECHARGE FROM PRECIPITATION. HOWEVER, GROUNDWATER MONITORING DATA SHOWS THAT LIMITING INFILTRATION HAS NOT BEEN SUCCESSFUL IN LIMITING THE MIGRATION OF GROUNDWATER CONTAMINATION. FIVE YEARS AFTER PREVIOUS INSPECTION (2008), CONTAMINATION HAS TRAVELLED FURTHER BEYOND THE POINT-OF-COMPLIANCE WELLS AND PROPERTY LINES; AND IS PRESENT IN THE NEARBY SURFACE WATER, COOPER CREEK, LOCATED NORTHEAST TO NORTHWEST OF THE SITE.

B. Adequacy of O&M

Describe issues and observations related to the implementation and scope of O&M procedures. In particular, discuss their relationship to the current and long-term protectiveness of the remedy.

AREAS OF EROSION, OVERGROWN VEGETATION AND ALGAE GROWTH IN DRAINAGE SWALES, DAMAGED OR INEFFECTIVE DRAINAGE PIPING AND GAPS ALONG BOTTOM OF FENCE INDICATE INADEQUATE MAINTENANCE OF LANDFILL CAP AND FENCE.

C. Early Indicators of Potential Remedy Problems

Describe issues and observations such as unexpected changes in the cost or scope of O&M or a high frequency of unscheduled repairs, that suggest that the protectiveness of the remedy may be compromised in the future.

N/A

D. Opportunities for Optimization

Describe possible opportunities for optimization in monitoring tasks or the operation of the remedy.

N/A

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Appendix E

Photograph Log

Photo: 182 **Date:** 02/28/13 **Description:** Facing east near back Landfill gate and fence. Waste yarn and gap at bottom of fence. **Photographer:** Rich Opem

Photo: 183 **Date:** 02/28/13 **Description:** Facing east near back Landfill gate and fence. Gap at bottom of fence. **Photographer:** Rich Opem

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Photo: 184 **Date:** 02/28/13 **Description:** Facing southwest near back Landfill gate and beyond fence. Left over bags of sand; bare grass spots in need of reseeding; low spot with standing water. **Photographer:** Rich Opem

Photo: 187 **Date:** 02/28/13 **Description:** Facing east at Landfill. Landfill grass cover. **Photographer:** Rich Opem

Photo: 189 **Date:** 02/28/13 **Description:** Facing northeast at Landfill near back gate fence. Monitoring well MW-3B. Well has no lock and well cap. **Photographer:** Rich Opem

Photo: 190 **Date:** 02/28/13 **Description:** Facing east at Landfill. Landfill with bare grass spots near north fence line. Standing water, drainage swale and gas vents (GV-1 and GV-2) in the background. **Photographer:** Rich Opem

Photo: 191 **Date:** 02/28/13 **Description:** Facing west at Landfill. Back Landfill gate and fence. Monitoring well MW-3B, standing water and left over bags of sand. **Photographer:** Rich Opem

Photo: 192 **Date:** 02/28/13 **Description:** Facing northwest at Landfill. Damaged vent screen at gas vent, GV-1. **Photographer:** Rich Opem

Photo: 193 **Date:** 02/28/13 **Description:** Damaged vent screen at gas vent, GV-1. **Photographer:** Rich Opem

Photo: 194 **Date:** 02/28/13 **Description:** Facing north at Landfill near GV-1. Bare grass spots in need of reseeding and standing water. **Photographer:** Rich Opem

Photo: 195 **Date:** 02/28/13 **Description:** Facing north at Landfill. Bare grass spots in need of reseeding. Standing water. **Photographer:** Rich Opem

Photo: 196 **Date:** 02/28/13 **Description:** Facing north at Landfill. Gas vent, GV-2, with damage to vent screen. Over grown vegetation in drainage swale in background. **Photographer:** Rich Opem

Photo: 197 **Date:** 02/28/13 **Description:** Over grown vegetation in drainage swale and rock dam near GV-2. Standing water and algae in drainage swale. **Photographer:** Rich Opem

Photo: 198 **Date:** 02/28/13 **Description:** Near GV-2 at Landfill. Standing water and algae in drainage swale. **Photographer:** Rich Opem

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Photo: 199 **Date:** 02/28/13 **Description:** Near GV-2 at Landfill. Over grown vegetation within rock dam. **Photographer:** Rich Opem

Photo: 200 **Date:** 02/28/13 **Description:** On Landfill. Monitoring well, MW-2SU, damaged protective concrete ring around well. **Photographer:** Rich Opem

Photo: 202 **Date:** 02/28/13 **Description:** Near GV-2 at Landfill. Over grown vegetation within rock dam. **Photographer:** Rich Opem

Photo: 203 **Date:** 02/28/13 **Description:** Facing west at Landfill near south of Landfill fence line. Several bare grass spots on landfill cover in need of reseeding. Standing water near southwest corner of fence line. **Photographer:** Rich Opem

Photo: 205 **Date:** 02/28/13 **Description:** On Landfill. Gas vent, GV-4, with damaged vent screen. **Photographer:** Rich Opem

Photo: 206 **Date:** 02/28/13 **Description:** Facing southeast within Landfill entrance gate. Bare grass spots in need of reseeding, 55-gallon IDW drum and trash-filled dumpster. **Photographer:** Rich Opem

Photo: 208 **Date:** 02/28/13 **Description:** Facing southeast within Landfill entrance gate. Bare grass spots in need of reseeding and trash-filled dumpster. **Photographer:** Rich Opem

Photo: 209 **Date:** 02/28/13 **Description:** Facing east within Landfill fence. Big pile of metal scraps and tire in woods beyond fenced area. **Photographer:** Rich Opem

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Photo: 210 **Date:** 02/28/13 **Description:** Facing northeast at Landfill fence near GV-6. Gap at bottom of fence and bare grass spot. **Photographer:** Rich Opem

Photo: 211 **Date:** 02/28/13 **Description:** Facing northeast at landfill near GV-6. damaged drainage pipe. **Photographer:** Rich Opem

Photo: 212 **Date:** 02/28/13 **Description:** On Landfill. Gas vent, GV-6, with damaged vent screen. **Photographer:** Rich Opem

Photo: 213 **Date:** 02/28/13 **Description:** Facing northwest at Landfill near GV-6. Bare grass spots on Landfill cover in need of reseeding. **Photographer:** Rich Opem

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Photo: 216 **Date:** 02/28/13 **Description:** Facing north near fence line. Riprap area in good condition with shrub growth. **Photographer:** Rich Opem

Photo: 217 **Date:** 02/28/13 **Description:** Facing north near fence line. East edge of riprap area with shrub growth and low spot with standing water. **Photographer:** Rich Opem

Photo: 218 **Date:** 02/28/13 **Description:** Facing north near fence line and MW-6S. West edge of riprap area, drainage swale with standing water. **Photographer:** Rich Opem

Photo: 220 **Date:** 02/28/13 **Description:** Facing west at Landfill near northeast fence line. Bare grass spots in need of reseeding. **Photographer:** Rich Opem

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Photo: 221 **Date:** 02/28/13 **Description:** Facing northwest at Landfill near north fence line. Bare grass spots in need of reseeding and standing water in drainage swale. **Photographer:** Rich Opem

Photo: 223 **Date:** 02/28/13 **Description:** Bare grass spot around clogged drainage pipe. Located at northwest corner of Landfill. **Photographer:** Rich Opem

Photo: 224 **Date:** 02/28/13 **Description:** Facing east of Landfill near south fence line. Standing water with algae in drainage swale. **Photographer:** Rich Opem

Photo: 225 **Date:** 02/28/13 **Description:** Southwest area of Landfill long south fence line. Standing water and gap at bottom of fence. **Photographer:** Rich Opem

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Photo: 226 **Date:** 02/28/13 **Description:** Looking down near south fence line. Standing water with algae in drainage swale. **Photographer:** Rich Opem

Photo: 227 **Date:** 02/28/13 **Description:** Facing southeast of Landfill near south fence line. Standing water in drainage swale. **Photographer:** Rich Opem

Photo: 229 **Date:** 02/28/13 **Description:** Looking down near south fence area of Landfill. Bare grass spot in need of reseeding. **Photographer:** Rich Opem

Photo: 230 **Date:** 02/28/13 **Description:** Inverted drainage pipe near bare grass spot in need of reseeding. Located at southeast corner of Landfill. **Photographer:** Rich Opem

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Photo: 231 **Date:** 02/28/13 **Description:** At monitoring well, MW-3B. Well protective casing missing lock. **Photographer:** Rich Opem

Photo: 232 **Date:** 02/28/13 **Description:** At monitoring well, MW-3B. Well pipe missing cap. **Photographer:** Rich Opem

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INTERVIEW DOCUMENTATION FORM

The following is a list of individuals interviewed for the five-year review. See the attached contact record(s) for a detailed summary of the interviews.

Rebecca Carter	County Administrator	Buckingham County	2/28/2013
Name	Title/Position	Organization	Date
Tommy Ranson	Building Inspector and General Property Supervisor	Buckingham County	2/28/2013
Name	Title/Position	Organization	Date
Karl Carter	Assistant County Administrator/Finance Director	Buckingham County	2/28/2013
Name	Title/Position	Organization	Date
Kevin Greene	Superfund and Voluntary Remediation Program Manager	Virginia DEQ	2/28/2013
Name	Title/Position	Organization	Date
Thomas Modena	Remedial Project Manager	Virginia DEQ	2/28/2013
Name	Title/Position	Organization	Date
Bob Nicholas	Remedial Project Manager	Virginia DEQ	2/28/2013
Name	Title/Position	Organization	Date
Name	Title/Position	Organization	Date
Name	Title/Position	Organization	Date
Name	Title/Position	Organization	Date
Name	Title/Position	Organization	Date
Name	Title/Position	Organization	Date
Name	Title/Position	Organization	Date

Buckingham Landfill Superfund Site Five-Year Review Interview Form

Site Name: Buckingham Landfill **EPA ID No.:**
Interviewer Name: Vance Evans **Affiliation:** EPA
Subject Name: Rebecca Carter **Affiliation:** Buckingham County (Administrator)
Subject Contact Information: bcty@moonstar.com
Time: 10:00 AM **Date:** 2/28/13
Interview Location: Buckingham County Administration Building

Interview Format (circle one): **In Person** Phone Mail Other:

Interview Category: **Local Official**

1. What is your overall impression of the project; including cleanup, maintenance, and reuse activities (as appropriate)? ***Our goal is to make sure the remedy is working, we are relying on information from EPA. (explanation from Chris Matta)***

2. What is your assessment of the current performance of the remedy in place at the Site? ***Reports given by EPA*** *– Chris Matta explained to Ms. Carter why the remedy is not functioning as designed and gave her a status update of where EPA/VADEQ is in the current FFS.*

3. Are you aware of any complaints or inquiries regarding site-related environmental issues or remedial activities from residents in the past five years? *No*

4. Has your office conducted any site-related activities or communications in the past five years? If so, please describe the purpose and results of these activities. ***No, just grass mowing, seeding, maintenance of the cap, gravel down to get the well sites, as required by EPA***

5. Are you aware of any changes to state laws that might affect the protectiveness of the Site's remedy? *No*

6. Are you comfortable with the status of the deed restrictions at the Site? If not, what are the associated outstanding issues? ***Yes, I rely on EPA to do their job (EPA Input:*** *no building/development of the cap area within the fence, no groundwater development restrictions in place yet.****) At one time someone was talking about putting a golf course there, groundwater said not to be used, not comfortable to put a well in, conclusion would need to bring in water. There is potential that the cap may have to be modified, and we could consider this.***

7. Are you aware of any changes in projected land use(s) at the Site***? Not at this point, it is zoned a landfill.***

8. Are you aware of any new developments in the area? ***Two new homes on Andersonville Rd. that are being built. There is a subdivision off Twin Creeks Rd.***

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9. Do you have any comments, suggestions or recommendations regarding the management or operation of the Site's remedy? ***Not at this point, we don't know where we are going with the site at this point.***

Additional questions/comments:

- ***Has/can the well at the dog pound been tested could calm fears (Answer:*** *Yes, we can grab a sample; Oak Hill Church was tested to determine communication, there was bacteria found at low, insignificant concern)*
- ***We would like to see the fear factor controlled, try to make it very clear that COCs have not entered wells.***
- ***Will it be a while before you hold another public meeting (Answer:*** *when we comfortably know what the groundwater conditions are, within the next year, once delineated)*
- ***Peggy Johnson is the Clerk for the town of Dillwyn, VA. Ervin Toney is the mayor***

Buckingham Landfill Superfund Site Five-Year Review Interview Form

Site Name: Buckingham Landfill **EPA ID No.:**
Interviewer Name: Vance Evans **Affiliation:** EPA
Subject Name: Kevin Greene **Affiliation:** VDEQ
Subject Contact Information: Kevin.greene@deq.virginia.gov
Time: 10:00 AM **Date:** 2/28/13
Interview Location: Buckingham County Administration Building

Interview Format (circle one): [✓ **In Person**] Phone Mail Other:

Interview Category: **Local Official**

1. What is your overall impression of the project; including cleanup, maintenance, and reuse activities (as appropriate)? ***Our goal is to make sure the remedy is working, we are relying on information from EPA. (explanation from Chris Matta)***

2. What is your assessment of the current performance of the remedy in place at the Site? Reports given by EPA

3. Are you aware of any complaints or inquiries regarding site-related environmental issues or remedial activities from residents in the past five years? ***No***

4. Has your office conducted any site-related activities or communications in the past five years? If so, please describe the purpose and results of these activities. ***No***

5. Are you aware of any changes to state laws that might affect the protectiveness of the Site's remedy? ***No***

6. Are you comfortable with the status of the deed restrictions at the Site? If not, what are the associated outstanding issues? ***Yes,***

7. Are you aware of any changes in projected land use(s) at the Site***? Not at this point, it is zoned a landfill.***

8. Are you aware of any new developments in the area? *No*

9. Do you have any comments, suggestions or recommendations regarding the management or operation of the Site's remedy?

What will be the process for the FYR

You will probably conclude the remedy isn't working?

Is it protective? (***EPA Answer:*** *Short term yes, long-term no, until groundwater is delineated)*

What are the steps? *Progressive, but we want to speed it up, as long as we are seeing nothing*

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in the monitoring wells, we are o.k. they are buying off on our suggestions for monitoring and are onboard

Who is paying? *PRPs*

Do conclusions of the FYR create an obligation to do something/an enforceable condition? ***(EPA Answer:*** *We track it internally. We do take it to the PRPs to say yes you are aware and the agency's position and need to act.)*

Is the PRP viable? *(Yes, they have to demonstrate financial ability, but this site is under anUAO.*

Can DEQ request a financial test of the PRP group. *(Yes, I will make sure it will be addressed even if it doesn't go into the report (better this way – DEQ). If it becomes fund lead the state will have to pay 50% of costs.)*

Is this getting worse or are we just finding out about the plume? *Was an existing plume, but cap had slowed its migration. Historical data is showing that levels are increasing and moving in different directions. In some areas it is going down CDM map fig. 4-22*

Does the 5YR come out as FYI or as concurrence? *(It isn't like a ROD that requires state concurrence, but the state gets to review, comment and make changes on the draft.)*

The site is now handled under PRP name Furniture Brands USA.