


MEMORANDUM

To: John Sandy
Alan Brewer

From: Mark Widdowson, Ph.D., P.E. 

Date: May 6, 2016

Subject: Review of Hidden Lane Landfill Final Remedial Investigation Report

Attached is a final draft of a review of the Final Remedial Investigation Report, Revision 3 for the Hidden Lane Landfill (HLLF) Superfund Site in Sterling, Virginia dated January 2015 (henceforth referred to as the RI).

The RI review consists of three sections. The first section (pages 1-7) address the RI conclusions with recommendations provided to address issues identified. The second section (page 8-12) identifies major concerns and deficiencies in five areas of the RI. The final section starting on page 13 are detailed comments organized by sections of the RI.

There are a number of issues of immediate concerns that are listed below. I recommend that Loudoun County communicate these to EPA as these issues related to potential risks to the community adjacent to the HLLF.

1. Concentrations of trichloroethene (TCE) in tap water (post treatment) have exceeded the maximum contaminant level (MCL) in 20 tap water samples and have exceeded the EPA Risk Screening Level (RSL) in 46 tap water samples. The concentration of other volatile organic compounds (vinyl chloride, chloroform and 1,2-dichloroethane) have exceeded RSLs in 244 tap water samples. The EPA address exposure, notification to residents, and concerns for human health as well as account for failures in the point of entry treatment systems (POETS) at residences.
2. Because metals in groundwater are present at concentrations that exceed RSLs and are not treated by the POETS, the EPA should direct the contractor to immediately begin monitoring consistently for the concentrations of metals in residential wells and in tap water at all residences. It is probable that the risk of exposure to metals in groundwater is underestimated in the human health risk assessment.
3. EPA should release the identification of the residential sampling locations which are redacted in the RI. Redaction of this data is a significant barrier to assessing public health concerns, runs counter to expectations for transparency, and is problematic to a review of the RI.
4. EPA should immediately release the work plan and reports (interim or final) including all data associated with the recently completed vapor intrusion study. Potential exposure pathways and impacts to human health due to TCE vapors were left as an open-ended question in the RI.
5. For the on-going treatability study, the EPA should immediately release the work plan and any interim reports including all data collected to date. Remediation of TCE by enhanced bioremediation is expected to significantly increase concentrations of cis-1,2-dichloroethene and vinyl chloride in groundwater and possibly release naturally-occurring arsenic and other metals from geologic material.

Review of Final Remedial Investigation Report
Hidden Lane Landfill Superfund Site
Sterling, Virginia

Mark A. Widdowson, Ph.D., P.E.
May 6, 2016

Summary

The Final Remedial Investigation (RI) report, Revision 3 dated January 2015, consists of an Executive Summary, seven chapters and 15 Appendices. EA Engineering, Science, and Technology, Inc. (EA) was contracted to conduct a Remedial Investigation/Feasibility Study (RI/FS) at the Hidden Lane Landfill (HLLF) Superfund site under contract with the United States Environmental Protection Agency (EPA).

This review begins with a critique of the main conclusions of the RI listed in the Executive Summary and also in Section 7.5 (Conclusions and Recommendations) of Chapter 7. Following the critique of the RI conclusions, significant concerns are identified and discussed including deficiencies of the RI in reaching the stated objectives. These concerns and deficiencies pertain to data gaps, speculative or incorrect interpretation of data and conclusions, and any potential current and future hazards. Several of these concerns elaborate on comments pertaining to the RI conclusions and findings listed immediately below in the Critique of RI Findings. The final section of this review contains detailed comments organized by numerical section of the RI.

Critique of RI Findings

The Executive Summary lists 11 bullet points as “results of the RI and associated risk assessments” starting on p. ES-1. The first nine are described as results in Section 7.5.1 (Conclusions). The latter two are stand-alone bullets in Section 7.5.2 (Recommendations).

This critique consists of a response to each of the 11 bullet points and a recommendation for further action, if applicable. At the completion of any remedial investigation, it is expected and essential to evaluate potential data gaps and determine what data is missing. Data gaps should be immediately addressed prior to proceeding with the FS or in conjunction with the FS. Recommendations in this critique and in the next section of this review are direct toward these data gaps.

RI Conclusions

1. Methane gas generation and migration is not a concern at the landfill.

Response: Concur, based on the 2008-12 monitoring data presented in the RI. However, as the FS moves forward, any remedial action to address site contamination should reflect an awareness of the potential of methane gas generated from the landfill.

Recommendations: Vapor intrusion (VI) of landfill gas (methane) into residences adjacent to the landfill has been documented previously (Chapter 1). The Landfill Gas Assessment did not include any evaluation of VI of methane into residents' homes in the Countryside or Broad Run Farms subdivisions. EPA should direct EA to re-evaluate laboratory methods used in the VI study and determine if methane was analyzed. Any further VI test should include methane.

2. The estimated volume of TCE was calculated to be between 2.7 and 67.9 gallons. This volume estimate was calculated from the TCE mass present in the dissolved-phase, and does not take into account the sorbed mass within the Balls Bluff Siltstone. Some TCE is present in the bedrock as evidenced by continued dissolved TCE emanating from the RI-14 area. As identified in the CSM (i.e., conceptual site model), TCE DNAPL (i.e., dense non-aqueous phase liquid) likely migrated from the landfill downward into the fractures of the Balls Bluff Siltstone. Subsequently, TCE DNAPL that migrated into fractured bedrock has dissolved over time into groundwater, creating a dissolved-phase plume. Observed low concentrations of TCE in the fractured bedrock source area indicate that DNAPL is no longer present, and only a sorbed source of TCE remains within or adjacent to specific bedrock fractures.

Response: Several statements pertaining to the CSM are supported by data: 1) a DNAPL source likely migrated from the landfill, and 2) TCE dissolved over time into groundwater, creating a dissolved-phase plume. However, the remaining statements in this paragraph are not supported by data and reflect serious data gaps and missed opportunities to characterize contamination and bedrock properties:

- A. The estimated volume of dissolved-phase TCE in groundwater “between 2.7 and 67.9 gallons” is based on interpolation of fracture data and TCE concentration data over a significant area between monitoring wells and does not take into account TCE concentration observed in untreated residential water wells. Data analysis of TCE concentrations clearly shows that the vertical and horizontal extent of the TCE plume in groundwater is not defined. As a result, the estimated volume is subject to considerable uncertainty. Further, the purpose of estimating the volume of dissolved-phase TCE in groundwater is never clearly defined in the RI.
- B. The statement “this volume estimate does not take into account the sorbed mass within the Balls Bluff Siltstone” reflects a significant data gap. Sorbed mass in the rock fractures was not quantified because data necessary for measurement of TCE sorption were not collected during the RI. A related data gap is quantifying sorption properties of the overburden geology where residual TCE may be present as a continuing source.
- C. The statement “Some TCE is present in the bedrock as evidenced by continued dissolved TCE emanating from the RI-14 area” is misleading because well RI-14 was only sampled once (Round 2 sampling event). The phrase “Some TCE” is also ambiguous.
- D. The statement that “DNAPL is no longer present, and only a sorbed source of TCE remains within or adjacent to specific bedrock fractures” is entirely speculative and relies only on groundwater concentrations.
- E. The persistence of TCE concentrations observed at residential domestic wells since 2008 and given these levels have often matched TCE concentrations observed at RI-14 are indications that the TCE source has not lost strength over time.

- F. A critical point missing from this finding is this; for as long as TCE remains as a source in the landfill, possibly as a dispersed DNAPL, then the TCE groundwater plume will persist and impact residential domestic wells in the Broad Run Farms subdivision. Further, the TCE source shows no indication of dissipation over time due to data gaps in the groundwater investigation.

Recommendation: Given that the persistence of TCE at the HLLF is strongly dependent on the amount of TCE present beneath the landfill, it is imperative to conduct a supplemental investigation to address this critical data gap. EPA should direct EA to collect additional data to test for the presence of DNAPL and to quantify sorbed TCE mass in fractures. The latter would include laboratory tests to quantify sorption parameters. While this will require the drilling of additional boreholes on the HLLF property, additional boreholes will address additional data gaps discussed below.

Additional monitoring wells along the western boundary of the HLLF are required to close the data gap resulting from over 800-ft of the landfill parameter being uncharacterized and the likely source of high TCE concentrations in groundwater entering the adjacent Broad Run Farms subdivision.

3. TCE in groundwater is the COPC (i.e., chemical of potential concern) at HLLF; the RI found no evidence that TCE has migrated into media other than groundwater within the overburden soil and fractured bedrock.

Response: This first part of this statement (“TCE in groundwater is the COPC at HLLF”) is challenged in responses A and B. The latter statement is subject to question and is addressed in response C.

- A. The statement “the COPC” implies a singular chemical whereas at Superfund sites, multiple chemicals of concern (i.e., more than one COPC) can be considered.
- B. Data gaps prevented the consideration of other groundwater constituents, specifically arsenic, chromium, vanadium, vinyl chloride, chloroform, and possibly other volatile organic compounds (VOCs), each as a COPC. Additional discussion and recommendations are addressed below (#5).
- C. The lack of investigation of TCE concentrations in soil gas and in soil and rock samples, is a noteworthy data gap. Therefore, the notion of “no evidence” has absolutely no justification when the site investigation did not evaluate TCE vapors in the soil around the landfill and did not measure TCE concentrations in soil or rock samples during the construction of borehole or screened monitoring wells.

Recommendation: EPA should direct a soil gas survey on the HLLF property to evaluate the concentration of TCE and other VOCs, including vinyl chloride, in soil vapor samples. In addition, although it is routine to collect and analyze soil samples for VOCs during the construction of boreholes, this was not executed during the HLLF RI for reasons that are never stated in the report. Any additional drilling at the HLLF should include evaluation of TCE, other VOCs and metals in soil samples.

4. Risks to ecological receptors from analytes present in surface media at HLLF are not expected.

Response: This statement reflects the findings of the Ecological Risk Assessment (ERA) and is problematic for the following reasons:

- A. This conclusion is predicated on the assumption of sufficient integrity of the landfill cap/cover and control of stormwater runoff and eroded soil from the HLLF. Neither were properly evaluated in the RI suggesting that ecological risk remains an open question.
- B. The lack of soil sampling in the RI is a data gap of concern. The 2009 ATSDR Public Health Assessment identified unrestricted access to the landfill as a potential exposure pathway (p. 11) for humans. Given that no soil samples were taken from the landfill during the investigation, and based on site data collected previous to the RI, the concentration of metals and of other COPC derived from the landfill should be considered.

Recommendation: EPA should direct EA to analyze drainage and engineering controls of runoff and erosion from the landfill to prevent risk to all potential receptors. EPA should also direct EA to collect and analyze new soil samples from the landfill and HLLF property. A suitable and scientifically-sound location for background soil samples must be identified to allow for a comparison of concentrations of metals and of other COPCs found on site.

5. Risks to human receptors from analytes present in surface media and groundwater at HLLF, other than TCE, are not expected.

Response: Although the Human Health Risk Assessment (HHRA) only identified TCE as a significant carcinogenic risk, other analytes in groundwater that greatly exceeded EPA-defined risk screening levels (RSLs) should be more closely examined. Data gaps in the groundwater investigation prevented the consideration of other groundwater constituents, specifically arsenic, vinyl chloride, and possibly other VOCs, as COPCs at HLLF. In addition, a significant data gap in the RI is the complete lack of geochemical data from monitoring wells. The fate and transport of VOCs and metals in aquifers is controlled by geochemical conditions in groundwater, yet the RI is silent on this determining factors.

Other groundwater contaminants were eliminated by EA in the HHRA as a COPC based on the concept of Frequency of Detection (FOD) using data collected at the residential wells. Some residential wells show no traces of TCE or other COPCs and skew the findings. However, a number of the residences immediately adjacent to the landfill show higher FODs for other compounds.

Regarding future risks to human receptors, a concern of significance is the selected remedy. Potential impacts on groundwater quality at the residential wells must be given serious consideration if enhanced bioremediation (using reductive dechlorination) is selected as a remedy at the HLLF. Two specific unintended consequences that must be addressed are:

- A. An expected result will be a significant increase in the concentrations of cis-1,2-dichloroethene and vinyl chloride in untreated residential domestic wells.
- B. A potential unintended consequence noted with this technology is the release of secondary constituents into the groundwater. These are typically elements associated with the native geologic units, resulting in increased concentrations of metals, particularly arsenic.

Recommendation: EPA should direct EA to re-examine the HHRA and particularly consider the FOD. Regarding data gaps, this re-examination will require additional sampling of both

monitoring wells and residential wells along with tap water and a more extensive analysis of VOCs, including vinyl chloride, metals, and parameters to characterize the geochemistry of the fractured-rock aquifer. EPA should direct EA to immediately begin to routinely monitor these constituents at residences, continue these analyzes indefinitely, and evaluate the results before completing the FS.

The second recommendation refers to future risks to human receptors resulting from enhanced bioremediation including the current treatability study. EPA should immediately release the Work Plan and any progress reports associated with the FS treatability study. EPA should direct EA to immediately begin analyzing groundwater samples for arsenic and other metals. As noted above (#3 and #4), samples of the overburden soil and fractured-rock aquifer should be collected and analyzed for metals including arsenic.

6. A TCE groundwater plume is present at HLLF and has impacted groundwater quality to the extent that exposure to groundwater poses the potential for unacceptable health risks to residential human receptors.

Response: Concur. However, as noted above (#3), the exclusive focus on TCE is not supported by the data.

Recommendation: EPA should direct EA to conduct a whole-site sampling of all groundwater monitoring wells and evaluate for a complete range of VOC, metals, and geochemical parameters in accordance with EPA best practices at chlorinated solvent sites.

7. The existing POETS (i.e., point of entry treatment systems) are sufficiently preventing exposure above regulatory standards for those residences with potable water wells and concentrations of TCE in untreated water that are greater than the MCL (i.e., maximum contaminant level).

Response: This finding is challenged on three counts based on concentration data observed at indoor taps.

- A. As this statement specifically pertains to TCE, data collected at the residential POETS suggests the treatment systems are not 100% effective in preventing TCE from reaching indoor taps at concentrations below RSLs and even MCLs.
- B. The POETS are not 100% effective in eliminating three other VOCs, vinyl chloride, chloroform and 1,2-dichloroethane, and concentrations of each have appeared in tap water at levels above RSLs.
- C. POETS are not effective in reducing the concentrations of metals to levels below RSLs, including arsenic, chromium, and vanadium.

Recommendation: EPA should direct EA to release the identification of the residential sampling locations. This recommendation pertains to redacted House numbers in the Broad Run Farms subdivision. Unless a communication system is in place, EPA should notify residences in a timely manner if the RSL or MCL for TCE or any other VOCs (i.e., immediately the data has been evaluated for quality metrics). EPA should direct the contractor to immediately evaluate the effectiveness of the POET, resample both well water and tap water, and perform appropriate maintenance on the treatment system.

EPA should direct EA to conduct an evaluation of the historical data to determine any relationship between the VOC concentrations in the untreated residential well water samples and tap water samples. Further, EA should evaluate the spatial proximity of any POETS that have exhibited problems relative to the landfill. Because the locations of the residential data were redacted in the RI, any evaluation of this nature cannot be determined.

EPA should direct EA to routinely analyze samples from both well water and tap water for the concentration of metals on a routine basis. EPA should direct EA to evaluate new and historical data and acknowledge in the RI that POETS are ineffective in reducing metal concentrations below RSLs.

8. Migration of TCE in groundwater is occurring and is controlled by flow in fractured bedrock.

Response: Concur; however, this statement implies that other physical-chemical factors controlling the persistence of TCE in groundwater are not important. Specifically, sorption of TCE and other VOCs and the release of TCE from a source that shows no signs of dissipating are not mentioned. Further, the statement suggests that biodegradation (i.e., attenuation by naturally-occurring bacteria resulting in transformation of TCE in groundwater) is also not a factor.

Recommendation: EPA should direct EA to revise the CSM for TCE only after sufficient data has been collected and evaluated including concentrations of other VOCs and metals in soil and groundwater, geochemical parameters in groundwater, and sorption parameters in the overburden soil and fractured-rock aquifer. The aim of this revision is to eliminate the speculative nature of the CSM and potential consequences in the form of negative impacts on remediation decision-making.

The groundwater flow system in the fractured-rock aquifer is inadequate to complete the FS. EPA should direct EA to conduct pumping test as stipulated in the RI Work Plan.

9. Vertical flow paths with downward gradients along fractures intersect the zone of highest TCE concentrations (in RI-14). Upward gradients prevalent near the Potomac River have resulted in upward discharge of the plume.

Response: Concur. In fact, vertical flow paths with downward gradients are observed in all wells with the exception of multi-screened well RI-10 located along the southern bank for the Potomac River. However, it is unknown whether the TCE plume is discharging into the river due to a lack of data.

Recommendation: EPA should instruct EA to continue collecting water level data at all monitoring wells on a quarterly basis to evaluate potential seasonal effects. In addition, EPA should instruct EA to instrument multi-screened well RI-10 to collect water level data to include the elevation of flow in the Potomac River at a nearby location. EPA should direct EA to identify groundwater wells north of the Potomac River including the river islands and determine availability of water level data and consider potential utility of any wells for water quality sampling.

RI Recommendations

10. A Feasibility Study is recommended to identify possible remedial alternatives that could prevent exposure to groundwater with concentrations of TCE that are above regulatory standards.

Response: Concur; however, as stated previously, the RI a process in which data gaps should be evaluated in the context of RI objective. Further, a plan should be implemented to address key data gaps in conjunction with the FS (sometime referred to as a Supplemental RI). The work to close data gaps should be completed in a timely manner to have a meaningful impact on decision making associated with the FS.

Recommendation: Data gaps identified in this review should be immediately addressed through additional site investigation and development of an improved, scientifically-defensible CSM for TCE. The HHRA must be revised and the CSM must be expanded to consider other COPCs and the FS should give consideration to COPCs other than TCE including metals, arsenic and chromium, and other VOCs (vinyl chloride and chloroform).

11. A vapor intrusion study would be needed to determine whether or not vapor migration is a complete or incomplete exposure pathway for human health receptors.

Response: Concur (see previous comments, #3). It is unclear why the VI study mentioned only in EPA Fact Sheets (November 2014 and November 2015) was not conducted during the RI. A VI study to evaluate the migration of TCE vapors into residences in both the Broad Run Farms and Countryside subdivisions was not conducted as a component of the RI. The 2009 ATSDR Public Health Assessment identified VI as a potential exposure pathway of VOCs into residences (p. 11) and recommended that the EPA “perform adequate soil gas sampling to determine if VI into nearby homes is a possibility, and take follow-up actions as necessary” (p. 14). Vapor intrusion of TCE into homes remains an open question. Given that residential participation in the VI study was voluntary and the sampling locations within the Broad Run Farms and Countryside subdivisions are unknown.

Recommendations. EPA should immediately release reports containing data and results of the VI investigation, including the location of residences where testing was conducted. EPA Fact Sheets indicate a VI study was completed in 2015 after the RI report was completed. Details of the Work Plan and results of the VI investigation are limited which prevents any technical evaluation. The methodology of the VI should be open to question including sampling methods and sample collection locations.

Major Concerns and Deficiencies in the RI

1. The Landfill as a Continuing Source of Groundwater Contamination

One of the key aims of any RI is delineation and characterization of the contaminant source(s). The outcome of this aim impacts RI Objectives 2 through 5 (p. 1-1). A strong technical argument could be made that source delineation and characterization should have been the RI Objective 1, which would include landfill gas. While it is indisputable that contamination has originated from the landfill, unfortunately, the HLLF RI source delineation and characterization is inadequate to contribute to the RI Objectives.

TCE Source

The notion that TCE migrated in the form of a DNAPL from the landfill is plausible due to the density differences of solvents relative to water. As previously stated in response to Conclusion 2, the persistence of TCE concentrations observed at residential domestic wells since 2008 and at levels reasonably close to TCE concentrations observed at RI-14 (Phase 2 and 3) is an indication that the TCE source has not lost strength over time. Because of RI data gaps, the form of the TCE source, DNAPL or desorbing from soil or fractures, is unknown.

Source Delineation – Data Gaps

There is a need to identify the location of the contamination source beneath the landfill. Data needed to describe subsurface conditions below the landfill are lacking. The RI multi-screen nested monitoring wells and borehole wells are insufficient to identify the location of the contamination source. Additional borings and wells are recommended.

In addition, there is no rationale for limiting the investigation to only a few monitoring wells along the western boundary of the HLLF adjacent to the Broad Run Farms subdivision. Over 800 ft of the HLLF western perimeter is uncharacterized, representing a significant data gap. Additional sampling locations are needed to improve delineation of contaminants migrating with groundwater leaving the HLLF and passing through the fractured-rock aquifer beneath the Broad Run Farms subdivision. Wells RI-14, RI-07S/D and RI-02S/D are insufficient for this task.

Source Characterization – Data Gaps

Opportunities to characterize the nature of the TCE source were missed during the groundwater investigation. Specifically, the use of the air/mud rotary drilling technique for borehole constructed resulted in a significant opportunity cost with respect to achieving the stated RI objectives. Rock coring allows detailed examination and testing. As a result, screening methods to identify the presence of DNAPL (e.g., hydrophobic-dye cloth liners) could not be used. Similarly, laboratory methods to extract and quantify TCE and other VOCs sorbed in the fractures could not be utilized.

This data gap could be addressed with the drilling of additional boreholes through rock coring and the use of field and laboratory methods to identify DNAPL and quantify TCE sorption.

Landfill Integrity

An underlying assumption of the RI is that contaminants (TCE) emanated from the landfill and that the residual source is dissipating. However, there is good reason to focus efforts to immediately improve the integrity of the landfill including a new cap to bring the HLLF up to current requirements.

The HLLF permit issued in July 1983 requires only a 6” clay cap with an additional 18” inches of soil capable of supporting vegetation. The RI refers to this as a “2-foot clay cover”, which is misleading. Recently, a memorandum to EPA from the site contractor contains observations that the cap does not meet these requirements as rocks and other debris are present within the top two feet of subsurface. Because the landfill cap contained debris and waste within the upper two feet of subsurface sampling, it would be appropriate to add a clay layer in accordance with current solid waste regulatory statute, 9VAC20-81-160.D.2.e.

A finding of the groundwater investigation is that mounding of groundwater was consistently observed at a well (RI-07S) immediately adjacent to the landfill. A key implication of the mounding of groundwater within the landfill is a lack landfill cap integrity that allows infiltrating rainwater to percolate through the landfill. This situation increases the flow of infiltration through the landfill, mobilizing contaminants, and providing more energy to move groundwater away from the landfill.

2. Groundwater Contamination in the Broad Run Farms Subdivision

Another key aim of any RI is delineation and characterization of the contaminants in groundwater. At the HLLF this includes both on-site groundwater beneath the landfill and HLLF property but particularly off-site groundwater beneath the Broad Run Farms subdivision. This aim is framed in RI Objective 2 and impacts Objectives 3 through 5. Although nearly 385 groundwater samples were analyzed for VOCs, the HLLF RI delineation and characterization of groundwater contamination is inadequate to meet the RI Objective 2.

TCE

Results of the groundwater investigation, as defined by monitoring well data, do not demonstrate that the horizontal bounds of the TCE plume are clearly defined. Data gaps in the horizontal bounding of the TCE plume are the result of an insufficient number of monitoring wells within the Broad Run Farms subdivision but also in residential areas to the south of the landfill. Further, there is insufficient data to delineate the eastern edge of the TCE plume in groundwater beneath the Countryside subdivision. The redaction of residential sampling locations correlated to TCE concentration data from the report contributes to this problem.

The vertical extent of the TCE plume is also unknown. Multi-screened wells constructed during Phase 1 were only completed to a depth of 150 ft below ground surface (bgs). TCE concentrations in

groundwater determined from Phase 2 and 3 sampling of borehole wells, particularly RI-14, show significant TCE contamination in groundwater well below 150 ft bgs and at concentrations that greatly exceed the MCL for TCE (5 µg/L).

Other VOCs

Other VOCs were analyzed inconsistently throughout the groundwater investigation. In particular, vinyl chloride (VC), a known carcinogen and a product of TCE biodegradation, was only included in one groundwater sampling event (Phase 2). During the Phase 2 event, VC concentrations exceeded the EPA Risk Screening Level (RSL) in 19 samples.

Metals

The concept that metals have migrated from the landfill into the groundwater beneath residential area is not established. However, the negative has not been proven either. From the start of the RI, the idea that metals were emanating from the landfill was discounted based on pre-RI investigations. An investigation in 2005 showed that EPA Region 3 Risk-Based Concentrations (RBCs) in 171 soil samples were exceeded in 171 out of 210 analyses for five metals including arsenic. The ATSDR Public Health Assessment recommended that “EPA include plans to sample landfill soil and subsurface soil for a full range of contaminants to determine the potential hazard associated with trespasser or recreation exposures at the landfill” (p. 11, ATSDR 2009). Despite these findings and recommendations, the site investigation did not include any evaluation of additional soil samples for metals or other COPC even from easily-obtained samples during well construction.

The same 2005 study showed that arsenic concentrations in domestic well samples were significantly above the EPA Region 3 RBC in all 56 samples, including post-treatment (POET) samples. Nevertheless, analysis of metals in the groundwater investigation was largely ignored and limited to the multi-screen nested monitoring wells in Phase 1, Round 1 and Phase 3 Packer Test in the deepest sampling zones of three borehole wells. Further, the use of passive diffusion bags in several groundwater sampling events prevented the analysis of metal concentrations. Quantifying background concentrations of metals at borehole well RI-12, identified as a “background” well, was never evaluated. By limiting the investigation of the concentration of metals in groundwater to a single sampling event, there is no opportunity to evaluate the frequency of detection (FOD) of metals potentially derived from HLLF and spatial distribution of metals in the fractured-rock aquifer.

3. Potential Current and Future Exposure Pathways

TCE – Residential Wells

TCE was detected in 95% of the 603 samples of untreated residential well water. TCE concentrations were above the MCL (5.0 µg/L) in 56% of the well water samples and above the RSL (0.26 µg/L) in 92% of samples. However, 22 of the 36 residential wells showed impacts above the MCL throughout nearly the entire monitoring program. Further, TCE concentrations in the impacted wells did not diminish with time.

Other VOCs – Residential Wells

Other VOCs, including the breakdown products of TCE biodegradation (VC and DCE), migrate to the residential wells and have been detected at frequencies ranging from 3% to 58% of all samples. For example, chloroform (23% FOD) was almost always above the RSL but all detected concentrations were below the MCL.

Metals – Residential Wells

Only one sampling round (March 2014) included the analysis of metals in untreated residential well water. However, the results are only provided in Appendix H and not discussed in the report. Arsenic and chromium were at concentrations above their respective RSL in 34 of 35 wells sampled. Lead was above the MCL in untreated residential well water at four residences.

Human Health Risk Assessment and POETS

The HHRA found that the carcinogenic risk in the Broad Run Farms subdivision for the resident adult and child combined to account for a lifetime cumulative carcinogenic risk based on untreated well water ranged from 1×10^{-4} to 2×10^{-4} . The EPA target risk range is 10^{-4} to 10^{-6} , meaning there is a clear health risk to being exposed to untreated well water. The health index for non-carcinogenic risk for exposure to untreated well water ranged from 6 to 43 for the resident child and 4 to 21 for the resident adult. A health index greater than 1.0 is unacceptable.

The RI views TCE as the only health risk and groundwater is the only media for exposure. An overlying assumption to the HHRA is that residents of the Broad Run Farms subdivision will always be protected by the POETs from health impacts due to exposure to TCE. A review of the TCE and VOC concentrations in tap water shows that the POETs are not 100% effective in eliminating TCE from reaching indoor taps at concentrations below RSLs and even MCLs and two other VOCs, vinyl chloride and chloroform, have appeared in tap water at levels above RSLs. POETS are not effective in reducing the concentrations of metals, including arsenic, chromium and vanadium to levels below RSLs at the tap. One exception appears to be lead.

Remedial Approach Using Bioremediation (Treatability Study)

One remedial approach currently being considered in the FS through an on-site treatability study involving enhanced bioremediation. Specifically, bacteria and nutrients are injected into the fractured-rock rock to promote TCE breakdown in a process known as reductive dechlorination. One outcome of this technology is the formation of both cis-1,2-dichloroethene (DCE) and VC in groundwater. Ideally, the bacteria are able also degrade DCE, forming VC, and then degrade VC to harmless end products.

A significant concern is the impact on groundwater quality at the residential wells if enhanced bioremediation (reductive dechlorination of TCE) is selected as a remedy at the HLLF. An expected result will be a significant increase in the concentrations of DCE and VC in untreated residential domestic wells above RLSs and in the case of VC, above MCLs. A potential unintended

consequence noted with this technology is the release of secondary constituents into the groundwater. These are typically elements associated with the native geologic units, resulting in increased concentrations of metals, particularly arsenic.

Vapor Intrusion

The notion that TCE migration from groundwater in the fractured-rock system to the vapor phase in soil pores is to a large extent discounted in Chapter 5. Vapor intrusion into residences between the TCE plume remains a potential exposure pathway. This concern is not addressed in the RI other than the final recommendation. Research gaps exist regarding TCE soil gas migration at sites where TCE contamination is derived from groundwater in fractured-rock aquifers. Soil gas surveys and/or phytoscreening to detect and quantify TCE and other VOCs could be readily performed to address this concern as a follow up to the VI study.

Landfill – Surface Water and Erosion

Engineering measures must also be implemented at the HLLF to control site drainage of stormwater runoff and soil erosion from the landfill. These recommended measures are in addition to the need for a competent landfill cap. Drainage patterns for the system of streams were not analyzed in the RI, making it impossible to evaluate the pathway of potentially-contaminated water and soil from the landfill to receptors.

4. Fate and Transport of TCE – Biodegradation

TCE Biodegradation

A glaring data gap is the absence of geochemical data and natural attenuation parameters in the RI. Only a very rudimentary understanding of TCE biodegradation is described in the RI (Chapter 5). Given the state of knowledge of TCE biodegradation and the available technology for professional practice at TCE sites, this component of the RI is a complete failure in support of the RI Objectives and the primary purpose of the RI. Given the current focus of a treatability study utilizing reductive dechlorination as a potential remedy, one would expect adequate data in support of this approach and communication of a basic understanding of factors that influence a successful outcome.

5. Characterization of Hydrogeology and Groundwater Flow with Implications for FS

The RI provides a description of the site hydrogeology that is limited in scope and appears incomplete. Important data gaps exist in the characterization of the site hydrogeology. Groundwater flow in the aquifer under natural conditions determines the rate of contaminant transport. Site hydrogeology also impacts the success potential for a number of remediation options involving the injection or recovery of groundwater. Inadequate characterization of the hydrogeology is problematic for any comparison of remediation options in the ongoing FS (RI Objective 5).

Groundwater Investigation – Hydraulic Properties of the Aquifer

It is unclear why pumping tests were not performed to quantify field-scale aquifer parameters and ascertain interconnectivity of the fracture network. The RI states that “An aquifer pump test proposed in the work plan was not completed” (p. 2-6), but no justification is given other than slug tests and step drawdown tests were “considered sufficient for the evaluation of site hydrogeology” (p. 2-6). Instead, step drawdown tests and slug tests were performed in the borehole but are not adequately documented in the RI. The advantages of conducting pumping tests greatly outweighs any potential risks. Specifically, compared to the pumping tests proposed in the work plan, step drawdown tests and slug tests do not provided the necessary data to characterize the fractured-rock aquifer to adequate conduct an analysis of contamination fate and transport in groundwater.

Groundwater Investigation – Groundwater Elevations and Flow Direction

It is unclear why water levels were measured only during the months of June and July. Groundwater flow (direction and rate) can vary with season of the year depending on inputs such as recharge. Assuming precipitation events led to direct recharge to the fractured-rock aquifer, it would be useful to measure variations in the flow pattern during wet and dry periods. The approach used in the investigation leads to uncertainty in achieving RI Objective 4.

1. Introduction

1.1. Purpose and Objectives

The Final Remedial Investigation Report, henceforth referred to as the RI, identifies a four-fold purpose (p. 1-1) to the investigation of the HLLF. Although not stated in the RI, the primary purpose should be to “collect data necessary to adequately characterize the site for the purpose of developing and evaluating effective remedial alternatives.” (Code of Federal Regulations, 40 CFR 300.430).

Five specific objectives of the RI are identified on p. 1-1.

1. Determine the nature and extent of potential landfill gas distribution in the subsurface soil adjacent to the landfill.
2. Identify and delineate the extent of COPC in surface water, groundwater, and sediment.
3. Identify potential and complete exposure pathways and assess risks associated with human and ecological receptor exposure to various media along complete pathways.
4. Perform fate and transport analysis of contamination in groundwater to determine the extent of concentrations that exceed acceptable risk levels.
5. Provide sufficient data for a FS.

1.2. Organization

The major sections and subsections of the RI are consistent with the components of similar reports documenting remedial investigations at other Superfund sites. However, any deficiencies to the content of this RI will be identified and described in this review. The structure of the RI is consistent with other Superfund RIs; however, Physical Characteristics of the Study Area (Section 3) often follows the Introduction (Section 1) and precedes the description of the Site Investigation (Section 2). Normally, this order of presentation allows the reader to put the investigation and field methods into a proper context and presents the framework for the physical system (i.e., geology, hydrology, etc.).

1.3. Site Background

1.3.1. Site Description

Redaction of the subdivision west of the HLLF (i.e., Broad Run Farms) is noted here and throughout the text of the report. However, the subdivision name is not redacted beginning on Figure 1-2 and in other report figures. Redaction of residential information is identified as a serious concern and is discussed elsewhere in this review (Chapters 4 through 6). **The key concern is that redaction of spatial data pertaining to the distribution of contamination is counter to each of the five RI objectives.** Redaction of data is an unusual step in documentation of remedial investigations and no justification is provided in the RI.

1.3.2. Site History

In this section, a brief synopsis of the site history from 1967 until 1986-87 is presented with a primary focus on landfill specifications and operation. It is not a complete timeline of events but does address a number of facts relevant to landfill construction and events leading up to environmental investigations.

In general, the discussion on close-out procedures (p. 1-4) appears to rely on one report of the Virginia Department of Health (VDH) in 1985 which suggests that the land fill cap was complete and competent even though the VDH site visit is identified as a “visible inspection”. Further, **the HLLF permit issued in July 1983 requires only a 6” clay cap** with an additional 18” inches of soil capable of supporting vegetation. **The RI refers to this as a “2-foot clay cover”, which is misleading.** The integrity of the landfill cover and drainage issues will be addressed elsewhere in this review.

1.3.3. Previous Investigations

This section provides details of pre-RI environmental investigations in chronological order beginning in 1986 with monitoring of landfill gas (methane). The following are omissions or errors in this section of the RI:

- The history of the four monitoring wells and historical results of groundwater concentrations are not included. Facts useful to the RI include:
 - The wells were installed in March 1981.
 - The wells (MW-1 through MW-4) were completed to a depth of 41 ft (Table 2-1) and screened at either 15- or 20-ft intervals. A comparison of drilling logs from nearby RI boreholes suggests the wells were screened at depths straddling the interface between saprolite (weathered bedrock) and the bedrock. Therefore, the finding that TCE was not detected in groundwater samples collected in 1988-89 site investigation (p. 1-5; NUS Corporation under EPA contract) only indicates that TCE was not present in the overburden above the fractured-rock aquifer.
 - In December 1983, a Law Engineering investigation detected metals in groundwater samples from all wells, including arsenic, cadmium, chromium, iron and lead.
- The findings of an investigation by Tetra Tech in 2005, under EPA contract, appear to be discounted with respect to metals in groundwater in domestic wells, tap water in Broad Run Farm residences, and in soil samples collected on the HLLF property. Several pertinent results of the Tetra Tech investigation mischaracterized in or missing from the RI were:
 - A total of 42 soil samples were collected and not 20 (p. 1-5).
 - Arsenic concentrations in soil samples exceeded the EPA Region 3 Risk-Based Concentration (RBC) in all 42 samples.
 - RBC for other metals in soil samples were also exceeded: chromium (19 of 42), iron (42 of 42), manganese (26 of 42), and vanadium (42 of 42).
 - **Domestic well samples showed arsenic concentrations significantly above the EPA Region 3 RBC in all 56 samples, including 14 post-treatment (POET)**

samples. None of the arsenic concentration in these samples exceed the maximum contaminant level (MCL, 10 µg/L).

- TCE concentrations in groundwater and in tap water at Broad Run Farms residences were evaluated in the 2005 Tetra Tech investigation.
 - TCE in the domestic well samples exceeded the EPA Region 3 RBC (0.026 µg/L) in all 56 samples. This finding is mischaracterized in the 2006 Tetra Tech report as 17 of 56, which the number of samples (17) that exceeded the TCE MCL (5 µg/L).
 - The maximum TCE concentration in the domestic well samples (130 µg/L) is 26 times greater than the MCL and exceeded the RBC by a factor of 5,000.
- The locations of the residential domestic wells sampled by Tetra Tech in October 2005 are redacted from Figure 1-4. The figure caption incorrectly lists the year as 2007.

2. Site Investigation

Site Investigation (SI) describes the approach and methods used in the field (i.e., at the HLLF site and areas surrounding the landfill impacted by contamination). Typically, deviations from the RI Work Plan are discussed in this section, but the lack of an available RI Work Plan for the HLLF site prevents any further comment.

Five objectives of the RI field activities are listed (p. 2-1) and can be linked to the overall objectives of the RI in Section 1.1 as listed below.

1. Provide data to identify and delineate the extent of COPC in surface water, groundwater, and sediment (see RI Objective 2: *Identify and delineate the extent of COPC in surface water, groundwater, and sediment*).
2. Provide data to determine the nature and extent of potential landfill gas distribution in the subsurface soil adjacent to the landfill (see RI Objective 1: *Determine the nature and extent of potential landfill gas distribution in the subsurface soil adjacent to the landfill*).
3. Identify potential and complete exposure pathways (see RI Objective 3: *Identify potential and complete exposure pathways and assess risks associated with human and ecological receptor exposure to various media along complete pathways*).
4. Provide data for a fate and transport analysis of contamination in groundwater (see RI Objective 4: *Perform fate and transport analysis of contamination in groundwater to determine the extent of concentrations that exceed acceptable risk levels*).
5. Provide data for completion of Risk Assessments (see RI Objective 3) and the FS (see RI Objective 5: *Provide sufficient data for a FS*).

The SI is delineated into three phases (p. 2-1) beginning in February 2009 and continuing through April 2012. A phased approach to a SI is not uncommon. This approach is designed with assessments of data at the completion of each phase and to allow the results to inform the direction of the next phase of work. Results of the investigation are presented in Chapter 4 with the exception of a Phase 1 groundwater sampling pilot study conducted in December 2009. The pilot study evaluated different groundwater sampling methods and results are tabulated in Table 2-2.

Additional sampling beyond April 2012 included in the SI are:

1. Groundwater sampling of residential domestic wells conducted from January 2013 through June 2014 (p. 2-12),
2. Landfill gas monitoring, and
3. Pond sediment sampling in 2013

Residential Point-of-Entry Treatment Systems (POETS) Operations and Maintenance (O&M) and sampling of residential domestic wells and landfill gas monitoring are identified as ongoing activities (p. 2-1).

2.1. Soil Investigation

As noted previously, the RI ignores the previous results of soil sampling (Tetra Tech, 2006) around the perimeter of the landfill. The rationale given in the RI for not conducting additional soil sampling is based on a single follow-up investigation (Tetra Tech 2007) of background soil samples. As shown in Figure 1-4, the “background” soil samples were collected on the HLLF property and only at a shallow depth. In addition, an opportunity was missed by not analyzing contaminant concentrations in soil samples derived from the construction of wells. **Not conducting a soil investigation (p. 2-1) disregards the Public Health Assessment (ATSDR 2009) recommendation under “Potential Exposure Pathways”:**

ATSDR recommends that EPA include plans to sample landfill soil and subsurface soil for a full range of contaminants to determine the potential hazard associated with trespasser or recreation exposures at the landfill. (p. 11, ATSDR 2009)

2.2. Landfill Gas Investigation

Any risk posed by landfill gas (primarily methane) was evaluated by installing eight wells in the overburden soil screened over five feet starting at a depth of nine feet below ground surface (bgs). These eight wells were installed in a line running north-south along the western edge of the HLLF adjacent to the Broad Run Farms subdivision. In addition, 13 of 14 previously installed landfill gas wells along the eastern edge of the HLLF adjacent to the Countryside subdivision were monitored. Sampling of soil gas consisted of purging ambient vapors from the wells using a vacuum pump and measuring the composition of the gas, including methane, using a Landtec GEM 2000 Gas Analyzer (http://www.geotechenv.com/pdf/air_quality/landtec_gem_2000_plus.pdf), a hand-held instrument designed for this purpose. Results of the 13 sampling events are presented in Section 4.2.1.

2.3. Ecological Characterization

The ecological characterization was completed in December 2008. Results of this component of the RI are presented in Section 3.7 in the chapter Physical Characteristics of the Study Area. These results then provide a framework for the Ecological Risk Assessment.

2.4. Groundwater Investigation

This section consists of six subsections which describes the installation of new monitoring wells at the HLLF, testing performed at the wells, and the approach to sampling groundwater. Results of the groundwater investigation are found in six companion subsections to Section 4.2.2.

The monitoring wells (excluding residential wells) used in the groundwater investigation are listed in Table 2-1. These include eight nested multi-level monitoring wells (i.e., two to three screened locations at different depths within the same borehole), nine open borehole wells, and an existing (pre-SI) monitoring well (Figure 2-2).

2.4.1. Existing Monitoring Wells

Only one of the four landfill monitoring wells remained operational for the RI (MW-3). As noted previously, these wells were installed at a shallow depth at the overburden-bedrock interface. Monitoring well MW-3 is screened over a 15 ft interval beginning at 23 ft bgs. The well is located due north of the HLLF adjacent to the sewer easement that runs east-west. Monitoring well MW-4 is incorrectly shown as a functioning well in Figure 2-2.

2.4.2. Monitoring Well and Open Bedrock Drilling

Three subsections in this section address drilling of borehole wells in Phases 1 through 3, respectively. This work is a critical component of the RI. The likelihood of success in meeting the RI objectives, particularly in delineating the extent of contaminants of potential concern (COPC) in groundwater, is predicated on the location of monitoring wells, and in this case, identifying the contaminant pathways in the fractured-rock aquifer.

Phase 1 consisted of drilling nine open bedrock wells to a depth of 150 ft bgs each. Six wells are located within the HLLF property boundary (RI-01, RI-02, RI-05, RI-06, RI-07 and RI-10). Two Phase 1 wells are located in the Broad Run Farms subdivision (RI-08 and RI-09) along the sewer easement. The remaining Phase 1 well (RI-11) is located on the eastern perimeter of the HLLF and west of open space adjacent to McPherson Cir. Five wells were later constructed as nested wells with 20-ft sampling intervals; two per borehole designed with either “S” for shallow or “D” for deep. The one exception is well RI-10, along the Potomac River, which was constructed with three 20-ft well screens including an intermediate (“I”) interval. Four other shallow wells (RI-01S, RI-05S, RI-10S and RI-11S) were constructed in separate boreholes. The depths of the sampling intervals vary in each well depending on the location of water-bearing fractures.

Phase 2 consisted of drilling nine additional open boreholes to a depth of 350 ft bgs. One exception is well RI-13 which was limited to 310 ft bgs. All Phase 2 wells remain as open borehole wells. Well RI-12 is located approximately 400 ft south of the HLLF and is described as a background well (p. 2-5). Well RI-13 is located north of RI-12 along the HLLF property boundary. Two Phase 2 wells are located within the HLLF; RI-14 between the landfill and Rosewood Drive and RI-20 north of the sewer easement and south of the Potomac River. The remaining five wells are located in the

Broad Run Farms subdivision (RI-15, RI-16, RI-17, RI-18 and RI-19). Phase 3 consisted of the deepening of three Phase 2 boreholes (RI-14, RI-18 and RI-19) to depths of 500 ft bgs.

Several comments on this section:

- All wells were drilled using an air rotary drilling technique with some by mud rotary drilling. Although this method is relatively cost-effective, **it is unclear why rock coring was not used as a drilling technique for well construction.** Rock coring enables examination and analysis of core samples in the field and laboratory. **The use of the air/mud rotary drilling technique for borehole constructed resulted in a significant opportunity cost with respect to achieving the stated RI objectives.**
- Rock coring has many significant advantages relative to air or mud rotary, including:
 - Direct identification of permeable, fractured strata, including characterization of depths and size of fracture openings and weathered zone, that could later be isolated for hydraulic testing and groundwater sampling
 - Use of screening methods to identify the presence of dense non-aqueous phase liquids (DNAPL), in this case TCE (e.g., hydrophobic-dye cloth liners)
 - Use of laboratory methods to extract and quantify chlorinated solvents and other volatile organic compounds (VOCs) sorbed in the fractures.
- The rationale pertaining to the locations of wells is not provided. There is no explanation for the limited use of wells within the suspected source (i.e., the landfill) and in the Broad Run Farms subdivision. Similarly, there is no rationale given for the location of the Phase 2 wells and specifically what data were used to direct the Phase 2 and 3 work.
- The number of boreholes drilled is incorrectly stated as 23 (p. 2-4). The correct number is 22 (13 in Phase 1 and nine in Phase 2). Counting the nested Phase 1 wells as individual monitoring wells, a total of 28 monitoring wells were constructed; 19 nested monitoring wells in Phase 1 and 9 borehole wells in Phase 2.
- The dates of borehole drilling and well construction are not provided in this chapter of the RI. The time periods provided at the beginning of the chapter for each phase of the investigation are not sufficient to address questions pertaining to the work timeline.

2.4.3. Geophysical Logging

The field methods identified in this section (p. 2-5) are consistent with standard geophysical logging techniques used at other fractured-rock aquifers. As stated in the RI, the purpose of geophysical logging is to identify fractures and water-bearing zones in the boreholes as a precursor for additional field methods.

2.4.4. Packer Testing

The use of packers to hydraulically isolate fractures and water-bearing zones in the boreholes is a standard and useful approach to (1) developing an understanding of the hydraulic properties of the fractured-rock aquifer, and (2) characterizing the distribution and identification of contaminant chemistry in groundwater and geochemical conditions. Packer testing at the HLLF was utilized for

these purposes. However, **it is unclear why pumping tests were not performed to ascertain field-scale aquifer parameters and interconnectivity of the fracture network.** The RI states that “An aquifer pump test proposed in the work plan was not completed” (p. 2-6), but no justification is given other than slug tests and step drawdown tests were “considered sufficient for the evaluation of site hydrogeology” (p. 2-6). Instead, step drawdown tests and slug tests were performed in the borehole but are not adequately documented in the RI.

The advantages of conducting pumping tests greatly outweighs any potential risks. **Specifically, compared to the pumping tests proposed in the work plan, step drawdown tests and slug tests do not provided the necessary data to characterize the fractured-rock aquifer to adequate conduct an analysis of contamination fate and transport in groundwater. Further, inadequate characterization of the hydrogeology is problematic for any comparison of remediation options in the ongoing FS.**

2.4.5. Monitoring Well Installation and Construction

Similar to the concern raised regarding a lack of justification for the locating of monitoring wells, it is unclear why the Phase 1 boreholes were later constructed as nested monitoring wells using 20-ft well screens at varying depths as compared to the Phase 2 boreholes which were not constructed in a similar manner. Instead, the Phase 2 monitoring wells were completed as open boreholes with surface casing. While there may be advantages to both construction methods, a comparison of results between Phase 1 wells and Phase 2 wells is non-ideal due to differences in construction.

2.4.6. Groundwater Sampling

This section is used to describe measurement of water levels in the RI wells and groundwater sampling events. Four water level measurement events were conducted at the RI wells. Two of the rounds of water levels measurements coincided with groundwater sampling events (June 2009 and June 2011). The initial round was limited to Phase 1 wells which was conducted after the nested wells were completed. The other two measurement rounds are listed as July 2011 and June 2012. Table 4-4 shows additional measurements were conducted on December 1, 2009 at four wells.

Water Levels

It is unclear why water levels were measured only during the months of June and July.

Groundwater flow (direction and rate) can vary with season of the year depending on inputs such as recharge. Assuming precipitation events led to direct recharge to the fractured-rock aquifer, it would be useful to measure variations in the flow pattern during wet and dry periods. **The approach used in the investigation leads to uncertainty regarding the stated objective to provide data for a fate and transport analysis of contamination in groundwater.**

Groundwater Analyses

The table below provides a summary of the Phase 1, 2 and 3 groundwater sampling rounds in chronological order. The results of these events are discussed in Chapter 4. One exception is the Phase 1 groundwater sampling pilot study in which results are tabulated in Chapter 2 (Table 2-2).

Event	Date	Number of Wells	Number of Samples	Method(s)	Field Parameters	Organics	Metals
Phase 1 (Packer)	March 2009	9	39	Three-Vol. Purge	No	VOCs (31 total)	No
Phase 1, Round 1	June 2009	19	21	Low-Flow	Yes	Yes	Yes (23 total)
Pilot Study	Dec. 2009	4	4	Three-Vol. Purge	No	VOCs (15 total)	No
Pilot Study	Dec. 2009	4	4	Low-Flow	No	VOCs (15 total)	No
Pilot Study	Dec. 2009	4	15	PDB	No	VOCs (15 total)	No
Phase 1, Round 2	Jan. 2010	18	53	PDB	No	VOCs (6 total)	No
Phase 2 (Packer)	Jan 2011	9	110	Low-Flow	Yes	VOCs (31 total)	No
Phase 2	July 2011	28	113	PDB	No	VOCs (17 total)	No
Phase 3 (Packer)	Mar 2012	3	26	Low-Flow	Yes	VOCs (31 total)	Yes (1 per well)
Field Parameters: pH, temperature, oxidation-reduction potential (ORP), conductivity, dissolved oxygen (DO) Organics (Phase 1, Round 1 only): Target Compound List (TCL) VOCs, TCL SVOCs, PAHs, PCBs, Pesticides Low-Flow: Well purging at low rate of flow until field parameters stabilize followed by sample collection PDB: Passive diffusion bags (14-day equilibration) Purge: Rapid removal of three well volumes followed by sample collection							

Phase 1 consisted of four sampling rounds involving the nine borehole wells: 1) Packer tests prior to installation of wells screens, 2) Round 1, 3) Pilot Test, and 4) Round 2. The most comprehensive chemical analysis was the Phase 1 Round 1 sampling event (June 2009), which involved testing of groundwater for Target Compound List (TCL) VOCs, TCL SVOCs, PAHs, PCBs, Pesticides, Target List metals, and field parameters (e.g., dissolved oxygen).

From a spatial perspective, the most comprehensive sampling round is the Phase 2 sampling event (June 2011); however, this was limited to the analysis of 17 VOCs. Phase 3 only examined the deepest 150 ft of bedrock after three boreholes were extended to 500 ft bgs.

The stated focus of the Phase 1 Pilot Test (p. 2-9) was to “determine the optimal method of groundwater sampling for the site (with respect to detection of TCE)”. **No rationale is provided that explains the exclusive focus on TCE in the pilot test.** As a result, the remaining groundwater sampling excludes metals with the sole exception of three samples collected in Phase 3. **As noted in the table, Phase 1 Round 2 and Phase 2 were conducted using passive diffusion bags (PDBs) which precludes the analysis of metals in groundwater.**

2.5. Surface Water, Seep and Sediment Sampling

Surface water samples were collected during the same time period of the Phase 1 Round 1 groundwater sampling event (June 2009). This included two streams on the HLLF property and the Potomac River. In addition, surface water samples were collected from two ponds located in the Broad Run Farms subdivision (Ponds 1 and 2) and one spring north of the Countryside subdivision and an adjacent pond (Pond 3). The report does not discuss the rationale for selecting the sampling locations. The spring and Pond 3 are not identified as control sites for comparison with the streams and ponds, respectively. An additional stream outside of the HLLF would be well advised as an additional control.

The report does not address the meteorological conditions or observations of flow or water clarity when the samples were collected. Historical precipitation data (www.wunderground.com) shows that 1.10 inches of rain was recorded on June 10, 2009 in Sterling the day prior to the sampling of the two streams and Pond 1. The spring and Ponds 2 and 3 were sampled on June 12. Two seeps at the base of the landfill were sampled the following year on March 25, 2010. A review of historical meteorological data shows seven precipitation events in the 21 days prior to sampling, which were all rain ranging from 0.01 to 0.60 inches of daily precipitation. Similarly, no field observations or description of the seeps were included in this section. Results are presented in Section 4.2.3.

Sediment samples (two) were collected along the southern bank of the Potomac River in June 2009. Sediment samples were obtained from each of the three ponds in June 2013 and is identified as a component of Phase 2. Results are presented in Section 4.2.4.

2.6. Residential Point-of-Entry Treatment Systems

The section describes the water sampling procedure for the residential domestic wells and POETS. Sampling associated with the SI includes quarterly events starting in September 2008 and ending in December 2012. Chemical analysis of samples was limited to VOCs (31 total). Metals were not analyzed in groundwater from residential domestic wells during the RI. VOC results of the untreated samples from the residential wells are presented in Section 4.2.5. Additional sampling results for the residential domestic wells and POETS between January 2013 and June 2014 are provided in Appendix H.

2.7. Investigative Derived Waste Characterization and Disposal

The section documents the procedures used in the field to capture and eliminate any waste, including environmental site materials (i.e., soil, groundwater, rock, etc.) generated through the construction of wells and sampling. Typically, one would expect a description of procedures used in the field to decontaminate equipment used for well construction and groundwater and soil sampling, but this is not addressed. Impacts of poor decontamination of equipment are discussed below as it pertains to the results of groundwater sampling (4.2.2)

2.8. Quality Assurance/Quality Control Sampling

This section briefly acknowledges that an approved Quality Assurance/Quality Control (QA/QC) plan for sample collection was implemented at the site. A more thorough discussion of QA/QC procedures such as data tracking and validation is contained in Chapter 4. Review comments pertaining to QA/QC are provided in the discussion of the HHRA and the ERA (Chapter 6).

Additional Concerns – Site Investigation

In addition to the issues raised regarding the technical approach to the SI provided above, there are a number of field activities and analyses that were not performed in the SI. The following are field activities and analyses missing from the RI and relevant to the RI objectives:

Biodegradation Parameters (Reductive Dechlorination of TCE) – Groundwater Sampling

At any and all sites where TCE is present, it is routine to evaluate geochemical parameters in relation to biodegradation of TCE by naturally-occurring microorganisms in a groundwater system. This mechanism, *reductive dechlorination of TCE*, is well understood, and the EPA has published technical guidelines for assessing the rate and extent of TCE biodegradation (EPA 1998)¹. **There is absolutely no indication that these guidelines were followed to evaluate lines of evidence of TCE biodegradation, specifically reductive dechlorination, in the fractured-rock aquifer at HLLF.** Given the on-going treatability study to assess the feasibility of TCE biodegradation as a site remedy, it is incomprehensible as to why biodegradation parameters were not measured and why biodegradation-based natural attenuation of TCE was not directly evaluated in the RI.

Compound Specific Isotope Analysis (CSIA) – Groundwater Sampling

More recently, Compound Specific Isotope Analysis (CSIA) has been developed for application to TCE and other solvents and aromatic petroleum hydrocarbons (e.g., toluene) at concentrations in water that are near their regulatory standards (EPA 2008)². *Reductive dechlorination of TCE* is a stepwise chemical transformation of TCE to a harmless compounds (ethane and ethane) in which TCE is initially transformed to cis-1,2-dichloroethene (cDCE), followed by vinyl chloride (VC), which is subsequently degraded to ethene. A major concern with remediation strategies involving

¹ EPA/600/R-98/128

² EPA 600/R-08/148

reductive dechlorination is the possibility of incomplete degradation and accumulation of cDCE and VC. CSIA is a useful tool to assess the biodegradation of each reductive dechlorination step.

Vinyl Chloride – Groundwater Sampling

As noted above, TCE biodegradation (reductive dechlorination) in groundwater is known to result in the formation of VC at measureable quantities above MCL. Vinyl chloride is a known carcinogen and has the potential to cause neurological and liver effects from long-term exposure at levels about the MCL³. **With the exception of the Phase 2 sampling event, VC concentrations were not measured in monitoring wells.** VC was analyzed in groundwater samples collected from the untreated residential domestic wells and in the samples of mid-system and treated water associated with the POETS. **However, analysis of VC in untreated residential well water samples was inexplicably discontinued beginning in 2013** (Appendix H, Table H-5).

Metals – Groundwater Sampling

Sampling of monitoring wells for the evaluation of metals in groundwater was limited to Phase 1, Round 1 and Packer Tests associated with Phase 3. The latter consisted of only three samples; one sample from each of the three borehole wells at one depth each. During Phase 2 and Phase 2 Packer Tests, no samples were analyzed for metals at the additional monitoring wells constructed following Phase 2. **By limiting the investigation of the concentration of metals dissolved in groundwater to a single sampling event, there is no opportunity to evaluate the frequency of detection (FOD) of metals potentially derived from HLLF.** Further, the Phase 2 monitoring well showing the greatest concentrations of VOC adjacent to the landfill (i.e., RI-14) was not sampled for metals. **With this approach, the spatial distribution of metals in the fractured-rock aquifer beneath the Broad Run Farms subdivision cannot be ascertained.**

In addition, it would have proven useful to determine background concentrations of metals in groundwater to compare with concentrations measured in the SI. **Quantifying background concentrations of metals at borehole well RI-12, identified as a “background” well (p. 2-5) was not undertaken.** Discussion of background concentrations of metals is absent from the RI.

Metals – Residential Wells

Arsenic, lead and other metals were only included in one sampling round (March 2014) of the raw well water in 35 residential wells and tap water in 34 homes of the 36 residential sampling locations in the Broad Run Farms subdivision. Four residential wells and corresponding tap water were resampled in June 2014. No rationale is provided in the RI as to why analysis of metals was not included in any of the quarterly sampling events during the period of the investigation (2008-2012).

Source Investigation and Location of Monitoring Wells – Groundwater Investigation

During Phases 1 and 2, five monitoring wells were located and constructed adjacent to the south end of the landfill; three nested monitoring wells (RI-01S/D, RI-07S/D, and RI-11S/D) and two open

³ EPA 811-F-95-004-C

borehole wells (RI-13 and RI-14). This portion of the landfill is approximately 9.5 acres or roughly one third of the total landfill. These monitoring wells showed the highest concentrations of VOCs including TCE during all phases of the groundwater sampling. However, in the overburden and fractured rock beneath this end of the landfill, source location and the distribution of contamination are unknown. It is unclear why there was no consideration of additional boreholes within this area of the landfill. **This concern is raised based on the need to identify the location of the contamination source beneath the landfill and to characterize source contaminants.**

Even if the technological challenge of drilling through the landfill was a justifiable rationale for not drilling beneath the southern end of the landfill, **there is no rationale for limiting the investigation to only a few monitoring wells along the western boundary of the HLLF adjacent to the Broad Run Farms subdivision.** The distance between wells RI-07S/D and RI-02S/D is over 1,000 ft with only one monitoring location (RI-14) in between. Borehole well RI-14 is located approximately 200 ft from RI-07S/D. **This means that over 800 ft of the HLLF western perimeter is uncharacterized, representing a significant data gap.**

Porosity Measurement – Groundwater Investigation

Measurement of the porous volume of fractured rock (i.e., porosity) is imperative for the calculation of contaminant volume in the TCE plume and the rate at which contaminants migrate through the aquifer (i.e., groundwater velocity). The RI describes the use of geophysical logging data as a means to estimate secondary porosity. It would have been useful and fairly routine to directly measure porosity of rock core as a way to verify the estimation-based approach used in the RI to calculate TCE plume mass.

3. Physical Characteristics of the Study Area

This chapter consists of seven sections with text and figures that describe the aspects of the site including (in order) 1) location, 2) topography, 3) hydrology, 4) soil type, 5) geology (regional and site), 6) hydrogeology (regional and site), and 7) ecological information (habitat and biota). Several comments pertaining to this chapter include:

3.1. Surface Hydrology

- **Drainage patterns from the landfill, within the HLLF property and adjacent subdivision was not determined or discussed in the RI. Given the significant concern for off-site movement of contaminated surface water and eroded soil from the landfill during storm events, this is a significant omission.**
- It is problematic that surface water is not properly identified in the chapter. A numbering system to identify the surface water (streams and ponds) could be easily implemented.
 - Streams in the figures are not identified with the one exception being the Potomac River (see Figures 3-1, 3-2, 3-4 and 3-6).
 - Ponds in the figures are not identified but in the previous chapter, sampled ponds are numbered.

- Flow directions to streams are not indicated in any of the figures or described in the text.
- Several streams shown in Figures 3-2, 3-4 and 3-6 do not appear in Figure 3-1.
- Some ponds in Figure 3-2 are not identified with a “W”. In particular, Pond 2 in the Broad Run Farms subdivision is missing.
- The spring that feeds into Pond 3 north of the Countryside subdivision is not shown on any figure in Chapter 3 and is not mentioned in the text.

3.5. Geology

- The following statement on p. 3-4 is not well-explained making it difficult to comprehend: *Site specific geology was determined by literature review and from data collected during RI field activities. The geology under the landfill has not been characterized in this RI/FS; therefore, the landfill is not included with references to site geology.*
- The Balls Bluff Siltstone in the Figure 3-3 legend (Geologic Map) is incorrectly labeled as Balls Bluff Sandstone..
- Should there be some consistency in the Faults shown in Figure 3-3 and the Primary Fractures shown in Figure 3-4? This is not addressed in the text.

4. Nature and Extent of Contamination

Chapter 4 presents and summarizes the results of all aspects of the field investigation described in Chapter 2. The chapter is organized in a manner that mirrors the sections of Chapter 2. Chapter 4 contains 10 tables of data, and results are rendered in 14 figures. The outcome of this chapter is particularly essential to two of the five RI objectives:

1. Determine the nature and extent of potential landfill gas distribution in the subsurface soil adjacent to the landfill.
2. Identify and delineate the extent of COPC in surface water, groundwater, and sediment.

4.1. Approach to Evaluation of Sampling Results

This section is a standard and important component of the RI. The first two sections address the approach used for positive identification of analytes, data quality, usability and validation including laboratory qualifiers summarized on pp. 4-1 and 4-2. Section 4.1.3 explains the selection of RI comparison criteria for each constituent and by media (i.e., groundwater, surface water and sediment).

The two comparison criteria for analytes detected in groundwater are (1) EPA MCLs for drinking water supplies and (2) EPA Region 3 Risk Screen Levels (RSLs) for tap water dated November 2012. These values were recently updated (November 2015), but it is unclear what conclusions, if any, should be reconsidered. It is stated here (p. 4-3) that tap water RSLs for non-carcinogenic compounds were lowered by an order of magnitude to achieve a Hazard Index (HI) of 0.1. The rationale for this conservative approach is due to the “potential for multiple COPC to be identified at HLLF (and thus a potential for cumulative effects)”.

The comparison criteria for surface water (stream, seeps, and spring) is the EPA Region 3 Biological Technical Assistance Group (BTAG) values for freshwater published in 2006. The RI states that EPA BTAG values were used to identify COPC for ecological receptors (p. 4-3). In addition, to identify COPCs for human receptors, surface water concentrations were compared to 10 times the RSL for tap water (November 2012). Also for human receptors, the RSLs for residential and industrial soil (R-RSL and I-RSL, respectfully) were increased by a factor of 10 and then compared to sediment concentrations. The rationale given for the order of magnitude increase in both the R-RSL and I-RSL is to account for “reduced exposure to these media [by] receptors” (p. 4-3).

4.2. Summary of RI Field Investigation Results

The second and final section to the chapter focuses on results of the RI field activities including laboratory analysis of samples. The five major subsections are 1) Landfill Gas, 2) Groundwater Sampling, 3) Surface Water Sampling, 4) Sediment Sampling, and 5) Residential Well Monitoring. The section is understandably lengthy. Analytical results for the groundwater investigation are presented in chronological form. Where appropriate, discussion of results in the latter four subsections below are organized by contaminants and categories of contaminants.

4.2.1. Landfill Gas Investigation

Results of the landfill gas investigation are described as negative. In the description of results (p. 4-4), methane concentrations above the instrument detect limit (0.3% by volume) were limited to one-time detections in three of 21 gas monitoring wells (LFGW-5, LFGW-10, and LFGW-13) at concentrations reported as percent volume in air of 1.7%, 0.80%, and 0.90%, respectively. These three wells are located along the HLLF eastern boundary. Examination of Table 4-1 indicates methane concentrations above 0.3% in six of the eight gas monitoring wells along the HLLF western boundary during sampling events immediately following installation of the wells. Comments indicate the presence of glue vapors during these events. In any event, the lower exposure limit (LEL) for methane stated in the RI (5% methane by volume) was not exceeded at any well during the 13 sampling events between December 2008 and December 2012.

4.2.2. Groundwater Investigation

This component of the Section 4.2 consists of six subsections that present results of geophysical logging, packer testing, groundwater elevations and flow direction, and groundwater sampling (Phases 1 through 3). Key findings and comments pertaining to the first three subsections are provided below in order. Results of groundwater sampling associated with packer testing and Phases 1 through 3 will be discussed by contaminants and categories of contaminants.

Borehole Geophysical Logging

Major observations of the geophysical logging of the boreholes, primarily physical features related to the transmission of groundwater and dissolved contaminants, are presented on p. 4-5. The analysis of the fractured-rock aquifer systems is presented in Section 5.3 of the RI. Appendix D contains the geophysical logging reports from two different firms. The Phase 1 boreholes were logged by Earth

Data Northeast, Inc. (report date March, 2009; page 47-164 in the PDF file). Logging of boreholes during Phases 2 and 3 are described in a June 2011 and June 2012 reports, respectively, by Bucks Geophysical Corp. (p. 165-298 and p. 299-347, respectively). Differences in the presentation of data is noted between the two firms.

Packer Testing – Groundwater Investigation

The RI provides a summary of results of hydraulic conductivity from slug tests (“approximately 0.85 ft/d to 65.4 ft/d”) on p. 4-5. These values apparently are the results of packing off fractures identified through geophysical logging (“jointly determined by EPA and EA”, p. 4-5) and introducing one gallon of distilled water into the hydraulically-isolated sections of a borehole (p. 2-6). However, tabulated results, a complete description of the experimental method, and test data for the slug tests are not provided anywhere in the RI. Therefore, it is impossible to assess the validity of these tests.

Section 2.4.4 states that the purpose of the step-drawdown tests is to “determine the hydraulic properties of the aquifer” (p. 2-6), but unfortunately, the step-drawdown test is not designed for this purpose. Hydrogeology textbooks and manuals describe the step-drawdown test as measure of a well capacity to produce water (rate of volume quantity relative to the amount of water level decline or drawdown). Further, a complete description of the experimental method and test data are not provided. Section 2.4.4 states that results of the step drawdown tests are “summarized in Chapter 4” (p. 2-7); however, step drawdown test results are absent from Section 4.2.2.2 and elsewhere in the RI. A final statement promises a “more detailed evaluation of the aquifer testing data obtained during packer testing, including hydraulic conductivities and how those values relate to TCE mass transport at HLLF, will be included in the FS” (p. 4-5).

Groundwater Elevations and Flow Direction

Section 4.2.2.3 discusses the results of the four rounds of water level measurements (Table 4-4). Spatial representation of water levels from two of the events (June 2011 and June 2012) are rendered in Figures 4-2 with 4-3 and Figures 4-4 with 4-5, respectively. The first set of figures in each group only utilize data collected in the nine “S” wells to represent the “shallow groundwater potentiometric surface”. The second set of figures incorporate water level data from the nine “D” wells combined with the nine one borehole wells to represent the “deep groundwater potentiometric surface”. Justification for combining data on p. 4-11 is reasonable. At other sites where the groundwater flow system is relatively thick in the vertical dimension, the use of multiple contour plots of the shallow and deep components of the system is common. Although standardized plotting or contouring of the data appears to have been used to produce these figures, in locations where data is incomplete, lines should be dashed, indicating that the contours lines (i.e., lines of equal water levels) are estimated.

Several points are missing from the discussion regarding groundwater flow (p. 4-10 and 4-11).

- The mounding of groundwater mentioned on p. 4-11 and evident in Figures 4-2 and 4-4 is not associated with well RI-8, but is instead a result of data collected at well RI-07S. Shallow groundwater at RI-07S was consistently observed at the highest recorded level compared to

all other wells for all four events. Therefore, groundwater flows vertically downward from this point and moves horizontally away from this location (RI-07S) in a radial pattern.

- A key implication of the mounding of groundwater within the landfill is the questionable integrity of the landfill cap. As noted above and will be discussed in Chapter 6, a critical concern is whether the landfill cap is uniform in areal extent and vertical thickness. These results are an additional line of evidence that the landfill cap is not adequate.
- Another implication of the mounding of groundwater shown in Figures 4-2 and 4-4 is a flow of groundwater from well RI-07S to well RI-01S generally in a southern direction from the HLLF into the adjacent residential area. Given that RI-01S is the only well in the vicinity of the southern boundary of the HLLF, it is impossible to map the entire recharge mound. Therefore, the TCE contamination in groundwater may extend further south, driven by groundwater flow.
- At every multi-level well with the exception of RI-10, water levels in the “S” wells are higher than the water levels in the companion “D” wells. Therefore, there is a vertical hydraulic gradient resulting in downward flow at these wells. The driving force for the flow pattern is precipitation events and recharge to the fractured-rock aquifer.
- At well RI-10, the flow pattern is upward from the deep to the intermediate to the shallow zone of the aquifer. The apparent eventual point of groundwater discharge is the Potomac River. Unfortunately, the water level in the Potomac River adjacent to RI-10 was not recorded, and a comparison with water levels in the wells is not possible. Based on these data and given that rivers and surface water naturally receive groundwater discharge in the form of baseflow, it is highly probable that groundwater from the fractured-rock aquifer discharges to the Potomac River. However, without water level data from the fractured-rock aquifer north of the Potomac River and from the river itself, it is impossible to determine.
- These patterns discussed in the five previous bullet points above are consistent for all four water level measurement events.
- Possibly the most important point is derived from the cumulative result of the previous bullet points. Downward groundwater flow strongly suggests that any source of contamination present inside and below the landfill will travel downward through the overburden material unimpeded to the fractured-rock aquifer and into the region beneath the Broad Run Farms subdivision. **So long as any contaminant source is present, particularly TCE, recharge percolating through the landfill will continue to contaminate the drinking water source.**

Trichloroethene (TCE)

Results of the groundwater sampling clearly demonstrate that TCE is most prevalent contaminant in the fractured rock aquifer beneath the Broad Run Farms subdivision and the HLLF. The TCE plume is approximately 0.9 miles in length from the landfill to the Potomac River, but the true extent is unknown because monitoring data terminates at northern boundary of the subdivision along the river.

Several key points pertaining to TCE in groundwater, as defined by the monitoring well data, are evident from the results

- **The horizontal extent of the TCE plume is not clearly defined.** This includes residential areas to the south, east and west of the landfill. The redaction of TCE concentration data from the report and an insufficient number of monitoring wells contributes to this problem.
- **The vertical extent of the TCE plume is unknown.** Phase 1 multi-screened wells were only completed to a depth of 150 ft bgs. Results from Phase 2 borehole wells, particularly RI-14, show significant TCE concentrations in groundwater (> MCL) below 150 ft.

The following is a summary of findings of the groundwater investigation pertaining to TCE in monitoring wells:

- TCE concentrations in packer test groundwater samples (Phases 1, 2 and 3) were
 - Above the RSL (0.26 µg/L) in 107 samples, representing a 57% FOD
 - Above the MCL (5.0 µg/L) in 72 samples
 - Maximum concentration of 420 µg/L (RI-14, Phase 3 – Depth = 345-365 ft bgs)
- TCE concentrations in the Phase 1, Round 1 groundwater samples were
 - Above the RSL in only 1 out of 21 samples from 19 wells (2.6 µg/L at RI-10D)
- TCE concentrations in the Phase 1, Round 2 groundwater samples were
 - Above the RSL in 12 out of 53 samples from 18 wells
 - Above the MCL in 7 samples
 - Maximum concentration of 45 µg/L (RI-01S)
- TCE concentrations in the Phase 2 groundwater samples were
 - Above the RSL in 75 out of 113 samples from 28 wells
 - Above the MCL in 50 samples
 - Maximum concentration of 270 µg/L (RI-14 – Depth = 226 ft bgs)

Other VOCs

Other VOCs were detected in groundwater samples at or above the individual compound-specific RSLs. The following are findings of the groundwater investigation:

- Thirteen other VOCs were detected at concentrations above RSLs (p.4-6) including five detected above MCLs in packer test groundwater samples (Phases 1, 2 and 3):
 - Toluene: 57 samples > RSL (86 µg/L); none above MCL (1,000 µg/L)
 - Cis-1,2-dichloroethene: 28 samples > RSL (2.8 µg/L); 1 > MCL (70 µg/L)
 - 1,1-dichloroethene: 3 samples > RSL (26 µg/L); 19 > MCL (7 µg/L)
 - Methylene chloride: 2 samples > RSL (8.4 µg/L); 3 > MCL (5 µg/L)
- Toluene were detected at all 10 depths in the background borehole well (RI-12) including four samples at concentrations above RSL
- Chloroform were detected at 5 of 10 depths in the background borehole well (RI-12) at concentrations exceeding the RSL

- In the Phase 1, Round 1 groundwater samples, only chloroform concentrations exceeded the RSL (0.196 µg/L) in two samples at RI-08S and RI-10S
- In the limited VOC analysis conducted in the Phase 1, Round 2 sampling only chloroform and cis-1,2-dichloroethene concentrations exceeded RSLs (3 and 2 samples, respectively).
- Five VOCs were identified as above RSLs or MCLs in the Phase 2 groundwater samples
 - 1,1-dichloroethene: 16 samples exceeded the MCL (7 µg/L)
 - Cis-1,2-dichloroethene: 22 samples exceeded the RSL
 - 1,1,2-trichloroethane: 4 samples exceeded the RSL
 - Chloroform: 6 samples exceeded the RSL
 - **Vinyl chloride: 19 samples exceeded the RSL**

Metals

As discussed above under Additional Concerns related to the SI, metal concentrations in groundwater were only evaluated in the Phase 1, Round 1 and Phase 3 sampling events totaling 28 samples between the two events (21 and 6, respectively). In contrast, 385 groundwater samples were analyzed for VOC concentrations. The following are findings of the groundwater investigation:

- Eleven of the 23 metals evaluated in groundwater samples (Phase 1, Round 1) were detected at concentrations above RSLs but none were detected above MCLs:
 - Antimony: 1 sample > RSL (0.6 µg/L)
 - **Arsenic: all 21 samples > RSL (0.045 µg/L)**
 - Barium: 5 samples > RSL (290 µg/L)
 - **Chromium: all 21 samples > RSL (0.031 µg/L)**
 - Cobalt: 7 samples > RSL (0.47 µg/L)
 - Iron: 3 samples > RSL (1,100 µg/L)
 - Manganese: 12 samples > RSL (32 µg/L)
 - Mercury: 1 sample > RSL (0.16 µg/L)
 - Nickel: 1 sample > RSL (30 µg/L)
 - Thallium: 7 samples > RSL (0.016 µg/L)
 - Vanadium: 9 samples > RSL (7.8 µg/L)
- Eight metals were detected at concentrations above RSLs including one detected above MCLs in packer test groundwater samples (Phase 3):
 - Arsenic: 6 of 6 analyses > RSL (0.045 µg/L); **one above MCL (10 µg/L) at RI-19**
 - Barium: 2 of 6 analyses > RSL (290 µg/L)
 - Chromium: 5 of 6 analyses > RSL (0.031 µg/L)
 - Cobalt: 2 of 6 analyses > RSL (0.47 µg/L)
 - Iron: 2 of 6 analyses > RSL (1,100 µg/L)
 - Manganese: 3 of 6 analyses > RSL (32 µg/L)
 - Vanadium: 5 of 6 analyses > RSL (7.8 µg/L)
 - Zinc: 2 of 6 analyses > RSL (470 µg/L)

Dissolved Oxygen and other Geochemical Parameters

As discussed above under Additional Concerns related to the SI, geochemical data including natural attenuation parameters were not collected as a part of the groundwater investigation. The one exception was a subset of these parameters (pH, temperature, ORP, conductivity, turbidity and DO) which have been recorded during the purging of wells in association with the Phase 1, Round 1 and Packer Tests (Phase 2 and 3) sampling events. The recorded data (Monitoring Well Field Purge Sheets) from Phase 1 (Round 1 and several Pilot Test wells) are provided in Appendix F. However, these data are not discussed in this chapter of the RI or in Chapter 5.

4.2.3. Surface Water

TCE was detected in one stream sample at a concentration of 3.8 µg/L which is greater than human health-based criteria (2.6 µg/L) but is less than the ecological criteria (21 µg/L). The sample is derived from the stream oriented in an east-west direction that is north of the landfill and approximately 50 ft north of the sewer easement (STRSW-5). Because drainage patterns for the system of streams were not analyzed in the RI, it is impossible to evaluate the pathway from the landfill. TCE was also detected in the seep sample (SELS) and field duplicate. The RI mentions detection of TCE in two unidentified surface water samples but this result could not be identified in Table 4-8.

PAH compounds were detected at levels above the human health-based criteria (EPA RSLs) and/or the ecological criteria (BTAGs) for six individual PAHs at the two landfill seeps. A total of 16 PAHs were evaluated, and all 16 were detected in the southeast landfill seep, including the duplicate sample. Only two PAHs were detected in the northwest landfill seep sample and both were B qualified. Although five of the 14 PAH detections from landfill seep samples were B qualified, these results indicate the presence of a PAH source (creosote, coal tar or leachate from landfill waste).

The landfill seep samples also contained concentrations of metals above the individual RSLs and BTAGs. Of the 24 metals analyzed in surface water samples from streams, concentrations of four metals (arsenic, chromium, iron and manganese) exceeded RSLs for human health and eight metals exceeded BTAGs (aluminum, barium, boron, calcium, copper, iron, magnesium, and manganese) for ecological assessment. Stream water samples also showed concentrations of five metals exceeded BTAGS (aluminum, barium iron, manganese and mercury) in all samples except mercury (4 of 7). Concentrations of four metals measured in the streams exceeded RSLs for arsenic (7 of 7), chromium (7 of 7), manganese (2 of 7), and thallium (2 of 7).

There is no discussion of the spring water sample in the RI or comparison to data from other surface water samples. The spring feeding into Pond 3 located north of the Countryside subdivision provides a possible control sample to characterize groundwater with the least likely impact due to the landfill. **Of the 24 metal analyzed, only barium was at a concentration that exceeded the BTAG.** Only one VOC (methylene chloride at 0.91 µg/L with a B designation) and one SVOC (Bis(2-ethylhexyl) phthalate at 4 µg/L) were detected at levels below both RSLs and BTAGs.

The ponds water samples showed no impacts above the comparison criteria for VOCs and only one SVOC was detected above the RSL (Indeno[1,2,3-c,d]pyrene, RSL of 0.29 µg/L) at a concentration of 0.71 µg/L in Pond 1 (sample 1-1). Of the 24 metals analyzed in nine pond water samples, four metals had concentrations that exceeded RSLs: arsenic (9 of 9), chromium (7), cobalt (1), and manganese (4). Concentrations of six metals measured in nine pond water samples exceeded BTAGS for aluminum (8 of 9), arsenic (1), barium (9), iron (8), manganese (7), and mercury (5). These results showed the least impact due to metals on Pond 3 (Countryside subdivision).

4.2.4. Sediments

Sediment samples collected from ponds showed no impacts above the comparison criteria for VOCs, SVOCs, PAHs or PCBs. Of the 24 metals analyzed in ten pond sediment samples, two metals had concentrations that exceeded the R-RSLs (i.e., EPA Residential Soil Regional Screening Level dated November 2012 multiplied by 10); arsenic (4 of 9) and chromium (9 of 9). Concentrations of four metals exceeded BTAGS for iron (3 of 10), manganese (4), mercury (1), and silver (7).

Sediment samples collected from the two streams, west of the landfill and north of the landfill, showed no impacts above the comparison criteria for VOCs, SVOCs, PAHs or PCBs. Three metals had concentrations that exceeded the R-RSLs in the west stream sediment samples; arsenic (2 of 3), chromium (3), and manganese (1). BTAGS were also exceeded in the west stream sediments for cadmium (1 of 3), iron (1), and manganese (1). The second sampling site (STRSED-2) located in the Broad Run Farms subdivision adjacent to the HLLF showed the greatest impact due to metals. In the stream to the north of the landfill, arsenic and chromium were above the BTAG in sediment samples (2 of 4 and 4 of 4, respectively). Manganese and mercury exceeded individual R-RSLs in the sediments collected from the stream located north of the landfill (2 of 4 and 1 of 4, respectively).

4.2.5. Residential Wells

A total of 41 VOCs were analyzed in the raw, pre-treatment groundwater at residential domestic wells identified in Table 4-10 as “House 1” through “House 38”. House 6 is not listed in Table 4-10, with no reason provided for missing data, and Houses 6 and 36 are missing from Table H-4 (2013-14 data). In addition, the identification of the first ten samples in Table 4-10 is redacted. The total number of sampling locations is confusing due to conflicting and incomplete statements such as:

- “well water from over 30 residences...is sampled” (p. 4-22)
- “well water samples were collected from 46 locations” (p. 4-22)

Redaction of locations and inconsistent statements are problematic because the data were used in the RI to “provide information that can be used to help characterize the nature and extent of the VOC contamination on the west side of the landfill” (Section 4.2.5, p. 4-22). As previously noted, the redaction of spatial locations of each sampled well limits technical evaluation of spatial data trends. Without data to locate the 37 residential wells and the sampling depth of each well, it will be impossible to understand how the data were used to help characterize the nature and extent of the TCE plume (discussed in Chapter 5) and impacts of other VOCs.

Additional data are provided in Appendix H. These include VOC concentrations in the mid-system and treated water for samples collected in 2008 through December 2012 (Tables H-2 and H-3, respectively). VOC concentrations in untreated, mid-system and treated water for samples collected in 2013 through June 2014 are presented in Tables H-4, H-5, and H-6, respectively. Concentration data for 1,4-dioxane collected in untreated residential wells in March 2013 are presented in Table H-7. Metal concentrations (22 total) collected in untreated residential wells in March 2014 through June 2014 are presented in Table H-8. The table caption incorrectly listed the sampling period for metals as January 2013 through June 2014.

Section 4.2.5 only addresses the VOC concentration data in the untreated well water collected from the residential wells contained in Table 4-10 with no discussion of VOC data from the tap water samples. Comments provided here includes data contained in Chapter 4 and Appendix H.

Trichloroethene (TCE)

Results for TCE in untreated residential well water are consistent with the findings of the groundwater investigation and clearly show that TCE is most prevalent contaminant in the fractured rock aquifer beneath the Broad Run Farms subdivision. Several key points pertaining to TCE in groundwater, as defined by the monitoring well data, are evident from the results:

- TCE was the most frequently detected VOC in 95% of the 603 samples (p. 4-24) with concentrations in residential wells
 - Above the RSL (0.26 µg/L) in 582 samples, representing a 92% FOD
 - Above the MCL (5.0 µg/L) in 353 samples (56%)
 - Above the RSL in one sample at the unidentified wells.
- The “highest [TCE] concentrations were consistently detected immediately west of the landfill, particularly due west of open borehole RI-14...and in the vicinity of borehole RI-15” (p. 4-24). However, no specific data or time trends are discussed in the RI.
- For this review, analysis of time trends in TCE detected in untreated residential well water indicate that **TCE concentrations in the impacted wells are not diminishing with time.**
- Residential wells showing a sustained and substantial impact from TCE contamination including nine homes in the Broad Run Farms subdivision with TCE concentrations in untreated well water above MCLs during the entire monitoring period (2008 through June 2014) with only one exception out of 203 samples (Houses 3, 8, 9, 12, 15, 18, 26, 28 and 34).
- The table below lists the maximum and minimum TCE concentrations in untreated well water and the date of sample collection for the nine residential wells. Data indicate some maximum concentrations are observed in more recent dates and the minimums were measured at prior to 2013. These results will be further addressed in Chapter 5.
- TCE concentrations in an additional 13 residential wells showed sustained levels above MCLs but generally at lower concentrations or with less consistency than the nine residences listed in the table. These residential wells are designated as Houses 1, 4, 5, 13, 16, 21, 22, 29, 30, 31, 32, and 35.

House	Maximum TCE Concentration (µg/L)		Minimum TCE Concentration (µg/L)	
	Concentration	Date	Concentration	Date
3	110	Jun-2012	4.1	Dec-2012
8	42	Dec-2009	17	Sep-2011
9	89	Jun-2009	28	Sep-2011
12	220	Mar-2013	42	Mar-2012
15	65	Sep-2013	20	Jun-2012
18	60	Jun-2012	18	Dec-2011
26	48	Mar-2013	17	Sep-2011
28	82.1	Jun-2009	23	Sep-2011
34	110	Jun-2012	25	Sep-2008

Other VOCs

Forty other VOCs were detected in untreated residential well water including 15 VOCs at concentrations above individual compound-specific RSLs (p. 4-22). Three of the 15 VOCs were detected at concentrations above individual compound-specific MCLs: 1,1-dichloroethene, 1,1,2-trichloroethane, and carbon tetrachloride (p. 4-22). The latter two along with eight other VOCs were qualified as low FOD (detected in less than 3% of samples).

The following are key findings of the residential well water monitoring related to the remaining five VOCs above RSLs (cis-1,2-dichloroethene, 1,1-dichloroethene, chloroform, chloromethane and 1,1-dichloroethane) and findings pertaining to other contaminants of interest including vinyl chloride and carbon tetrachloride:

- Vinyl chloride, cis-1,2-dichloroethene and 1,1-dichloroethene, which are products of TCE biodegradation (reductive dechlorination), were all detected in untreated residential well water samples. This suggests that production of these contaminants resulting from the reductive dechlorination of TCE can migrate from the landfill to the residential wells.
- Cis-1,2-dichloroethene was frequently detected (40%) but concentrations exceeding the RSL were infrequent (p. 4-23).
- 1,1-dichloroethene was frequently detected (58%) with concentrations exceeding the MCL in 16 samples, but the RSL was never exceeded (p.4-24).
- 1,1-dichloroethane (11% FOD) and carbon tetrachloride are produced from biodegradation (reductive dechlorination) of chlorinated solvents.
- Chloroform (23% FOD) was almost always above the RSL but all detected concentrations were below the MCL (p. 4-23).
 - However, it is noted in the RI that chloroform was detected consistently at four residential wells; House 11 (detections in 14 of 15 samples), House 16 (18 of 22), House 17 (11 of 15), and House 37 (8 of 13).
 - The RI states that chloroform concentrations are decreasing over time at all four locations or are non-detects (p. 4-23). However, a review of the most recent VOC

concentration data (Table H-5) shows persistence of chloroform and that the RSL was exceeded at House 11 (above RSL in 2 of 3 samples), House 16 (4 of 5), House 17 (1 of 2), and House 37 (2 of 4).

- Table H-5 also shows chloroform concentrations exceeded the RSL at five additional residential wells at least once in 2013-14: House 8 (above RSL in 1 of 6 samples), House 19 (1 of 7), House 26 (1 of 4), House 34 (1 of 4), and House 38 (6 of 6).
- Chloromethane (14% FOD) was thought to be an artifact due to contamination from sample bottles (p. 4-23), but no results from the laboratory evaluation of bottleware is included.
- Toluene, although present in groundwater beneath the landfill, was not detected in any samples, which suggests that natural attenuation is an effective control on toluene under present conditions.

POETs – Effectiveness of Treatment Systems

Although not discussed in this section of the RI, results on the effectiveness of the POETs to prevent exposure of VOCs is presented here. One of the findings of the RI is *the existing POETS are sufficiently preventing exposure above regulatory standards for those residences with potable water wells and concentrations of TCE in untreated water that are greater than the MCL*. However, as noted previously, there is no discussion of the effectiveness of the POETs based on the VOC concentrations analyzed in tap water samples. These data are located in Appendix M in Table H-3 (2008-2012) and Table H-6 (2013-2014).

The following is a summary of the TCE and other VOC concentrations in tap water samples collected from 2008 through June 2014. Specifically, there are instances in which the concentrations of TCE in tap water exceeded either MCL or RSL and concentrations of other VOCs (vinyl chloride, chloroform, and 1,2-dichloroethane) exceeded RSLs.

- TCE concentrations exceeded the MCL in 20 tap water samples from nine residences in Broad Run Farms. These residential tap water samples were derived from Houses 4, 8, 10, 11, 22, 27, 28, 32, and 35.
 - TCE concentrations exceeded the MCL in more than one tap water sample from four residences in Broad Run Farms: House 4 (2 samples), House 11 (6), House 22 (3), and House 32 (2).
- The RSL for TCE was exceeded in an additional 46 tap water samples from 13 residences in Broad Run Farms. Residential tap water samples exceeding the RSL were derived from Houses 2, 7, 9, 10, 11, 15, 22, 24, 25, 27, 28, 32, and 35.
- The majority of the instances when TCE concentrations exceeded either the MCL or RSL occurred during the RI (2008-2012).
- Vinyl chloride concentrations exceeded the RSL in 39 tap water samples from 14 residences in Broad Run Farms.
 - Houses with multiple tap water samples above the RSL were House 2 (6 samples), House 15 (10), House 18 (2), House 23 (2), House 24 (4), and House 29 (6).
 - The RSL for VC was exceeded only once at Houses 3, 5, 8, 12, 21, 26, and 34.

- Chloroform concentrations exceeded the RSL in 148 tap water samples from 22 residences in Broad Run Farms.
 - The RSL was exceeded in multiple residential tap water samples at most locations. The most frequent sampling locations were House 1 (13 samples), House 3 (7), House 8 (5), House 9 (7), House 11 (17), House 14 (14), House 17 (15), House 21 (6), House 22 (12), House 23 (12), House 26 (5), and House 29 (14).
 - The RSL for chloroform was exceeded only once at Houses 15, 31, and 34.
 - Residences where the RSL was exceeded more than once but less than five times were House 2 (3), House 10 (3), House 13 (2), House 16 (3), House 27 (3), House 32 (2), and House 36 (2).
- The concentration of 1,2-dichloroethane in 57 tap water samples exceeded the RSL at six residences
 - Residences where the RSL for 1,2-dichloroethane was exceeded more than once were House 9 (9 samples), House 14 (19), House 17 (9), and House 29 (18).
 - The RSL was exceeded only once at Houses 32, and 33.

Metals

As discussed previously, analysis of metals at residences in the Broad Run Farms subdivision was limited to one primary sampling event. Samples from untreated residential well water were collected at 35 of the 36 residences in March 2014 using the same numbering system as indicated in the RI. Additional sampling was conducted in June 2014 at five locations: Houses 22, 23, 28, 34 and 35. Tap water samples were also collected inside the homes at 34 residences and analyzed for metals. House 3 was a tap sample only. Houses 37 and 38 were raw water samples only.

The concentration of 22 metals in residential domestic well water and tap water samples were determined. **Mercury was not analyzed in any samples**, which is a common COPC at landfills. The results of metals are only discussed in Chapter 6 in relation to the HHRA.

Appendix H states “No significant exceedances of metals criteria were found in treated water (tap samples) from residential drinking water wells adjacent to the Site” (unidentified page). The POETS are designed primarily for the removal of VOCs from water and are not generally recommended for the treatment of metals.

The following are findings related to these results (Appendix H, Table H-8):

- Eleven of the 23 metals were detected at concentrations above RSLs in untreated residential well water
 - **Arsenic: 34 samples** > RSL (0.045 µg/L)
 - Barium: 17 samples > RSL (290 µg/L)
 - **Chromium: 34 samples** > RSL (0.031 µg/L)
 - Copper: 6 samples > RSL (62 µg/L)
 - Iron: 1 sample > RSL (1,100 µg/L)
 - **Lead: 4 samples** > RSL not listed

- Manganese: 2 samples > RSL (32 µg/L)
 - Nickel: 3 samples > RSL (30 µg/L)
 - Thallium: 3 samples > RSL (0.016 µg/L)
 - Vanadium: 23 samples > RSL (7.8 µg/L)
 - Zinc: 1 sample > RSL not listed
- Seven of the 23 metals were detected at concentrations above RSLs in tap water samples (post-treatment system).
 - Antimony: 1 sample in tap water > RSL (0.6 µg/L)
 - **Arsenic: 34 samples** > RSL (0.045 µg/L)
 - Barium: 14 samples > RSL (290 µg/L)
 - **Chromium: 33 samples** > RSL (0.031 µg/L)
 - Copper: 2 samples > RSL (62 µg/L)
 - Iron: 1 sample > RSL (1,100 µg/L)
 - Vanadium: 27 samples > RSL (7.8 µg/L)
- **Two metals, chromium and lead, were detected in untreated residential well water samples above MCLs:**
 - Chromium: 1 sample above MCL (100 µg/L); House 23
 - Lead: 5 samples above MCL (15 µg/L); Houses 11, 22, 28 and 35
- **Chromium:** The concentration of chromium in House 23 was reduced from 118 µg/L in raw well water to 4.1 µg/L in tap water samples, which still is above the RSL (March 2014).
- **Lead:** Concentrations of lead were reduced in tap water samples relative to the raw well water samples:
 - House 11: 64.6 µg/L in raw and 1.2 µg/L in tap (March 2014)
 - House 22: 144 µg/L in raw and 0.4U µg/L in tap (March 2014)
 - House 22: 138 µg/L in raw and 1U µg/L in tap (June 2014)
 - House 28: 27.9 µg/L in raw and 0.4U µg/L in tap (March 2014)
 - House 35: 41.2 µg/L in raw and 0.4U µg/L in tap (March 2014)

5. Contaminant Fate and Transport

Chapter 5 addresses factors controlling the persistence and migration of contaminants in all media. The sole focus is TCE as a “primary COPC” with the rationale that TCE “was the only compound observed consistently at concentrations above the MCL” (p. 5-1) and that “no other compounds were consistently detected at concentrations above both comparison criteria” (p. 4-18). The outcome of this chapter pertains to RI Objective 4: *Perform fate and transport analysis of contamination in groundwater to determine the extent of concentrations that exceed acceptable risk levels.*

5.1. Potential Routes of Migration

The description of potential migration of TCE contamination from the landfill to other media is comprehensive but there are several key points that are subject to question:

- Soil erosion from the landfill is ruled out as a pathway because the “landfill is covered/capped”. **The integrity of the landfill cap has not been established.** Further, the HLLF has no means to control stormwater runoff including water and sediment.
- The statement that “volatilization of TCE through the soil column and into air has not been addressed through sampling (i.e., sub slab) during this RI” (p. 5-1) suggests that soil gas monitoring was not considered. The lack of TCE soil gas concentrations data is a noteworthy data gap given no rationale is provided for this missing component of the SI.
- Note that there are additional and potentially conflicting statements regarding TCE in soil gas in Section 5.3.3.1 (Vapor Migration of TCE).
- The statement that “there is no evidence that TCE has migrated into sediment or surface water” ignores the surface water sample showing TCE above the RSL.

5.2. Contaminant Persistence

This section consists of two subsections. The first simply describes the physical properties of TCE, particularly as it applies to sorption. The second discusses degradation mechanisms.

5.2.1. Physical Properties

The last paragraph in Section 5.2.1 discusses chemical properties as it pertains to the propensity of TCE to sorb to non-aqueous media (specifically, TCE sorbs to carbon contained in soil and rock). Missing from the discussion is a communication of basic equations including retardation factors. This is standard material for the RI as sorption impacts travel time of contaminants moving through the groundwater system. Desorption of TCE from non-aqueous media to groundwater impacts the persistence of the TCE sources over time. Significant RI data gaps associated with the partitioning of TCE to media are:

- Not quantifying sorption/desorption properties of the overburden soil and fractured rock, and
- Not measuring sorbed TCE mass in the overburden soil and geology and the rock fractures during construction of borehole wells.

5.2.2. Mechanism of Degradation

Other than attempting to describe reductive dechlorination of chlorinate ethane including TCE, Section 5.2.2 does little to contribute to the RI Objectives. As previously stated, the site investigation provided no substantial data in support of assessing lines of evidence to determine the rate and extent of reductive dechlorination at the HLLF. **There is literally no data in the RI to characterize the geochemistry of the groundwater.** Given the state of knowledge of TCE biodegradation and the available technology for professional practice at TCE sites, this component of the RI is a complete failure in support of the RI Objectives and the primary purpose of the RI. Given the current focus of a treatability study utilizing reductive dechlorination as a potential remedy, one would expect adequate data in support of this approach and communication of a basic understanding of factors that influence a successful outcome.

5.3. Contaminant Migration

This section consists of three subsections. The first subsection focuses on an analysis of the local fracture system in the Balls Bluff Siltstone that serves as the framework for groundwater flow and contaminant transport. The second subsection summarizes the approach for and the results of calculated estimates of TCE mass and volume in groundwater. The final section addresses vapor migration in soil including TCE (without data) and landfill gas (methane).

5.3.1. Fracture Analysis

Two methods to represent the major fractures in the Balls Bluff Siltstone are described. A “spatial analysis” is described in Section 5.3.1.1 with supporting data in Appendix L. The outcome is summarized in a table on p. 5-5. For unknown reasons, this table is not numbered and is not identified in the Table of Contents. Four primary fractures are identified and characterized in the table but no graphics are provided to illustrate the results.

The second approach is the EVS Model (Section 5.3.1.2 with supporting data in Appendix M). The latter is described as containing “EVS model output and an explanation of the methodology used to generate the model” (p. 5-7). However, Appendix M consists of one Power Point slide and the same table and many of the same figures found in Chapter 5. Again, for unknown reasons, the table of results (p. 5-7) is not numbered and is not listed in the Table of Contents. Six primary fractures are identified and characterized using the EVS model. The relationship or differences between the two analyses, including four major fracture groups and six major fracture planes, is unclear.

Both sections contain a semi-quantitative description of the major fractures along with a qualitative description of the fracture connectivity and factors controlling groundwater flow. However, if pumping tests had been performed, much of this qualitative description could be confirmed with actual hydraulic data. No where in Section 5.3 is the information gained through slug test or step-drawdown test conducted in the boreholes ever incorporated into the analyses.

5.3.2. Dissolved-Phase TCE Mass and Volume Estimation

While the objective of this analysis is clearly stated (i.e., “estimate TCE dissolved-phase plume mass using the existing data”, p. 5-9), the usefulness of this effort is never discussed. Two methods for this calculation are discussed and the results vary considerably. The first method detailed in Excel spreadsheets found in Appendix N resulted in an estimate of 827 lbs of TCE in the dissolved-phase plume (i.e., groundwater). No sample calculations are provided to explain the methodology but the approach involves assigning pore volumes and TCE concentrations to horizontal areas to calculate TCE mass with depth. Each component is summed over the entire area and depth of the TCE plume.

The second method utilizes output of the EVS model involving kriging-based interpolation of the porosity of the fractured-rock aquifer and interpolated TCE concentrations. It is unclear if all calculations were performed using the EVS model (i.e., direct output of the software). The reported result using the EVS model is “32.94 lbs”.

The “variability” of these results is attributed to “the method of their calculation and is a function of data resolution with depth” (p. 5-9). No sensitivity analysis to either model is provided. Both approaches are limited by the available spatial data and the fact that Phase 1 boreholes were terminated at 150 ft bgs. In fact, given that the horizontal bounds of the TCE plume are not clearly defined and the vertical extent of the TCE plume is unknown, these results are suspect, and may likely underestimate the dissolved TCE mass.

5.3.3. Vapor Migration

The notion that TCE migration from groundwater in the fractured-rock system to the vapor phase in soil pores is to a large extent discounted in the discussion (p. 5-10). Research gaps exist regarding TCE soil gas migration at sites where TCE contamination is derived from groundwater in fractured-rock aquifers. However, the fracture analysis results could be utilized to evaluate potential pathways to homes in the Broad Run Farms subdivision. Soil gas surveys and/or phytoscreening could be readily performed to address this concern.

5.4. Conceptual Site Model for TCE Fate and Transport

This final section provides a narrative for the fate and transport of TCE based on site conditions and SI data. A properly-constructed CSM is an ideal outcome of any RI and a necessary and useful tool for the FS. The CSM for TCE fate and transport has several key points that are subject to question and comment:

- The statement that “a separate DNAPL source appears to no longer exist” is speculative and relies only on groundwater concentrations limited spatially by data gaps along the western boundary of the HLLF and a lack of data underneath the landfill itself.
- The persistence of TCE concentrations observed at residential domestic wells since 2008 is consistent with the statement that “the TCE plume appears to be in a steady-state condition”.
- Redaction of the upper part of Figure 5-1 limits the entire purpose of the CSM.

6. Baseline Risk Assessment

Chapter 6 consists of two major sections: the human health risk assessment (HHRA, Section 6.1) and the ecological risk assessment (ERA, Section 6.2). The full text of the HHRA is contained in Appendix K, and the complete ERA is contained in Appendix O. Both Appendices are stand-alone documents each with a Table of Contents and attachments.

6.1. Summary of the HHRA

This section consists of five subsections addressing 1) data evaluation and hazard assessment, 2) exposure and toxicity assessments, 3) risk characterization including results, 4) evaluation of residential wells, and 5) HHRA conclusions.

For the HHRA, two separate exposure areas were evaluated for potential receptor exposure to media affected by the HLLF: 1) Landfill and Adjacent Wells Exposure Area, and 2) Potomac River Exposure Area. The two areas were delineated using data collected at monitoring wells and residential wells but a figure showing the exact delineation of these areas is not provided. Table 11 (Appendix K) is reproduced below and summarizes the results of calculations in the HHRA.

Receptor	Media	Carcinogenic Risks ¹	Non-Carcinogenic Hazards	COPC Contributing Significantly to Results
Landfill and Adjacent Wells Exposure Area				
Child Resident ¹	Groundwater	1×10^{-4}	42	TCE, Arsenic, Cobalt, Manganese
	Surface Water	1×10^{-7}	0.07	Not applicable
	Sediment	1×10^{-6}	0.8	Not applicable
	Seeps	1×10^{-6}	0.05	Not applicable
	Cumulative Results	2×10^{-4}	43	
Adult Resident ¹	Groundwater	1×10^{-4}	21	TCE, Arsenic, Cobalt, Manganese
	Surface Water	1×10^{-7}	0.02	Not applicable
	Sediment	1×10^{-6}	0.1	Not applicable
	Seeps	1×10^{-6}	0.02	Not applicable
	Cumulative Results	2×10^{-4}	21	
Potomac River Exposure Area				
Child Resident ¹	Groundwater	1×10^{-4}	5	TCE, Arsenic
	Surface Water	3×10^{-7}	0.05	Not applicable
	Sediment	9×10^{-7}	0.7	Not applicable
	Cumulative Results	1×10^{-4}	6	
Adult Resident ¹	Groundwater	1×10^{-4}	4	TCE, Arsenic
	Surface Water	3×10^{-7}	0.02	Not applicable
	Sediment	9×10^{-7}	0.1	Not applicable
	Cumulative Results	1×10^{-4}	4	
1. Cancer risk for the resident adult and child is presented as a total lifetime cumulative cancer risk.				

The key findings of the HHRA are summarized below with comments where appropriate:

COPCs used in the Hazard Assessment

- The rationale for choosing analytes was not included in this report and the analytes chosen varied between study areas.
- Landfill and Adjacent Wells Exposure Area (Area 1) was assessed using
 - Groundwater (9 VOCs and 10 metals)
 - Sediment (6 metals)
 - Surface water (7 metals)
 - Seep water (4 PAHs, 1 SVOC, and 1 VOC)
- Potomac River Exposure Area (Area 2) was assessed using
 - Groundwater (4 VOCs, 1 PAH and 8 metals)
 - Sediment (5 metals and 1 PAH)
 - Surface water (6 metals)

Non-carcinogenic Results

- A health index (HI) **greater than 1 is an unacceptable risk**
- The non-carcinogenic HI is the cumulative effect of contributing COPCs in all media.
- Results of the cumulative non-carcinogenic HI in each area are:
 - Area 1 is **43** for the resident child and **21** for the resident adult due to TCE, cobalt, and manganese
 - Area 2 is **6** for the resident child and **4** for the resident adult due to TCE
- All four results are primarily due to exposure to groundwater.

Carcinogenic Results

- Carcinogenic risks for the resident adult and child are combined to account for a lifetime cumulative carcinogenic risks.
- **EPA target risk range is 10^{-4} to 10^{-6} .**
- Results of the cumulative carcinogenic risk due to the combined effect of TCE and arsenic and primarily due to exposure to groundwater are:
 - Area 1 is **2×10^{-4}** , which is in excess of the upper limit
 - Area 2 is **1×10^{-4}** , which is just at the upper acceptable limit

The HHRA concludes that groundwater is the only media of concern for human health (p. 6-5).

- Carcinogenic risks due to arsenic in each exposure area (i.e., Areas 1 and 2) are 7×10^{-5} . These risks are driven by arsenic concentrations in groundwater that are generally below the MCL and are described as possibly “attributable to naturally occurring levels” (p. 6-5). As noted previously, background levels for metals were never established through the SI even with an available “background” borehole well (RI-12) constructed south of the landfill and upgradient of groundwater flow. Without an evaluation of geochemical conditions in the fractured-rock aquifer, removing arsenic as a COPC is not warranted.
- Non-carcinogenic risks due to metals in Area 1 are discounted in the final HHRA conclusions. The rationale given is that oral RfD for both cobalt and manganese have uncertainties that “would result in an overestimation of the potential for risks” (p. 6-6).
- A significant concern is the impact on groundwater quality at the residential wells if enhanced bioremediation (reductive dechlorination) is selected as a remedy at the HLLF.
 - An expected result will be a significant increase in the concentrations of cis-1,2-dichloroethene and vinyl chloride in untreated residential domestic wells.
 - A potential unintended consequence noted with this technology is the release of secondary constituents into the groundwater. These are typically elements associated with the native geologic units, resulting in increased concentrations of metals, particularly arsenic.
- An overlying assumption to the HHRA is that residents of the Broad Run Farms subdivision will always be protected by the POETS from health impacts due to exposure to TCE.

6.2. Summary of the ERA

Results of the ERA were less definitive compared to the HHRA. Steps 1 through 3 of the 8-step process defined by EPA for use at Superfund sites were conducted. As noted in Appendix O (p. 4-1), “based on comparisons to screening values, the Screening Level ERA (SLERA) identified metals and PAHs as COPC for exposures to sediment, and metals as COPC for surface water. In addition, four metals and two VOCs in sediment were retained for further evaluation since no EPA Region 3 screening level benchmarks were available. A refined assessment of risks was performed to provide a more site-specific and realistic risk characterization for the site.”

Step 3 led to a refinement of the ERA known as Baseline Risk Assessment and Problem Formulation (BRAPF). The purpose of Step 3 is “build upon the results of the SLERA to identify chemicals driving risks to receptors that must be carried forward into further risk assessment or risk management based on a scientific management decision point” (p. 4-1 of the ERA). This involved a “refinement of risk estimates using more site-specific assumptions and information” (p. 6-9). However, how this was achieved is unclear. It is reported that “While the results of the SLERA provide an initial list of COPC, these results are conservative and do not represent population level risks” (p. 6-9).

The findings of the refined ERA (p. 6-10) are summarized:

- Aluminum was identified as exceeding the Toxicity Reference Value (TRV) in all surface waters evaluated but that the pH was not low enough to pose risks to ecological receptors.
- Chemicals in sediment and surface water in the areas of the Palustrine Wetlands, Ponds, and the Spring are unlikely to pose risk to receptors.
- Although mercury and vanadium exceeded TRVs in the Potomac River, low magnitude of exceedance and the comparison to background, these COPC do not pose risks to receptors.
- Chemicals in sediment and surface water in the Potomac River area unlikely to pose risk to receptors.

Additional Concerns

Integrity of the Landfill Cap

The EPA requested that EA re-evaluate the landfill cap/cover after auger refusal was encountered at many of the original borings. A short memorandum from EA indicated that the cap was “too consistent of silt and some clay at an observed thickness of 2 ft”. The landfill was permitted as a construction and demolition debris landfill, where closure requirements are listed in the current solid waste regulatory statute, 9VAC20-81-160.D.2.e. **From the EA memorandum, the cap does not meet these requirements as rocks and other debris are present within the top two feet of subsurface.**

- A competent landfill cap is imperative as it limits oxygen to subsurface bacterial activity, which creates heat. When the “hot spots” come in contact with methane pockets in the landfill, a fire can be ignited.
- Methane emissions from the Hidden Lane landfill have been an issue for residents nearby since 1989 when an Enforcement Order was drafted to address the methane migration and a methane vent trench was installed in the Countryside subdivision.
- A competent landfill cap would also discourage wildlife from burrowing into the landfill subsurface.
- Because the landfill cap contained debris and waste within the upper two feet of subsurface sampling, it would be appropriate to add a clay layer (in accordance with 9VAC20-81). This would help eliminate methane emissions and lower the risk for potential landfill fires.
- Engineering measures are recommended to control site drainage of stormwater runoff and soil erosion from the landfill.

Additional Assessments to Human Health

- Vapor intrusion of TCE and potentially other VOCs into homes remains an open question. **Given that residential participation in the VI study was voluntary and the sampling locations within the Broad Run Farms and Countryside subdivisions are unknown, it would be prudent to follow up with a soil gas survey on the HLLF property to evaluate TCE and other VOCs in soil vapor samples.**
- Although the HHRA only identified TCE as a significant carcinogenic risk, other analytes that greatly exceeded screening levels should be more closely examined. This will require additional sampling of both monitoring wells and residential wells along with tap water and a more extensive analysis of VOCs, including vinyl chloride, metals, and parameters to characterize the geochemistry of the fractured-rock aquifer.
- Background levels of metals in soil and groundwater should be evaluated, particularly for FOD metals including arsenic.
- Soil samples in the vicinity of the landfill should be collected and analyzed for metals and other COPCs. In the event that concentrations above background levels are measured, the HHRA should be revised.

Quality of Data

The following issues were identified as impacts to the quality of data and the HHRA:

1. Raw data summary sheets from the laboratory should be included in the report along with the validation report. Exact QA/QC procedures were not identified. For example, were blank samples included with each sampling event?
2. Several samples arrived at the lab in broken containers – semi-volatile organic compounds may have volatilized. Samples were run with remaining aliquot.

3. Duplicate samples were collected and analyzed, however, it was disclosed to the laboratory which samples were duplicates of each other. This is not a typical standard operating procedure.
4. Sample containers were mislabeled with sampling location and sampling time on occasion. Supplementary information was supplied to the lab to correct this oversight.
5. Chloromethane was detected in high concentrations during the December 2009 sampling event. These detections were attributed to blank contamination which detected chloromethane around a concentration of 400 ppb.
6. Treated water samples periodically had elevated TCE concentrations – this could possibly be due to malfunction of the treatment system, or a manual removal.
7. Arsenic is one of the constituents of concern and attributing to the overall risk for human health. The feasibility of treatment systems (e.g., reverse osmosis) should be evaluated for installation in Broad Run Farms residences to eliminate this potential threat to human health.
8. RI samples (not residential) Chain of Custody were not always signed as received with a date and time.
9. Mercury was not analyzed for residential samples.
10. Several coolers did not contain enough ice for samples to remain under the mandated 6°C. Samples should have been qualified as estimated, but sometimes were not. Chromium is the only metal required to be submitted under 6°C.