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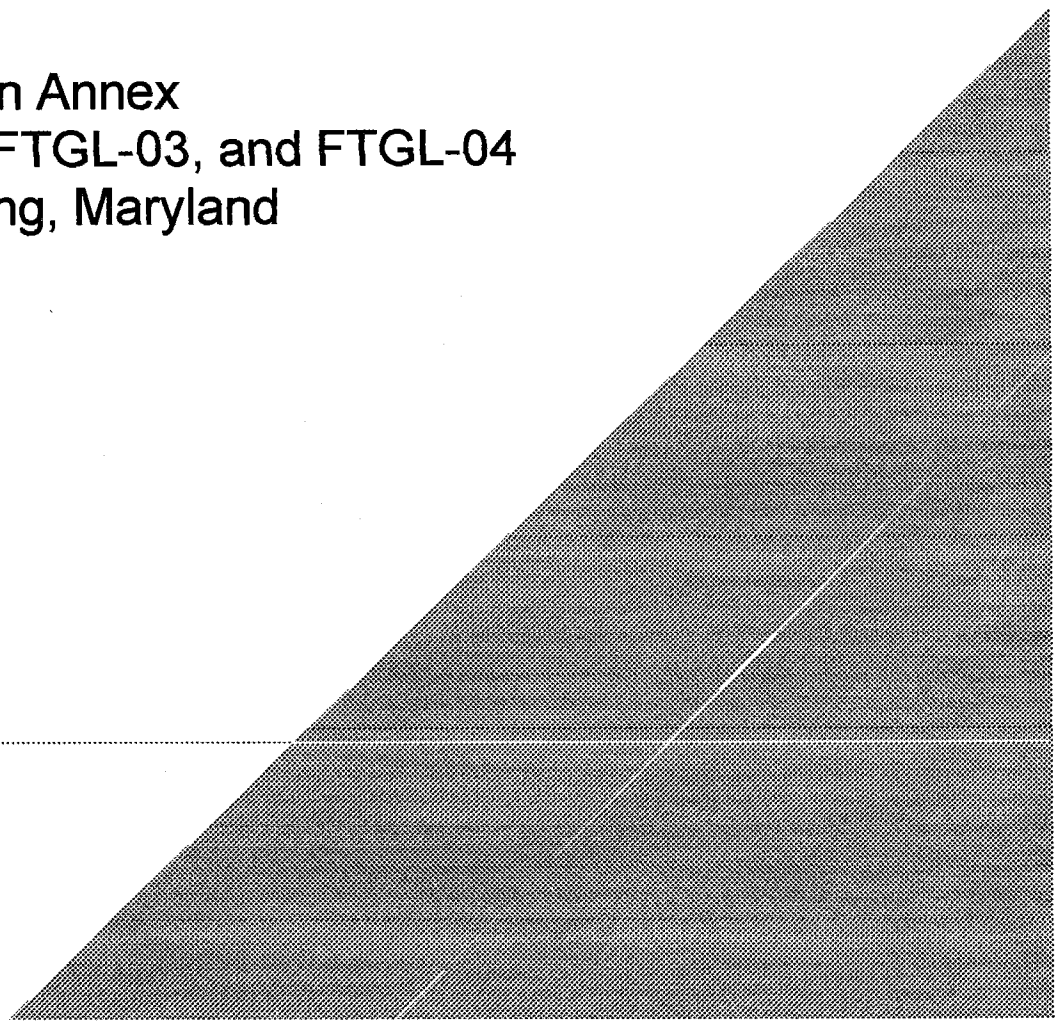
United States Army Environmental Command

DRAFT FINAL REMEDIAL INVESTIGATION REPORT

Forest Glen Annex
FTGL-02, FTGL-03, and FTGL-04
Silver Spring, Maryland

February 2017



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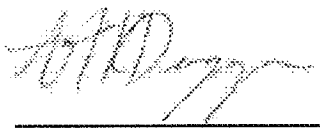

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EXECUTIVE SUMMARY

The Baltimore District of the U.S. Army Corps of Engineers (USACE) contracted AECOM in 2010 to conduct a Remedial Investigation (RI) at Fort Detrick's Forest Glen Annex (FGA) in Silver Spring, Maryland. The RI was conducted for four FGA Installation Restoration Program (IRP) sites including: FTGL-02 (Ballfield/Helipad/Rubble Dump Site); FTGL-03 (Commissary Landfill); FTGL-04 (Building 511 Landfill); and FTGL-05 (Building 607 Washdown Rack [also known as Stream E]). The RI was performed within the statutory framework of the Defense Environmental Restoration Program and the Comprehensive Environmental Response, Compensation, and Liability Act. The Maryland Department of the Environment (MDE) is acting as the lead regulator.

The U.S. Army Environmental Command (USAEC) subsequently contracted the PIKA-Arcadis Joint Venture (the JV) under Contract W91ZLK-13-D-0009-0008, Modification 01 to complete the RI report for FTGL-02, FTGL-03, and FTGL-04 in 2015. Completion of the RI for FTGL-05 was awarded under a separate contract and will be submitted under a separate cover.

The overall objective of the FGA RI for sites FTGL-02 through FTGL-04 was to determine the nature and extent of contamination due to past facility operations and use these results to develop and evaluate response action alternatives that address unacceptable risk and achieve site closure requirements. The Technical Project Planning (TPP) process was used by stakeholders at the start of the project to aid in determining specific site objectives, data needs, and data quality objectives in order to obtain the right type, quality, and quantity of RI data to collect to meet project objectives.

The specific project objectives identified for the three landfill sites (FTGL-02, -03, and -04) included the following:

- Delineate landfill waste extent (lateral and vertical) and location relative to groundwater;
- Characterize landfill surface soils;
- Characterize the potential release to perimeter/downgradient environmental media from landfill;
- Evaluate the potential vapor intrusion exposure pathway; and
- Evaluate human health and ecological risk.

An underlying assumption at the start of the investigation was that a presumptive remedy of containment may be implemented at the landfills. Subsurface characterization at the landfills was not part of the scope of work.

Subsequent project objectives that were identified following the completion of the draft RI Report and agreed to by the Army and MDE in 2013 to address supplemental investigation needs included the following:

- Complete additional background assessment for metals and radionuclides in media at sites FTGL-02 through FTGL-04; and

- Complete additional human health risk assessment based on updated exposure parameters and factors, site-specific metals and radionuclide background levels, and utilize the RESRAD model and risk assessment methodology to evaluate radiological constituents.

The RI characterization efforts at the three sites were conducted in accordance with the final approved RI Work Plan (WP) (AECOM, 2011) and RI WP Addendum (AECOM, 2014). Initial RI field investigation activities under the RI WP (AECOM, 2011) were conducted between November 2010 and January 2012, and supplemental RI field investigations under the RI WP Addendum were conducted between July and September 2014.

Initial RI field operations started with geophysical surveys over the three landfill sites to aid in defining the lateral extent of landfill materials and estimated depths. The largest component of the RI effort was the collection of over 1,000 media samples for analysis to determine the presence/absence and extent of contaminants. Media sampled included surface and subsurface soil, shallow and deep groundwater, sediment, surface water, and vapor/air. Laboratory testing of these samples was conducted for a broad range of analyses including volatile organic compounds (VOCs), semi-volatile organic compounds, pesticides, herbicides, dioxins/furans, metals, radionuclides, biological, and/or geochemical parameters. Site analytical data results were directly compared against applicable chemical- or radiological-specific screening criteria to evaluate the nature and extent of contamination, and statistically compared to background levels to determine if contaminants were site-related. The fate and transport of site contaminant exceeding screening criteria and background was then assessed.

In addition to evaluating the nature and extent of contaminants at each of the sites, a baseline human health risk assessment (BHHRA) and screening-level ecological risk assessment (SERA) were completed. The result of the BHHRA identified risk to future residents and/or construction workers above carcinogenic and/or the noncarcinogenic risk levels of concern at the three sites. Contaminants that were significant risk drivers for future residents at the landfill sites included polycyclic aromatic hydrocarbons (PAHs), dieldrin, and dioxin in surface soils. For future construction workers at the landfill sites, manganese in surface and subsurface soils, and chlorinated solvents in groundwater were significant risk drivers. For the construction worker scenarios at all FGA sites, manganese is not considered a contaminant of concern requiring future action since routine dust suppression measures on construction sites would eliminate unacceptable risk. The results of the SERA found no significant risk of adverse effects to ecological receptors at the sites.

The following summarizes additional key investigation results/findings, data limitations and recommendations, and preliminary remedial action objectives (RAOs) for the sites.

Landfill Delineation at Sites FTGL-02, FTGL-03, and FTGL-04

Revised landfill boundaries illustrating the estimated lateral extent of the landfill material at Sites FTGL-02, -03, and -04 were completed based on geophysical survey, intrusive landfill perimeter investigation, and historical site data and observations. Additionally, estimated profiles of the three landfill sites were prepared.

Soils at Sites FTGL-02 through FTGL-04

The most significant contamination encountered in soils at the FGA sites was PAHs. PAH contamination was consistently encountered in surface soils across each of the three landfills (FTGL-02, -03, and -04) and their surrounding perimeters. Potential sources of PAHs include oil based products including asphalt pavement, and byproducts of burning of wood and fossil fuels. PAHs were also detected in subsurface soils

around the landfill perimeters; however, only in areas where disturbed soils/fill activities were encountered. PAH contamination in surface soils was most prevalent and at the highest concentrations at FTGL-03 followed by FTGL-04. The highest site concentrations were found in samples in the northeast portion of the FTGL-03 landfill and in perimeter samples collected along its eastern boundary. Subsurface concentrations were also the highest at FTGL-03 relative to the other sites but much more limited to disturbed areas as compared to their widespread presence in surface soils. In addition to PAHs, more limited contamination associated with metals, dioxins/furans, polychlorinated biphenyls (PCBs), and pesticides was encountered in site soils. Dioxin contamination was most prevalent along the eastern boundary of the FTGL-03, which may be the result of herbicide application. Isolated and/or sporadic detections of pesticides appear to be indicative low level contamination associated with typical pesticide application.

Groundwater at Sites FTGL-02 through FTGL-04

The most significant contamination in groundwater encountered at the FGA sites was chlorinated solvents along the eastern FGA property boundary. A primary tetrachloroethene (PCE) plume, with a maximum detected concentration of 4,000 µg/L, was identified along the eastern boundary of FTGL-03. PCE degradation products including trichloroethene and cis-1,2-dichloroethene were also detected within the eastern boundary wells indicating some natural degradation is occurring. Sampling data suggests the PCE plume is migrating south toward the former headwaters/drainage of Stream D, which was historically filled during facility development. This contamination is then being redirected westward along the former drainage and is likely discharging into the surface waters of Stream D based on elevated chlorinated solvent detections. PCE has also been detected in the bedrock monitoring wells located within this plume. In addition to the primary plume, much lower concentrations of PCE were detected in a secondary chlorinated VOC plume located to the north of FTGL-03. This plume is believed to be influenced by a topographic high near Linden Lane that may be the dividing line for the primary and secondary plumes, and appears to be influenced by the Stream A drainage running to the northwest. The source(s) of the two PCE plumes identified at FTGL-03 is uncertain. There may be one source migrating onsite from an upgradient and off-site location, or multiple sources may be present. The last area of PCE detection at FGA was at FTGL-02 in one monitoring well (FG208) historically installed within the landfill boundary. PCE was first detected in this well during RI sampling at a concentration of 12 µg/L.

In addition to the PCE, chloroform was identified as a significant contaminant given multiple elevated detections in groundwater at all of the sites. The detected concentrations exceeded the tap water screening level but were below the drinking water maximum contaminant level goal. The source of chloroform in the groundwater may potentially be due to the degradation of carbon tetrachloride present in groundwater, from historical disposal of lab wastes, or from an offsite source.

Surface Water and Sediment at Sites FTGL-02

A broad range of contaminants including PAHs, metals, pesticides, and dioxins were detected in FTGL-02 sediments. The predominant contaminant in sediments at both sites was PAHs. PAH contamination was present in all samples collected from FTGL-02 Stream C, Steam D, and at lesser concentrations in the stormwater retention pond. At FTGL-02, metals including nickel and manganese were elevated in a majority of the samples. These elevated levels in Stream D may be due to the influence of the upgradient landfills potentially mobilizing these metals in groundwater and ultimately discharging to and depositing in Stream D. Lastly, isolated exceedances of pesticides and dioxin occurred in the FTGL-02 stormwater retention pond.

Similar to FTGL-02 sediments, a broad range of contaminants were detected in surface water at FTGL-02 including TCE, metals, DEHP, and pesticides. Elevated TCE was detected in the most upstream surface water sample in FTGL-02 Stream D near the stormwater outlet pipes and is likely from the primary PCE groundwater plume in FTGL-03 discharging to the stream. Consistent with iron staining observed at the stormwater outlet pipes, iron and manganese exceedances were also highest in the most upstream Stream D samples and decrease in concentration moving downstream. Arsenic was detected at elevated concentrations in all surface water samples at Stream D. These elevated concentrations may be attributed to discharge from upgradient groundwater shown also to have elevated concentrations. DEHP was elevated in four samples in FTGL-02 and is likely an artifact of the surface water sampling equipment. Only one pesticide was detected at elevated concentrations in two surface water sample locations at Stream D.

Data Limitations and Recommendations for Future Work

The investigations completed at the three landfill sites (FTGL-02, -03, and -04) achieved investigation objectives including the identification of site contaminants and associated risks. The RI for landfill sites FTGL-02, -03, and -04 was planned and completed based on the assumption that a presumptive remedy of containment would be implemented as the future remedy at these sites. Additionally, risk assessment findings identified site-related risk above acceptable levels for future residents and/or construction workers at all three of the sites. Based on these investigation findings, further assessment of both cover/capping as a remedy for the landfills and contaminated media above acceptable risk levels is recommended as part of a feasibility study analysis to develop remedies that are protective of human health and the environment at these sites.

Additionally, the following recommendations for additional investigation work at FGA were identified:

- Conduct a coordinated investigation with MDE to identify and assess the source of the primary and secondary chlorinated solvent plumes identified during FTGL-03 investigations.
- Conduct additional investigation to define the nature and extent of chlorinated solvent contamination in deep groundwater.
- Conduct additional investigation to further define the nature and extent of contamination in the secondary plume.

The results of these additional recommended investigations would be used by the Army in feasibility study analysis for groundwater remedy development if this contamination is determined to be site related.

Recommended Remedial Action Objectives

Proposed preliminary RAOs at the landfill sites FTGL-02, -03, and -04 include:

- Prevent human and ecological exposure to uncharacterized landfill waste;
- Prevent human (resident and construction worker) exposure to landfill surface and perimeter contamination above acceptable risk thresholds;
- Prevent or minimize the downgradient migration of landfill waste/contaminants for the protection of local groundwater and stream resources;
- Restrict land use to commercial/industrial or recreational activities only; and
- Restrict the use of groundwater to limit exposure.

These objectives will likely be achieved through containment, removal of contaminants to an acceptable level, and/or implementation of land use controls to eliminate or limit exposure. The above preliminary RAOs for the three sites will be refined and finalized as part the feasibility study assessment for these sites.

7 SUMMARY AND CONCLUSIONS

7.1 Summary

The overall objective of the FGA RI for sites FTGL-02 through FTGL-04 was to determine the nature and extent of contamination due to past facility operations and use these results to develop and evaluate response action alternatives that address unacceptable risk and achieve site closure requirements. The TPP process was used by stakeholders at the start of the project to aid in determining specific site objectives, data needs, and DQOs in order to obtain the right type, quality, and quantity of RI data to collect to meet project objectives.

The specific project objectives identified for the three landfill sites (FTGL-02, -03, and -04) included the following:

- Delineate landfill waste extent (lateral and vertical) and location relative to groundwater;
- Characterize landfill surface soils;
- Characterize the potential release to perimeter/downgradient environmental media from landfill;
- Evaluate the potential vapor intrusion exposure pathway; and
- Evaluate human health and ecological risk.

Subsequent project objectives that were identified following the completion of the draft RI Report and agreed to by the Army and MDE in 2013 to address supplemental investigation needs included the following:

- Complete additional background assessment for metals and radionuclides in media at sites FTGL-02 through FTGL-04; and
- Complete additional human health risk assessment based on updated exposure parameters and factors, site-specific metals and radionuclide background levels, and RESRAD risk assessment methodology for radiological constituents.

Initial RI field characterization efforts at the three sites were completed between November 2010 and January 2012, and supplemental RI field investigations were completed between July and September 2014.

The remainder of this section summarizes the RI findings including the nature and extent of contamination by site, fate and transport of site contaminants, and human health and ecological risk due to site-related contaminants.

7.1.1 Nature and Extent of Contamination

7.1.1.1 FTGL-02: Ballfield/Helipad/Rubble Dump Site

FTGL-02 Landfill Delineation

Based on the cumulative RI and historical investigation results at FTGL-02, a revised landfill boundary was delineated for the site as illustrated in **Figure 4-1**. Starting from the former landfill boundary identified in the 2009 Forest Glen Installation Action Plan (U.S. Army, 2009), an interpreted landfill perimeter was initially identified based on EM anomalies and MASW survey results. Subsequent test pits, soil borings, and soil gas results were used to further adjust the lateral limits. Lastly, visual observation and assessment of site topography along the perimeter of the landfill was used to make final refinements in delineating the revised landfill boundary. Uncertainty exists in estimating the depth of landfill materials at FTGL-02 since intrusive activities into the landfill were not part of the RI scope of work. Based on the MASW survey, soil boring data, and historical topographic information, the maximum depth of landfill material present in the MASW traverse running along the northern limits of the landfill was estimated to be approximately 45 ft bgs. An estimated profile of landfill material at FTGL-02 is presented in the conceptual cross-section in **Figure 3-5**. As can be seen on this profile, landfill waste is anticipated to be mostly above the static groundwater elevation.

FTGL-02 Landfill Surface Soil Characterization

A total of 20 surface soil samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, metals, and/or radionuclides to characterize landfill surface soils and assess human health and ecological risk. The following summarizes the chemical exceedances (and number of samples) above screening criteria and background:

- Four PAHs, benzo(a)anthracene (2 samples), benzo(a)pyrene (17 samples), benzo(b)fluoranthene (5 samples), and dibenz(a,h)anthracene (3 samples), exceeded residential RSLs.
- One metal, cobalt (1 sample), exceeded the residential RSL.

As shown on **Figure 4-2**, PAH contamination (primarily benzo[a]pyrene) was present above residential screening levels at locations throughout the FTGL-02 landfill surface soils.

FTGL-02 Landfill Subsurface Soil Characterization

Not scoped under this RI.

FTGL-02 Landfill Perimeter Investigation

Surface Soils. A total of 26 surface soil samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, metals, and/or radionuclides to characterize surface soils outside the perimeter of the landfill and assess human health and ecological risk. The following summarizes the chemical exceedances (and number of samples) above screening criteria and background:

- Two PAHs, benzo(a)pyrene (17 samples) and benzo(b)fluoranthene (1 sample), exceeded residential RSLs.
- The dioxin 2,3,7,8-TCDD TEQ (4 samples) exceeded the residential RSL.
- One metal, cobalt (1 sample), exceeded the residential RSL.

Similar to FTGL-02 landfill surface soils, benzo(a)pyrene was present above residential screening levels in a majority of the perimeter surface soil samples surrounding the landfill. Three of the four 2,3,7,8-TCDD TEQ exceedances of the residential screening level in perimeter surface soils were present on the north side of the landfill (**Figure 4-2**).

Subsurface Soils. A total of 33 subsurface soil samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, metals, and/or radionuclides to characterize subsurface soils outside the perimeter of the landfill and assess human health and ecological risk. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Four PAHs, benzo(a)anthracene (2 samples), benzo(a)pyrene (6 samples), benzo(b)fluoranthene (2 samples), and dibenz(a,h)anthracene (2 samples), exceeded residential RSLs.
- One herbicide, MCPP (1 sample), exceeded the residential RSL.
- One PCB, Aroclor 1260 (2 samples), exceeded the residential RSL and/or the industrial RSL. Subsequent congener analysis of these samples identified PCB-126 (1 sample) above residential and industrial RSLs.
- The dioxin 2,3,7,8-TCDD TEQ (1 sample) exceeded the residential RSL.

The PAHs, MCPP, Aroclor-1260, and TCDD detections above screening exceedances in FTGL-02 landfill perimeter subsurface soils ranged in depth from 4 to 15 ft bgs, and all occurred east and northeast of the landfill where fill material (including C&DD) is present as documented in historical records and confirmed during RI geophysical survey, soil borings, and test pits (**Figure 4-3**).

Shallow Groundwater. A total of 23 groundwater samples were collected in 2011/2012 over two rounds of sampling and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, metals, and/or radionuclides to characterize shallow groundwater outside the perimeter of the landfill and assess human health and ecological risk. An additional round of sampling was also conducted in 2014 for metals and radionuclide analysis. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Six VOCs, 1,1,2-TCA (1 sample), 1,4-DCB (2 samples), benzene (2 samples), chloroform (7 samples), naphthalene (1 sample), and PCE (1 sample), exceeded tap water RSLs. PCE also exceeded the MCL.
- One SVOC, hexachlorobenzene (1 sample), exceeded the tap water RSL.
- Two pesticides, alpha BHC (1 sample) and delta BHC (1 sample), exceeded tap water RSLs.
- Two metals, arsenic (32 samples) and mercury (1 sample), exceeded the tap water RSLs and/or MCLs.

Chloroform was the most frequently detected VOC in FTGL-02 groundwater above tap water RSLs in monitoring wells north and south of the landfill. The remaining organic chemical exceedances were each only detected at one well including: PCE in monitoring well FG208 located within the landfill boundary; 1,4-DCB, benzene, and naphthalene in monitoring well FG302 located south of the landfill; 1,1,2-TCA in monitoring well FG301 located south of the landfill; hexachlorobenzene in monitoring well HODMW01 located within the landfill boundary; and pesticides alpha- and delta-BHC in monitoring well FG207 located south of the landfill (**Figure 4-4**). The widespread elevated arsenic concentrations may be attributed suspended sediments in the unfiltered samples and/or increased solubility and/or mobility of metals in the subsurface as the result of fill materials/wastes creating a more reducing state.

Bedrock Groundwater. A total of two groundwater samples were collected in 2011/2012 over two rounds of sampling from bedrock monitoring well FG401 and analyzed for VOCs, SVOCs, pesticides, herbicides,

PCBs, metals, and/or radionuclides to evaluate if contamination has migrated into bedrock groundwater. An additional round of sampling was also conducted in 2014 for metals and radionuclide analysis. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Two VOCs, 1,1,2-TCA (2 samples) and chloroform (1 sample), exceeded tap water RSLs.
- One pesticide, beta-BHC (1 sample), exceeded the tap water RSL.

The VOCs 1,1,2-TCA and chloroform detected at concentrations exceeding the tap water RSL in bedrock monitoring well FG401 were also elevated in the adjacent clustered shallow monitoring well FG301 (**Figure 4-4**).

Sediment. A total of 11 sediment samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, metals, and/or radionuclides to characterize sediments outside the perimeter of the landfill and assess human health and ecological risk. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- One VOC, carbon disulfide (3 samples), exceeded the BTAG benchmark.
- A total of 13 PAHs exceeded BTAG benchmarks. Five PAHs, benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-c,d)pyrene, exceeded the residential and/or industrial RSLs.
- Two pesticides, chlordane (1 sample) and p,p'-DDE (1 sample), exceeded BTAG benchmarks.
- The dioxin 2,3,7,8-TCDD TEQ (1 sample) exceeded the residential RSL.
- Five metals, total chromium (2 samples), copper (4 samples), manganese (9 samples), nickel (9 samples), and zinc (2 samples), exceeded BTAG benchmarks and/or RSLs.

PAH exceedances occurred at all sample locations in Streams C and D and at lesser concentrations in the stormwater retention pond; the highest PAH concentrations were in the most downstream sample 02-SE03 in Stream D. Manganese and nickel exceedances occurred at all sample locations in Streams C and D except for the most downstream samples 02-SE03. The chlordane and DDE pesticide exceedances occurred in the stormwater retention pond (**Figure 4-5**).

Surface Water. A total of eight surface water samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, metals, and/or radionuclides to characterize surface water outside the perimeter of the landfill and assess human health and ecological risk. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- One VOC, TCE (1 sample), exceeded the NRWQC for human health.
- One SVOC, DEHP (4 samples), exceeded the NRWQC for human health.
- One pesticide, beta BHC (2 samples), exceeded the NRWQC for human health.
- Three metals, arsenic (all 8 samples), iron (3 samples), and manganese (5 samples), exceeded NRWQC for aquatic life and/or human health.

The TCE exceedance was in the most upstream sample (02-SW09) in Stream D near the stormwater outlet pipe. Detections of VOCs, including PCE and degradation daughter products of TCE and cis-1,2-DCE, are

highest in sample 02-SW09 and generally decrease as you move downstream from this location. The source of these contaminants in Stream D is most likely from the upgradient chlorinated solvent contamination at site FTGL-03 discharging into to Stream D. DEHP is likely an artifact of the surface water sampling equipment. Similar to the VOC contamination, iron and manganese exceedances were highest in the most upstream Stream D samples and decreased as you move downstream. The Beta BHC exceedances only occurred in the downstream surface water samples. The widespread elevated arsenic concentrations in Stream D surface water may be attributed to suspended sediments in the stream samples and/or upgradient impacted groundwater discharging into Stream D (**Figure 4-6**).

7.1.1.2 FTGL-03: Commissary Landfill

FTGL-03 Landfill Delineation

Based on the cumulative RI and historical investigation results at FTGL-03, a revised landfill boundary was delineated for the site as illustrated in **Figure 4-7**. Starting from the former landfill boundary identified in the 2009 Forest Glen Installation Action Plan (U.S. Army, 2009), an interpreted landfill perimeter was initially identified based on EM anomalies and MASW survey results. Subsequent soil borings and soil gas results were used to further adjust the lateral limits. Lastly, visual observation and assessment of site topography along the perimeter of the landfill was used to make final refinements in delineating the revised landfill boundary. Uncertainty exists in estimating the depth of landfill materials at FTGL-03 since intrusive activities into the landfill were not part of the RI scope of work. Based on the MASW survey, soil boring data, and historical topographic information, the maximum depth of landfill material along the MASW traverses running north-south and east-west across landfill was estimated to be approximately 20 ft bgs. Estimated profiles of landfill material at FTGL-03 are presented in the conceptual cross-sections in **Figures 3-5 and 3-6**. As can be seen on these profiles, landfill waste is anticipated to be above the static groundwater elevation.

FTGL-03 Landfill Surface Soil Characterization

A total of 18 surface soil samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, metals, and/or radionuclides to characterize landfill surface soils and assess human health and ecological risk. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Five SVOCs, benzo(a)anthracene (4 samples), benzo(a)pyrene (17 samples), benzo(b)fluoranthene (9 samples), dibenz(a,h)anthracene (4 samples), and indeno(1,2,3-c,d)pyrene (2 samples), exceeded residential and/or industrial RSLs.
- The dioxin 2,3,7,8-TCDD TEQ (1 sample) exceeded the residential RSL.
- One metal, iron (1 sample), exceeded the residential RSL.

Similar to FTGL-02 landfill surface soils, PAH contamination detected above screening levels is located throughout the landfill surface soils at FTGL-03. However, more than just benzo(a)pyrene is prevalent and PAH concentrations are generally higher in the northeastern corner of the landfill. The single 2,3,7,8-TCDD exceedance was located in the southern portion of the landfill (**Figure 4-8**).

FTGL-03 Landfill Subsurface Soil Characterization

Not scoped under this RI.

FTGL-03 Landfill Perimeter Investigation

Surface Soils. A total of 27 surface soil samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, metals, and/or radionuclides to characterize surface soils outside the perimeter of the landfill and assess human health and ecological risk. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Five SVOCs, benzo(a)anthracene (6 samples), benzo(a)pyrene (26 samples), benzo(b)fluoranthene (8 samples), dibenz(a,h)anthracene (7 samples), and indeno(1,2,3-c,d)pyrene (6 samples), exceeded residential and/or industrial RSLs.
- One PCB, Aroclor 1260 (1 sample), exceeded the residential RSL. Subsequent congener analysis of this sample identified PCB-169 above the residential RSL.
- The dioxin 2,3,7,8-TCDD TEQ (4 samples) exceeded the residential RSL.

Similar to FTGL-03 landfill surface soils, benzo(a)pyrene was present above RSLs in almost all of the perimeter surface soil samples surrounding the landfill. The highest PAH concentrations were detected along the eastern boundary of the landfill. The single PCB exceedance occurred just outside the southwest perimeter of landfill. The four 2,3,7,8-TCDD exceedances were along the eastern boundary of the landfill (**Figure 4-8**).

Subsurface Soils. A total of 33 subsurface soil samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, metals, and/or radionuclides to characterize subsurface soils outside the perimeter of the landfill and assess human health and ecological risk. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Five SVOCs, benzo(a)anthracene (3 samples), benzo(a)pyrene (8 samples), benzo(b)fluoranthene (3 samples), dibenz(a,h)anthracene (4 samples), and indeno(1,2,3-c,d)pyrene (2 samples), exceeded residential and/or industrial RSLs.
- One metal, manganese (1 sample), exceeded the residential RSL.

PAH screening exceedances in FTGL-03 landfill perimeter subsurface soils ranged in depths from 4 to 20 ft bgs. The highest PAH concentrations were south and east of the landfill in areas of historic disturbances (**Figure 4-9**).

Shallow Groundwater. A total of 33 groundwater samples were collected in 2011/2012 over two rounds of sampling and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, metals, and/or radionuclides to characterize shallow groundwater outside the perimeter of the landfill and assess human health and ecological risk. An additional round of sampling was also conducted in 2014 for metals and radionuclide and radionuclide analysis. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Eight VOCs, 1,1,2-TCA (1 sample), bromodichloromethane (1 sample), carbon tetrachloride (3 samples), chloroform (5 samples), cis-1,2-DCE (1 sample), methylene chloride (1 sample), PCE (15 samples), and TCE (8 samples), exceeded tap water RSLs and/or MCLs.

- One SVOC, hexachloroethane (1 sample), exceeded the tap water RSLs.
- Four pesticides, beta chlordane (1 sample), delta BHC (1 sample), dieldrin (4 samples) and gamma BHC (1 sample), exceeded tap water RSLs.
- Four metals, aluminum (4 samples), arsenic (41 samples), beryllium (9 samples), and total chromium (1 sample), exceeded tap water RSLs and/or MCLs.

PCE and TCE were the most frequently detected VOCs above tap water RSLs and MCLs in monitoring wells located along the east side of the landfill. The highest PCE and TCE concentrations were in monitoring wells FG203 and FG213. PCE was detected as far west as monitoring well FG215, to the north at monitoring well FG220, and to the south at monitoring well FG216. The source of this contamination is unknown and may be from an offsite release. Chloroform exceedances occurred mostly in monitoring wells north of the landfill with the highest concentration north of Building 178. The pesticide dieldrin exceeded tap water RSLs in monitoring wells FG204 and FG205 located in the southwest corner of the landfill. Similar to FTGL-02, the widespread elevated arsenic concentrations may be attributed suspended sediments in unfiltered samples and/or increased solubility and/or mobility of metals in the subsurface as the result of fill materials/wastes creating a more reducing state (**Figure 4-10**).

Bedrock Groundwater. One groundwater sample was collected in 2011/2012 from bedrock monitoring well FG402 and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, metals, and/or radionuclides to evaluate if contamination has migrated into bedrock groundwater. An additional round of sampling was also conducted in 2014 for metals and radionuclide analysis. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Two VOCs, methylene chloride (1 sample) and PCE (1 sample), exceeded tap water RSLs and MCLs.

Similar to nearby shallow monitoring well FG213, bedrock monitoring well FG402 located on the east side of the landfill exceeded the tap water RSL and MCL for PCE. Methylene chloride, a common lab contaminant and a degradation daughter product of chloroform, was also detected in the FG402 sample (**Figure 4-10**).

FTGL-03 Vapor Intrusion Investigation

During the June 2011 VI sampling event, three VOCs, benzene, chloroform, and ethylbenzene, were detected at concentrations exceeding the factored residential and/or industrial air RSLs. No compounds exceeded the OSWER screening levels. During the December 2011 VI sampling event, three VOCs, 1,2-dichloroethane, chloroform, and ethylbenzene, were detected at concentrations exceeding the factored residential air RSL, but below the factored industrial air RSL and OSWER screening levels.

7.1.1.3 FTGL-04: Building 511 Landfill

FTGL-04 Landfill Delineation

Based on the cumulative RI and historical investigation results at FTGL-04, a revised landfill boundary was delineated for the site as illustrated in **Figure 4-11**. Starting from the former landfill boundary identified in the 2009 Forest Glen Installation Action Plan (U.S. Army, 2009), an interpreted landfill perimeter was initially identified based on MASW survey results. Subsequent soil boring and soil gas results were used to further adjust the lateral limits. Lastly, the limits were also modified based on soil boring results from the 1990

WRAIR Building 503 site characterization. Uncertainty exists in estimating the depth of landfill materials at FTGL-04 since intrusive activities into the landfill were not part of the RI scope of work. Based on the MASW survey, soil boring data, and historical topographic information, the maximum depth of landfill material along the MASW traverses running northwest to southeast across landfill was estimated to be approximately 20 ft bgs. The estimated profile of landfill material at FTGL-04 is presented in the conceptual cross-section in **Figure 3-6**. As can be seen on the profile, landfill waste is anticipated to be above the static groundwater elevation.

FTGL-04 Landfill Surface Soil Characterization

A total of ten surface soil samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, metals, and/or radionuclides to characterize landfill surface soils and assess human health and ecological risk. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- One SVOC, benzo(a)pyrene (8 samples), exceeded the residential RSL.
- Four pesticides, chlordane (1 sample), dieldrin (1sample), p,p'-DDE (1 sample), and p,p'-DDT (1 sample), exceeded residential and/or RSLs.
- The dioxin 2,3,7,8-TCDD TEQ (1 sample) exceeded the residential RSL.

Similar to FTGL-02 and FTGL-03, benzo(a)pyrene at concentrations exceeding the residential RSL is present throughout the landfill surface soils at FTGL-04. However, concentrations in general are lower at FTGL-04 compared to the other two sites. The four pesticides were detected in one sample located in the motor pool parking lot. The 2,3,7,8-TCDD exceedance occurred on the lawn of Building 511 (**Figure 4-12**).

FTGL-04 Landfill Subsurface Soil Characterization

Not scoped under this RI.

FTGL-04 Landfill Perimeter Investigation

Surface Soils. A total of 20 surface soil samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, metals, and/or radionuclides to characterize surface soils outside the perimeter of the landfill and assess human health and ecological risk. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Five SVOCs, benzo(a)anthracene (1 sample), benzo(a)pyrene (13 samples), benzo(b)fluoranthene (2 samples), dibenz(a,h)anthracene (3 samples), and indeno(1,2,3-c,d)pyrene (1 sample), exceeded residential and/or industrial RSLs.
- The dioxin 2,3,7,8-TCDD TEQ (2 samples) exceeded the residential RSL.

Similar to FTGL-04 landfill surface soils, benzo(a)pyrene was also present above RSLs in a majority of the perimeter surface soil samples surrounding the landfill. The highest PAH concentrations were detected in a sample collected from the northeast corner of the Building 511 parking lot. The two 2,3,7,8-TCDD exceedances occurred outside the southern perimeter of the landfill. (**Figure 4-12**).

Subsurface Soils. A total of 25 subsurface soil samples were collected and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, dioxins/furans, metals, and/or radionuclides to characterize subsurface soils

outside the perimeter of the landfill and assess human health and ecological risk. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Five SVOCs, benzo(a)anthracene (3 samples), benzo(a)pyrene (5 samples), benzo(b)fluoranthene (4 samples), dibenz(a,h)anthracene (3 samples), and indeno(1,2,3-c,d)pyrene (1 sample), exceeded residential and/or industrial RSLs.
- One pesticide, dieldrin (1 sample), exceeded the residential RSL.

All of the PAH screening exceedances in FTGL-04 perimeter subsurface soils occurred within the revised landfill boundary ranging in depths from 5 to 13 ft bgs. The highest PAH concentrations in a sample were from a soil boring located on the western edge of the Building 511 parking lot. The single dieldrin exceedance occurred within the motor pool area at a depth of 5 feet bgs (**Figure 4-13**).

Shallow Groundwater. A total of eight groundwater samples were collected in 2011/2012 over two rounds of sampling and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, metals, and/or radionuclides to characterize shallow groundwater outside the perimeter of the landfill and assess human health and ecological risk. An additional round of sampling was also conducted in 2014 for metals and radionuclide analysis. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Three VOCs, chloroform (6 samples), MTBE (2 samples), and TCE (2 samples), exceeded tap water RSLs.
- One pesticides, beta BHC (3 samples), exceeded the tap water RSL.
- Three metals, aluminum (2 samples), arsenic (10 samples), and lead (2 samples), exceeded tap water RSLs and/or MCLs.

The TCE and MTBE exceedances occurred in monitoring well FG308 north of the landfill. The TCE exceedance is most likely related to the chlorinated solvent contamination present in groundwater at FTGL-03. Chloroform exceedances occurred in all monitoring wells with the highest detected concentration north of the landfill. The pesticide beta BHC exceeded tap water RSL in monitoring wells FG201, FG202, and FG308 located west and north of the landfill. Similar to FTGL-02 and -03, the widespread elevated arsenic concentrations may be attributed suspended sediments in unfiltered samples and/or increased solubility and/or mobility of metals in the subsurface as the result of fill materials/wastes creating a more reducing state (**Figure 4-14**).

Bedrock Groundwater. A total of four groundwater samples were collected in 2011/2012 from bedrock monitoring wells FG403 and FG404 and analyzed for VOCs, SVOCs, pesticides, herbicides, PCBs, metals, and/or radionuclides to evaluate if contamination has migrated into bedrock groundwater. An additional round of sampling was also conducted in 2014 for metals and radionuclide analysis. The following summarizes chemical exceedances (and number of samples) above screening criteria and background:

- Two VOCs, chloroform (2 samples) and TCE (2 samples), exceeded tap water RSLs.
- One metal, arsenic (5 samples), exceeded the tap water RSL.

TCE exceeded the tap water RSL in bedrock monitoring well FG403 and was also exceeded in adjacent clustered shallow monitoring well FG308. Similar to FG308, the TCE exceedance FG403 is most likely

related to the chlorinated solvent contamination present in groundwater at FTGL-03. The elevated arsenic detections in bedrock groundwater are likely due the same reasons provided above for shallow groundwater exceedances (**Figure 4-14**).

Vapor Intrusion Investigation

During the June 2011 VI sampling event, concentrations of chloroform and ethylbenzene in soil gas samples were detected at concentrations exceeding the factored Residential Air RSL in Buildings 503 and 511. Detected concentrations of chloroform also exceeded the factored Industrial Air RSL and OSWER screening levels. During the December follow-on 2011 VI sampling event, chloroform, ethylbenzene, and TCE were detected at concentrations exceeding the factored Residential Air RSL and/or the OSWER screening levels. Detected concentrations of chloroform also exceeded the factored Industrial Air RSL.

Based on the results of the RI sub-slab vapor samples, the USAPHC collected IAQ samples in Building 503 and Building 511 to evaluate the exposure of workers to potentially hazardous concentrations of site contaminants via subsurface vapor intrusion. Two indoor air samples were collected at Building 503, and one indoor air sample was collected at Building 511. The indoor air samples were analyzed for VOCs using a modified OSHA PV2120/USEPA TO15 method. An additional five samples from Building 503 and four samples from Building 511 were collected and analyzed using a charcoal adsorption method, including analysis of chloroform (NIOSH Method 1003), ethylbenzene, and xylenes (NIOSH Method 1501).

At Building 503, isopropyl alcohol, acetone, and toluene were the only VOCs detected in the two indoor air samples. All other VOCs were not detected above their level of quantitation LOQ. At Building 511, isopropyl alcohol and acetone were the only VOCs detected in the two indoor air samples; all other VOCs were not detected above their LOQ.

As discussed above, chloroform was detected above its screening level in the sub-slab vapor samples collected during the RI at Buildings 503 and 511. Chlorform was not detected in the indoor air samples collected via USEPA Method TO-15. An LOQ of 1 ppbv (4.8 µg/m^3) was achieved for chloroform via USEPA Method TO-15. This LOQ exceeds its cancer RSL of 0.53 µg/m^3 based on the target risk level of 1E-06, but is less than its cancer RSL of 5.3 µg/m^3 based on a target risk level of 1E-05.

7.1.2 Fate and Transport

7.1.2.1 Volatile Organic Compounds

Two groundwater PCE plumes, primary and secondary, are present in shallow groundwater on the eastern and northern sides of FTGL-03, respectively. The source(s) of these two plumes have not been determined or fully delineated at this time and may be migrating onsite from an upgradient and off-site source. The primary plume with the highest detected concentrations of PCE appears to be migrating south to the former drainage feature (since filled in) that once was the headwaters of Stream D. This drainage is then believed to influence the plume movement to the west with some potential discharge to Stream D based on chlorinated solvent detections in the most northern monitoring wells at FTGL-04 and Stream D surface waters. The plume is believed to be directly influenced by the topographic expression of the site, the weathering profile of the subsurface soils and saprolite, the structural conditions (e.g., bedding orientation, fractures, faults and foliation) that are present in the underlying saprolite and fractured bedrock, and underground man-made structures (e.g., utilities such as sewer pipes). Additionally, some degradation of

plume is apparent through natural attenuation processes based on the presence of PCE daughter products (i.e., TCE, 1,2-DCE) in groundwater samples.

Chloroform was observed in shallow and deep groundwater during the RI. Additionally, chloroform was identified in sub-slab vapor during the VI survey. Chloroform tends to partition mainly into the atmosphere and groundwater, and can be relatively persistent. When released to the atmosphere, chloroform exists in the vapor phase and can be transported long distances. Chloroform may be removed from the atmosphere by wet deposition; however, it is likely to reenter by volatilization. When released to groundwater, chloroform dissolves easily in water and is expected to persist for a long time.

7.1.2.2 Semi-Volatile Organic Compounds

Elevated PAH (primarily benzo(a)pyrene) detections have been identified throughout most of the FGA sites. Their presence in surface soils and sediment is consistent with their generally slow environmental degradation. PAHs are persistent and generally immobile in soil matrices under normal environmental conditions. The PAHs tend to bioaccumulate because they are non-polar. In surface water, PAHs tend to sorb to particles that either have settled to the bottom or are suspended in the water column. Generally, groundwater sample results at the sites indicate that PAHs observed in surface and subsurface soils are not mobile in the groundwater aquifer.

The phthalate ester DEHP was identified as a contaminant at FGA in surface waters at FTGL-02 and FTGL-05. Phthalate esters are used as plasticizers in plastics and surface coating materials (i.e., paint, etc.) and tend to be ubiquitous in the environment. Additionally, phthalate esters are, because of their presence in plastics (e.g., sampling tubing), a common laboratory contaminant. DEHP detections were not widespread and were not consistently detected during each sample event that would suggest that this is likely an artifact of surface water sampling equipment that contains plastics and not an indicator of contamination.

7.1.2.3 Pesticides

Isolated and/or sporadic detections of pesticides and degradation by-products (e.g., alpha-BHC, delta-BHC, gamma-BHC, beta-chlordane, and dieldrin) at the FGA sites do not appear to be significant contaminant sources indicative of waste disposal but rather typical of low level contamination associated with its intended uses. Pesticides are generally persistent in the environment, primarily due to their resistance to degradation, low aqueous solubility and volatility, ability to substantially bioaccumulate in aquatic organisms (except for aldrin and BHC isomers), and very high adsorptive affinity for soils and organic matter.

7.1.2.4 Polychlorinated Biphenyls

Environmental behavioral characteristics of PCBs are similar to those described above for pesticides, but the sources and uses of PCBs are quite different. Due to their non-flammability, chemical stability, high boiling point, and electrical insulating properties, PCBs were used in hundreds of industrial and commercial applications. PCB compounds are very persistent in soil. These compounds demonstrate strong adsorption to soil and sediment media indicating that significant leaching to groundwater should not occur. PCB compounds may leach into the groundwater when combined with organic solvents, which demonstrate significant leaching capabilities. Adsorption of PCB compounds is elevated by increased organic, clay, and

microparticle content of the soil or sediment. Biodegradation can occur under both aerobic and anaerobic conditions, but only at a slow rate. No chemical process is known to degrade PCB compounds in soil. The persistence of elevated PCB levels in the subsurface soil at FTGL-02 and in the surface soil at FTGL-03 is consistent with the strong adsorptive affinities of PCBs for soils. The lower concentration of PCBs detected in the sediment at FTGL-02 are also expected to be persistent in the environment and may become mobilized from the sediment during erosional processes related to storm events.

7.1.2.5 Dioxins

Sporadic elevated detections of dioxins have been identified primarily in landfill surface soils. Dioxin are highly persistent in the environment similar to PCBs. Dioxin is an unintentional by-product of many industrial processes. The major source of dioxin in the environment comes from waste-burning incinerators where burning chlorine-based chemical compounds with hydrocarbons forms dioxins. Dioxins are hydrophobic (water-fearing). Because these compounds are poorly soluble in water they have not been found to be a groundwater problem in the environment. These compounds are soluble in fats (e.g., lipophilic [fat-loving] and eventually work their way to the top of the food chain through storage in fat cells by bioaccumulation. Neither soil microbes nor animals are able to effectively break down the dioxins quickly. These compounds are expected to remain persistent in the environment.

7.1.2.6 Metals

In general, metals have a high adsorptive affinity for inorganic mineral surfaces, such as iron and manganese oxides, iron hydroxides, clays, and organic matter. Adsorption, for most metals, is highly pH-dependent, with desorption generally favored for positively charged metal ions at low pH and sorption mechanisms dominating for positively charged metal ions at higher pH conditions. Additionally, chemical speciation determines the relative degree of adsorption among different species of a particular metal. Based on data available for site soils, sorption is a significant fate process for metals. Aerobic conditions in site surface water and shallow groundwater are likely to promote the precipitation of ferromanganese oxides and oxyhydroxides to which other metals will readily adsorb.

The metals identified in FGA media are persistent and of limited mobility within these media under normal environmental conditions. Their persistence is primarily related to cycling and removal mechanisms. Cycling mechanisms involve mineral precipitation/dissolution under fluctuating oxidizing and reducing conditions, such as may occur in the zone of water table fluctuation in an unconfined or semiconfined shallow aquifer with organic content. Removal mechanisms include processes such as mineral precipitation, adsorption, and organic anion complexation, which decrease mobility. Chemical speciation of metals in the environment results in their presence in both solid and aqueous media. However, geochemical conditions occurring near contaminant sources at the site may affect the fate reactions and behavior of these metals, resulting in increased or decreased metal concentrations in a particular medium. Overall the groundwater chemistry data suggest that slightly to strongly reducing conditions have developed in areas downgradient and surrounding the landfills which would tend to increase the solubility and/or mobility of some total or dissolved metals in the subsurface.

7.1.3 Risk Assessment

7.1.3.1 Human Health Risk Assessment

A full summary of BHHRA results for the FGA sites without considering background as well as after removing COPCs within background was previously summarized in Section 6. The following **Table 7-1** presents a summary of the site-related human health risks/hazards for receptor pathways with total cancer risk above the target risk level of 1E-04 and/or a total HI above the benchmark level of concern of 1. Also, provided in the table are the individual site-related COPC risk drivers that contributed significantly to these total risks/hazards.

As summarized in **Table 7-1**, the estimated risks and hazards for the future construction worker receptor exceed the target risk level and/or noncarcinogenic benchmark level of concern. For future construction workers at the landfill sites FTGL-02, -03, and -04, contaminants that were significant drivers of risk include:

- Manganese in surface and subsurface soils at all 3 sites; and
- PCE in shallow groundwater at FTGL-02 and PCE, TCE, and1,1,2-TCA in shallow groundwater at FTGL-03.

Details on the location and extent of the above contaminants in site media can be found in the Section 4 and the **Appendix W** screening tables.

Table 7-1. Receptor Pathways with Site Related Risk >1E-04 and/or HI >1

Receptors	Carcinogenic Risk	Non-carcinogenic Total HI (Endpoint HI)	Risk Driver (Media)
FTGL-02			
Future Construction Workers – Surface Soil Scenario	NE	2.2 (neurological effects 1.5)	Manganese[1] (*Surface Soil*)
Future Construction Workers – Excavation Scenario	NE	3.7 (neurological effects1.6)	Manganese[1] (*Surface & Subsurface Soil*) PCE (*Groundwater*)
FTLG-03			
Future Construction Workers – Surface Soil Scenario	NE	2.4 (neurological effects1.6)	Manganese[1] (*Surface Soil*)
Future Construction Workers – Excavation Scenario	NE	31 (neurological effects19 Nasal 1.4 Thymus 9.1 Reproductive 9.2)	Manganese[1] (*Surface & Subsurface Soil*) PCE/TCE/1,1,2-TCA (*Groundwater*)
FTGL-04			
Future Construction Workers – Surface Soil Scenario	NE	2.2 (neurological effects1.6)	Manganese[1] (*Surface Soil*)
Future Construction Workers – Excavation Scenario	NE	2.0 (neurological effects1.4)	Manganese[1] (*Surface & Subsurface Soil*)

[1] Manganese was identified as HI risk drivers; however, assuming routine dust suppression is implemented during construction operations, this metal is not considered contaminants of concern requiring further action in the subsequent FS.

NE: threshold of cumulative cancer risk exceeding 1E-04 or total endpoint HI greater than 1 was not exceeded for receptor.
NA: not available

7.1.3.2 Ecological Risk Assessment

As discussed in the summary of the SERA in Section 6.2, no significant risk of adverse effects to ecological receptors has been identified at FGA sites FTGL-02 through FTGL-04.

7.2 Conclusions

This section presents key conclusions concerning site and media investigation activities, data limitations and recommendations for future work, and preliminary RAOs that will be used in the development of response action alternatives to address unacceptable risk or closure requirements associated with sites.

7.2.1 Landfill Delineation at Sites FTGL-02, FTGL-03, and FTGL-04

As summarized above for FGA landfill sites FTGL-02, -03 and -04, the objective of delineating the landfills at this RI stage of the CERCLA process has been achieved. As presented on **Figures 4-1, 4-7, and 4-11**, revised landfill boundaries illustrating the estimated lateral extent of the landfill material at Sites FTGL-02, -03, and -04 have been completed based on geophysical survey, intrusive landfill perimeter investigation, and historical site data and observations. Uncertainty exists in estimating the depth of landfill materials at the sites since intrusive activities into the landfill were not part of the RI scope of work. The estimated profile of landfill material at the three landfill sites is presented on conceptual cross-sections in **Figure 3-5** and **Figure 3-6**.

7.2.2 Soils at Sites FTGL-02 through FTGL-04

As discussed in this report, soils at the FGA sites have been significantly disturbed over the past 70 years as part of installation operations and development. Soils have been cut and filled across the installation during development activities, and construction and waste materials have been used to fill low-lying areas and valleys.

The most significant contamination encountered in soils at the FGA sites was PAHs. PAH contamination was consistently encountered in surface soils across each of the three landfills (FTGL-02, -03, and -04) and their surrounding perimeters. Potential sources of PAHs include oil based products including asphalt pavement, and byproducts of burning of wood and fossil fuels. Benzo(a)pyrene was the most frequently detected PAH at the sites. PAHs were also detected in subsurface soils around the landfill perimeters; however, only in areas where disturbed soils/fill activities were encountered. PAH contamination in surface soils was most prevalent and at the highest concentrations at FTGL-03 followed by FTGL-04. As previously indicated in **Table 7-1**, PAHs in surface soil were identified as risk drivers for elevated total risk at these two sites. The highest site concentrations were found in samples in the northeast portion of the FTGL-03 landfill and in perimeter samples collected along its eastern boundary. Subsurface concentrations were also the highest at FTGL-03 relative to the other sites but much more limited to disturbed areas as compared to their widespread presence in surface soils.

In addition to PAHs, more limited contamination associated with metals, dioxins/furans, PCBs, and pesticides was encountered in site soils. Cobalt, iron, and manganese were detected at elevated concentrations in surface and/or subsurface soils at isolated locations. As previously indicated in **Table 7-1**, manganese in soil was identified as a risk driver for elevated total risk at all of the sites. Dioxin contamination (TCDD) was found sporadically in surface soils at FTGL-02, and -04; however, at FTGL-03 dioxin detections were concentrated along the eastern boundary of the landfill and at higher concentrations where it was identified as a risk driver. These boundary detections may be from possible past use of herbicides along the fence line. In perimeter subsurface soils, only isolated dioxin exceedance occurred. PCB and pesticide contamination in soils was also very isolated with few elevated detections in surface and subsurface soils. Dieldrin in surface soils at FTGL-04 was the only pesticide identified as a risk driver. Isolated and/or sporadic detections of pesticides and degradation by-products (e.g., alpha-BHC, delta-BHC, gamma-BHC, beta-chlordane, and dieldrin) across the site do not appear to be significant contaminant sources indicative of waste disposal but rather typical of low level contamination associated with its intended use as pesticide.

7.2.3 Groundwater at Sites FTGL-02 through FTGL-04

The most significant contamination in groundwater encountered at the FGA sites was chlorinated solvents along the eastern FGA property boundary. A primary PCE plume, with a maximum detected concentration of 4,000 µg/L at monitoring well FG213, was identified along the eastern boundary of FTGL-03. This plume extends south along the eastern boundary of the landfill with decreasing concentrations of 880 µg/L at FG203 and 91 µg/L at FG216. Since monitoring wells have not been installed further west within the landfill a complete understanding of the plume boundary onsite is not known. PCE degradation products including TCE and cis-1-2-DCE were also detected within the eastern boundary wells indicating some natural degradation of PCE is occurring. The data suggests the PCE plume is migrating downgradient (south) along preferred pathways (fractures or foliation) toward the former headwaters of the Stream D drainage that was historically filled during facility development. This contamination is then being redirected westward along the former drainage past shallow and deep clustered monitoring wells 04-FG308 and 04-FG403 where elevated TCE concentrations were detected. Further west low level concentrations of PCE (3.4 µg/L and 1.1 µg/L) were detected in the two upstream surface water samples 02-SW09 and 02-SW08 which would indicate that the plume may have infiltrated the buried storm sewer piping or annulus and is discharging into the surface waters of Stream D. An elevated PCE concentration of 2,600 µg/L was also detected in the bedrock monitoring well FG402 located near upgradient monitoring well FG213 further confirming that deeper groundwater has been impacted by this release.

In addition to the primary plume, much lower concentrations of PCE were detected in a secondary VOC plume located to the north of FTGL-03 represented by monitoring wells FG214 (70 µg/L), FG303 (110 µg/L), FG220 (32 µg/L), and FG215 (11 µg/L). This plume is believed to be influenced by a topographic high near Linden Lane that may be the dividing line for the primary and secondary plumes, and appears to be influenced by the Stream A drainage running to the northwest.

The source(s) of the two PCE plumes identified at FTGL-03 is uncertain. There may be one source migrating onsite from an upgradient and off-site location, or multiple sources may be present. Given the limited knowledge concerning the plume source, and the limited rounds of groundwater samples that have been collected to date, it is difficult to conclude if the plumes are increasing or decreasing in concentration or moving. In looking at PCE concentrations in monitoring well FG213 over time, concentrations have generally decreased over the four sampling events conducted to date from a high concentration of 13,000 µg/L during the 2005 Expanded Site Inspection to 4,000 µg/L during the most recent RI sampling. Neighboring downgradient monitoring well FG203 has shown a general increase in the concentration of PCE from a low concentration of 54 µg/L during the 2008 Sitewide Groundwater Monitoring investigation to 880 µg/L during the most recent RI sampling. These data points suggest that the primary plume may be moving but additional data is needed to confirm this assessment. Sufficient investigation coverage as well as rounds of data are not available for an assessment of the status of the secondary plume. As previously indicated in **Table 7-1**, PCE and TCE in groundwater were identified as risk drivers for elevated total risk at FTGL-03.

The last area of PCE detection at FGA was at FTGL-02 in one monitoring well (FG208) historically installed within the landfill boundary. PCE was not detected historically in this well or during the first round of RI groundwater sampling; however, it was detected during the second round of RI sampling at a concentration of 12 µg/L. As previously indicated in **Table 7-1**, PCE in groundwater was identified as a risk driver for elevated total risk at FTGL-02.

In addition to the PCE, chloroform was a significant contaminant given that there were multiple elevated detections in groundwater at all of the sites. The detected concentrations exceeded tap water RSLs but were below the MCLG. The source of chloroform in the groundwater may potentially be due to the degradation of carbon tetrachloride present in groundwater, from historical disposal of lab wastes, or from an offsite source. Isolated detections of carbon tetrachloride were found along the northeast portion of the FTGL-03 landfill near Linden Lane, and methylene chloride, a degradation product of chloroform, was also detected in groundwater in this area.

Metals detected in the groundwater above screening criteria and background included aluminum, arsenic, beryllium, and lead. Of these metals, arsenic was by far the most prevalent at all sites. The elevated arsenic concentrations throughout the sites may be attributed suspended sediments in the unfiltered samples and/or increased solubility and/or mobility of metals in the subsurface as the result of fill materials/wastes altering the natural redox conditions of the aquifer matrix towards a more reducing state. None of the metals detected in groundwater were identified as risk drivers for the receptors/pathways evaluated in the risk assessment.

7.2.4 Surface Water and Sediment at Sites FTGL-02 through FTGL-04

A broad range of contaminants including PAHs, metals, pesticides, and dioxins were detected in FTGL-02 sediments. The predominant contaminant in sediments at both sites was PAHs. PAH contamination was present in all samples collected from FTGL-02 Stream C, Steam D, and at lesser concentrations in the stormwater retention pond. At FTGL-02, metals including nickel and manganese were elevated in a majority of the samples. These elevated levels in Stream D may be due to the influence of the upgradient landfills potentially mobilizing these metals in groundwater and ultimately discharging to and depositing in Stream D. Lastly, isolated exceedances of pesticides and dioxin occurred in the FTGL-02 stormwater retention pond. None of the above contaminants detected in sediment were identified as risk drivers for the receptors/pathways evaluated in the risk assessment.

Similar to FTGL-02 sediments, a broad range of contaminants were detected in surface water at FTGL-02 including TCE, metals, DEHP, and pesticides. Elevated TCE was detected in the most upstream surface water sample in FTGL-02 Stream D near the stormwater outlet pipes and is likely from the primary PCE groundwater plume in FTGL-03 discharging to the stream (See Section 7.2.3). Consistent with iron staining observed at the stormwater outlet pipes, iron and manganese exceedances were also highest in the most upstream Stream D samples and decrease in concentration moving downstream. Arsenic was detected at elevated concentrations in all surface water samples at Stream D. These elevated concentrations may be attributed to discharge from upgradient groundwater shown also to have elevated concentrations (See Section 7.2.3). DEHP was elevated in four samples in FTGL-02 and is likely an artifact of the surface water sampling equipment. Only one pesticide was detected at elevated concentrations in two surface water sample locations at Stream D. None of the above contaminants detected in surface water were identified as risk drivers for the receptors/pathways evaluated in the risk assessment.

7.2.5 Data Limitations and Recommendations for Future Work

As documented in this RI, investigations completed at the three landfill sites (FTGL-02, -03, and -04) achieved investigation objectives including the identification of site contaminants and associated risks. The RI for landfill sites FTGL-02, -03, and -04 was planned and completed based on the assumption that a

presumptive remedy of containment would be implemented as the future remedy at these sites. Additionally, risk assessment findings identified site-related compounds (or constituents) contributing to hazards above the noncarcinogenic benchmark HI of 1 for the construction worker at all three sites. The cumulative cancer risk estimates for all receptor groups and sites are within or below USEPA's acceptable cancer risk range (1E-06 to 1E-04). This risk was driven by chlorinated solvent and metals contamination in surface soil, subsurface soil, and/or groundwater. Based on these investigation findings, further assessment of both cover/capping as a remedy for the landfills and contaminated media above acceptable risk levels is recommended as part of a feasibility study analysis to develop remedies that are protective of human health and the environment at these sites.

Even with achieving investigation objectives, the following data needs and recommendations for additional investigation work at FGA has been identified:

- The source of the primary and secondary chlorinated solvent plumes identified during FTGL-03 investigations has not been identified onsite. The chlorinated solvent contamination detected in groundwater along the eastern boundary of the site may be from an offsite source. A coordinated investigation with MDE to identify and assess potential offsite sources through records review, interviews, and sampling is recommended.
- The nature and extent of chlorinated solvent contamination in deep groundwater identified during FTGL-03 investigations has not been defined. Although not an objective of this RI, defining this deep contamination is important to the design of a future groundwater remedy for the site. Therefore, additional investigation to define the nature and extent of chlorinated solvent contamination in deep groundwater is recommended.
- The secondary chlorinated solvent plume located north of FTGL-03 has not been fully characterized including its source that may be located offsite and the same as the primary plume. This plume appears to be influenced by the topographic high dividing the site near Linden Lane and the Stream A drainage running to the northwest. Therefore, additional investigation to further define the nature and extent of contamination in this area is recommended.

The results of these additional recommended investigations would be used by the Army in feasibility study analysis for groundwater remedy development if contamination is determined to be site related.

7.2.6 Recommended Remedial Action Objectives

Based on the results of the RI, the following preliminary RAOs were developed for discussion and use in subsequent feasibility study analysis addressing FGA sites FTGL-02 through FTGL-04.

For landfill sites FTGL-02, -03, and-04, proposed preliminary RAOs include:

- Prevent human and ecological exposure to uncharacterized landfill waste;
- Prevent human (resident and construction worker) exposure to landfill surface and perimeter contamination above acceptable risk thresholds;
- Prevent or minimize the downgradient migration of landfill waste/contaminants for the protection of local groundwater and stream resources;
- Restrict land use to commercial/industrial or recreational activities only; and

- Restrict the use of groundwater to limit exposure.

These objectives will likely be achieved through containment, removal of contaminants to an acceptable level and/or implementation of land use controls to eliminate or limit exposure. The above preliminary RAOs for the three sites will be refined and finalized as part the feasibility study assessment for these sites.