FINAL

GROUNDWATER INVESTIGATION TECHNICAL MEMORANDUM GROUNDWATER OPERABLE UNIT OU2

Middlesex Sampling Plant Middlesex, New Jersey

Prepared for

United States Army Corps of Engineers New York and Kansas City Districts

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Completion of Independent Technical Review

Project: Middlesex Sampling Plant FUSRAP Site Deliverable: Final Groundwater Investigation Technical Memorandum **Revision and Date:** 08/18/17

Ecology and Environment, Inc. has completed the above referenced deliverable. Notice is hereby given that an independent technical review, that is appropriate to the level of risk and complexity inherent in the project, has been conducted as defined in the Contractor Quality Control Plan. During the independent technical review, compliance with established policy principles and procedures, utilizing justified and valid assumptions, was verified. This included review of: assumptions; methods, procedures, and material used in analyses; alternatives evaluated; the appropriateness of data used and level obtained; and reasonableness of the result, including whether the product meets the customer's needs consistent with law and existing USACE policy. The independent technical reviewers confirmed that all comments were responded to and the changes made in the documents as stated. The independent technical review was accomplished by following signatories. All comments resulting from ITR have been resolved.

Independent Technical Review Team Leader/Project Manager

Date: 08/18/17

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Program Manager

As noted above, all concerns resulting from independent technical review of the project have been considered.

Jacquelyn C Hillings Quality Control Manager

Date: 08/18/17

The Middlesex Sampling Plant Site (MSP) located in Middlesex, New Jersey, was used primarily for sampling, analysis, storage and shipment of uranium, thorium and beryllium ores under contract with the United States Atomic Energy Commission (AEC) and the Manhattan Engineering District. In 1967, AEC terminated site activities and decontaminated on-site structures to meet criteria that were in effect at the time. In 1980, control of the property was transferred to the United States Department of Energy (USDOE), which began to remediate MSP vicinity properties (VPs) and the Middlesex Municipal Landfill (MML) under the Formerly Utilized Sites Remedial Action Program (FUSRAP). Responsibility for execution of response actions on sites included in FUSRAP was transferred from USDOE to the United States Army Corps of Engineers (USACE) in 1997, and long term programmatic authority was specifically provided to USACE in 1999. The MSP site was added to the National Priorities List (NPL) in the Federal Facilities Section in 1999.

This document is the *Groundwater Investigation Technical Memorandum* (GWITM), which summarizes the installation, logging and testing activities/results for new bedrock monitoring wells (MWs) and overburden wells; the monitoring results from 16 sampling events conducted from August 2008 to January 2016; an evaluation of possible volatile organic compound (VOC) contaminant sources; the fate and transport of VOC contaminants; and an assessment of the monitored natural attenuation (MNA) characteristics of the contaminants and subsurface environment.

Remedial investigations of soil and groundwater at the MSP site were conducted for two Operable Units (OUs) by the USACE from 1999 through 2005. OU-1 was established for soil and OU-2 was established for groundwater. During 2006 and 2007, the OU-1 remedial action (RA) removed radioactive and non-radioactive soil and debris contamination from the MSP property. The Soils OU-1 RA was completed and accepted by the US Environmental Protection Agency (EPA) in 2010. A Final Remedial Investigation Report for Groundwater OU-2, prepared by the USACE in 2005, established the initial characterization of VOC contamination in bedrock.

This GWITM documents the results of additional groundwater investigations for OU-2 from 2008 to 2016, conducted after the Soils OU-1 RA was completed, and will serve as an addendum to the 2005 Groundwater Remedial Investigation report. The investigations were specifically designed to: establish an adequate monitoring well network for both the overburden and bedrock; characterize and monitor the residual radionuclide impact to groundwater; further define the extent of VOC contamination in the bedrock groundwater, and evaluate the potential for MNA. This was accomplished through a program of temporary test hole installation and testing, monitoring well installation, sampling, analysis, and reporting.

Pre-OU-1 RA shallow groundwater MWs were abandoned during the Soils OU-1 RA. The network of shallow MWs was replaced in 2008, following the Soils OU-1 RA, backfill, and site restoration.

A shallow MW network has been used for water level measurements and groundwater sample collection from August 2008 to February 2013. Groundwater samples from the shallow MWs were analyzed for total uranium and specific parameters associated with natural attenuation of total uranium. Bedrock MWs installed prior to and after the OU-1 RA also have been used for water level measurements and groundwater sample collection from August 2008 to February 2013.

The data collected from the shallow MW network through 2009 did not provide adequate information on the sources and the extent of VOC contaminants that were detected in three of the shallow bedrock MWs (URS-MW-2D, URS-MW-22D, and URS-MW-24D) within the northern portion of the MSP site. Additional bedrock groundwater investigation activities were initiated in early 2010. These activities were designed to re-assess the bedrock as a leaky multi-unit aquifer, by investigating zones of relatively higher transmissivity along bedding planes and fractures that influence the fate and transport of contaminants.

From 2010 to 2013, a total of 20 bedrock MWs were installed to better define the bedrock hydrostratigraphy beneath the MSP site; to delineate the VOC contaminant plumes; to identify sources of the VOC contaminants, and to determine the fate and transport of VOC contaminants. All sampling activities were performed in accordance with the *Field Sampling Plan* (FSP) *and Quality Assurance Project Plan* (QAPP) *of the Overburden Monitoring Well Installation*, (USACE, 2008b).

Groundwater samples were collected from overburden (OB) MWs and bedrock MWs during sampling events between August 2008 and February 2013. Samples from the overburden wells were analyzed for total uranium. Samples from the bedrock wells were analyzed for VOCs. Carbon tetrachloride (CT), chloroform (CF), tetrachloroethylene (PCE), trichloroethylene (TCE), and 1,1-dichloroethene (1,1-DCE) are VOCs that were detected at concentrations above the EPA Maximum Contaminant Level (MCL) and/or the New Jersey Department of Environmental Protection (NJDEP) Specific Ground Water Quality Criteria (SGWQC) for Class IIA aquifers (groundwater used for potable water supply) and are the focus of this report (NJDEP 2010). Based on the VOC analytical results from the 54-foot-deep bedrock well ECC-MW-30B, an onsite source of CT and CF, and possibly TCE, existed in the vicinity of ECC-MW-30B. VOC analytical results also showed that high concentrations for all five VOCs occurred in bedrock MWs (ECC-MW-24B, URS-MW-24D, ECC-MW-25C, and ECC-MW-25D) that are either upgradient or side-gradient relative to the groundwater flow paths within the three bedrock aquifer units (Unit B, Unit C and Unit D) identified at the MSP site. Therefore, the sources for

some of the VOC contamination were interpreted to be off-site. At least one nearby property with known VOC contamination present in groundwater was identified as a potential source for the VOC contaminants detected on the MSP property.

The groundwater investigation provided a much better understanding of site contaminant distribution (likely attributable to on-site and off-site sources), and a general characterization of the contaminant impact on-site and off-site. The analytical results from the sampling events (SE) 13 and SE 14 showed a vertical and horizontal distribution of the VOCs that supported a probable on-site source of TCE and CT, with possible contributions of TCE and other VOCs from off-site locations. The downgradient extent of CT was delineated by extrapolation of data from ECC-MW-35B and ECC-MW-35C. However, a definitive delineation of off-site contamination (plume bounded by VOC results below the cleanup criteria) was not completed.

Since an evaluation of MNA parameters from August 2008 (SE 1) to February 2013 (SE 14) indicated that reductive dechlorination of VOCs in the bedrock does not occur naturally at the site, continued collection and evaluation of MNA parameters was not warranted.

From August 2014 through October 2014, and from September 2015 through January 2016, additional data gathering field programs were conducted which included installing a total of 10 bedrock MWs. Additional investigations of groundwater were completed to verify/further delineate both the potential source area and downgradient off-site impacts from VOCs.

Concentrations of CT and TCE in monitoring wells have remained somewhat stable over the course of the sampling history with two exceptions, the ECC-MW-30B and the EE-MW-41S bedrock wells. The significant reduction of CT and TCE concentrations seen in these on-site wells indicate that the initial elevated concentrations of these contaminants may have been a secondary effect of drilling through minor residual contaminants in the unsaturated portion of the weathered bedrock, beneath the limits of the remedial excavation of site soils (OU-1 remedial action). Thus, groundwater screening samples and monitoring well samples collected from Unit B and the top of bedrock aquifer (shallow bedrock wells) indicate that residual materials may be contained in the unsaturated portion of the weathered bedrock but are limited to a small area on the northcentral portion of the site around ECC-MW-30B, EE-MW-41S, and the former sump of the Process Building. This sump was used for disposal of wastewater and could have been used for disposal of non-water residuals although site records do not indicate the use of solvents as part of site operations. This sump was 12 feet long, by 6 feet wide, by 10 feet deep and had a feeder line leading from it to the main pipe chase line. Records indicated that the sump was open and in communication with groundwater (overburden). The bottom of the sump would have been near the interface of the overburden groundwater unit and on top of the unsaturated weathered bedrock providing a migration pathway directly to the bedrock aquifer. Residuals disposed of at this depth would have spread downward and outward from this point along

fractures and partings within the unsaturated bedrock before reaching the water table. CT and TCE were not detected in groundwater samples collected from the overburden wells or overburden screening samples during the most recent sampling events SE 15 and SE 16.

CT and TCE have had the most impact on groundwater in the Unit B bedding plane. The monitoring well network (on-site and off-site) has delineated the extent of CT and site-related TCE migration in the most highly contaminated bedding plane/fracture zone (Unit B) portion of the bedrock aquifer and is deemed sufficient to proceed with the completion of a feasibility study (FS).

Total uranium groundwater results from the last 16 sampling events show that the OU-1 (soil) RA has improved MSP groundwater quality. Although total uranium has been detected in all overburden wells since completion of the OU-1 RA, the concentrations have been consistently below the MCL, with sporadic occurrences above the MCL at four wells (MW-OB-7, MW-OB-8, MW-OB-10, and MW-OB-12). However, total uranium results have been below the MCL during the last two sampling events (SE 15 and SE 16). The lack of total uranium in the overburden groundwater samples confirms no sources of uranium contaminants in the overburden, which was expected as the result of the removal of on-site soils during the OU-1 remedial action.

ES.1 RISK SUMMARY

A Baseline HHRA was prepared as part of the *Final Groundwater Operable Unit Remedial Investigation Report* Middlesex Sampling Plant, Middlesex, New Jersey, (USACE 2005a). A Supplemental HHRA, which is provided in Appendix A, was prepared to address VOCs in bedrock groundwater following the soils removal action and installation and sampling of a groundwater monitoring well network. The Supplemental HHRA was performed using the two most recent groundwater sampling rounds (2014 and 2015). Both HHRAs evaluated hypothetical groundwater exposure pathways. Groundwater at the site is not currently used, and there are no current plans for its use in the future.

Baseline HHRA

The Baseline HHRA (USACE 2005a) evaluated the risks from contaminants (radionuclides, VOCs, semi-volatile organic compounds [SVOCs], and metals) in on-site groundwater to hypothetical future residential receptors at the site. This Baseline HHRA concluded that:

• The potential cancer risks associated with groundwater were approximately 1×10^{-4} for site-wide average concentrations, which is equal to the upper limit of the United States Environmental Protection Agency's (EPA's) acceptable risk range. The

potential cancer risk at the well showing the highest radioactive contamination, well B18W24S, was $6x10^{-4}$. Ingestion of uranium in drinking water was the greatest contributor to the risk.

- Hazard indices exceeded the non-cancer hazard index (HI) of 1 for the residential scenario for average site-wide groundwater exposure. The exceedance was primarily due to the concentration of manganese, which appeared to be present as a natural background constituent. Uranium and CT contributed to HIs greater than 1 in two monitoring wells.
- The annual radiation dose from drinking water (i.e., groundwater with no treatment) projected for a site resident was 10 millirems (mrems)/year. The NJDEP (NJAC 7:28-12), all pathways, 15 mrem annual dose was exceeded in one well (B18W24S).
- Exposure to sediments and surface water at the MSP posed a cancer risk of $2x10^{-5}$, which is within EPA's acceptable risk range of $1x10^{-6}$ to $1x10^{-4}$. Non-cancer health effects from sediments and surface water were considered unlikely.

Based on the risks and hazards calculated for the chemicals of potential concern (COPCs), the following contaminants were identified as chemicals of concern (COCs) in the Baseline HHRA: total uranium (as a toxic metal); uranium-238 and uranium-234 (as radioactive contaminants); CT; and manganese. There was no evidence that manganese had been used for government activities and it was determined to be part of the natural background at the site (Serfes 1994). Therefore, manganese was not retained as a COC.

Supplemental Human Health Risk Assessment

The Supplemental HHRA for the MSP site (Appendix A) evaluated the risks associated with volatile organic compounds (VOCs) in groundwater to hypothetical future on-site workers and hypothetical future off-site residential receptors. Sample results from five wells within the core of the plume were used for the risk assessment. The groundwater data used in the risk assessment included VOC data collected from those wells during two sampling events conducted in 2014 and 2015. The results of the Supplemental HHRA are summarized below:

- For the adult worker exposure to groundwater, the reasonable maximum exposure (RME) cancer risk exceeded EPA's acceptable risk range. The total cancer risk of 1.4 x 10⁻³ was primarily due to CT. The central tendency exposure (CTE) cancer risk was within the acceptable risk range at 9.0 x 10⁻⁵. The HI for the adult worker exposure to groundwater was 17.3 for the RME scenario primarily due to CT and TCE. The HI for the CTE scenario was 4.2, primarily due to CT.
- For the child residential exposure to groundwater, the RME cancer risk exceeded EPA's acceptable risk range. The total cancer risk of 1.2 x 10⁻³ was primarily due to CT. The CTE cancer risk also exceeded the acceptable risk range at 2.5 x 10⁻⁴. The HI for the

child resident exposure to groundwater was 59.1 for the RME scenario primarily due to CT, chloroform, and TCE. The HI for the CTE scenario was 17.9 due to CT and TCE.

• For the adult residential exposure to groundwater, the RME cancer risk exceeded EPA's acceptable risk range. The total cancer risk of 3.4 x 10⁻³ was primarily due to CT and chloroform. The CTE cancer risk also exceeded the acceptable risk range at 4.6 x 10⁻⁴. The HI for the adult resident exposure to groundwater was 48.6 for the RME scenario primarily due to CT, chloroform, and TCE. The HI for the CTE scenario was 15.9 due to CT and TCE.

Based on the risks and hazards calculated for the COPCs, the following contaminants were identified as COCs in the Supplemental HHRA: CT, chloroform, and TCE. Low levels of VOCs were detected in the site background well indicating that off-site, upgradient sources of VOCs could be impacting groundwater conditions at the MSP site. However, in most instances, the concentrations of COPCs from within the core of plume were significantly higher than the background values.

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LIST OF ACRONYMS AND ABBREVIATIONS

μg/L	micrograms per liter
1,1-DCE	1,1-dichloroethene
AEC	Atomic Energy Commission
amsl	above mean sea level
ATSDR	Agency for Toxic Substances and Disease Registry
ATV	acoustic televiewer
bgs	below ground surface
BOD	biological oxygen demand
°C	degrees Celsius
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CF	chloroform
cis-1,2-DCE	cis-1,2-dichloroethene
COC	chemicals of concern
COD	chemical oxygen demand
COPC	chemicals of potential concern
CSM	conceptual site model
СТ	carbon tetrachloride
CTE	central tendency exposure
CV	Comparison Value
CVOC	chlorinated volatile organic compound
DHC	Dehalococcoides spp.
DO	dissolved oxygen
DQCR	Daily Quality Control Report
DSR	Data Summary Report
E & E	Ecology and Environment, Inc.
EC	electrical conductance
ECC	Environmental Chemical Corporation
EPA	United States Environmental Protection Agency
FS	Feasibility Study
FSP	Field Sampling Plan
ft/min	feet/minute
FUSRAP	Formerly Utilized Sites Remedial Action Program
gpd/ft	gallons per day per foot
gpm	gallons per minute

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

GWITM	Groundwater Investigation Technical Memorandum
HBGWC	Health Based Groundwater Criteria
HHRA	Human Health Risk Assessment
HI	hazard index
M&A	Michalski & Associates, Inc.
MCL	Maximum Contaminant Level
MED	Manhattan Engineering District
mg/L	milligrams per liter
MIS	Middlesex Industrial Site
MML	Middlesex Municipal Landfill
MNA	monitored natural attenuation
mrems	millirems
MSP	Middlesex Sampling Plant
MTBE	methyl tert-butyl ether
mV	millivolts
MW	monitoring well
NJDEP	New Jersey Department of Environmental Protection
NPL	National Priorities List
OB	overburden
ORP	oxidation-reduction potential
OU	Operable Unit
pCi/L	picocuries per liter
PCE	tetrachloroethene
PCOR	Final Preliminary Closeout Report
PP	Proposed Plan
PRAR	Final Post Remedial Action Report
Protocol	Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water - EPA/600/R-98/128
QAPP	Quality Assurance Project Plan
QCSR	Quality Control Summary Report
RA	Remedial Action
RI	Remedial Investigation
SARA	Superfund Authorization and Reinvestment Act
SE	sampling event

LIST OF ACRONYMS AND ABBREVIATIONS (continued)

(New Jersey) Specific Ground Water Quality Criteria
Screening-Level Ecological Risk Assessment
scope of work
spontaneous potential
semi-volatile organic compound
static water level
trichloroethylene
top of casing
temporary test hole
hexavalent oxide of uranium
United Lead Company
United States Army Corps of Engineers
United States Department of Energy
vinyl chloride
volatile organic compound
vicinity property

1.0 INTRODUCTION

The United States Army Corps of Engineers (USACE) initiated a groundwater investigation following the Soils Operable Unit (OU) 1 remedial action (RA) to address the groundwater (OU2) at the Middlesex Sampling Plant (MSP) (USACE 2004). The investigation results, presented in this Groundwater Investigation Technical Memorandum (GWITM), are intended to supplement data available in the *Final Groundwater Operable Unit Remedial Investigation Report Middlesex Sampling Plant, Middlesex, New Jersey* (USACE 2005a). Data from these reports will be used to develop the Feasibility Study (FS) for the MSP.

Between 2008 and 2016, the USACE installed shallow (overburden) and deep (bedrock) groundwater monitoring wells (MWs) at the MSP and on adjacent properties located in Middlesex, New Jersey. The USACE conducted downhole geophysical and hydrogeological testing and collected groundwater samples from the new and existing MWs. These activities were conducted to assess the nature and extent of contamination remaining in groundwater at the site and to characterize the fate and transport of the volatile organic compound (VOCs) in the bedrock aquifer. Information gathered during this investigation was used to assess the risks to human health and the environment, in context of the exposure pathways that were identified. The additional data collected between 2008 to 2016 will serve as an addendum to the 2005 Groundwater Remedial Investigation (RI) report.

This GWITM presents summaries of the following investigation activities from 2008 to 2016:

- Field activities that were completed and the data obtained during the installation and subsequent monitoring of 30 new bedrock MWs;
- Groundwater analytical results from the 33 bedrock MWs and 15 overburden MWs during 16 sampling events (SEs);
- Determination of the nature, extent, fate and transport of groundwater contaminants;
- Evaluation of possible contaminant sources; and
- Assessment of the natural attenuation characteristics of the subsurface environment for the VOCs.

Overburden and bedrock monitoring wells were initially installed on-site in 2001 as part of the groundwater OU-1 RI (B18W29SR [overburden well] and URS-MW-2D [bedrock well]). All overburden wells were removed during the Soils OU RA in 2008 (USACE 2010a) with the exception of well B18W29SR. The overburden (OB) well network (MW-OB-1 through MW-OB-13) was replaced in 2008, following the soils removal for OU-1. Three bedrock wells (URS-MW-2D, URS-MW-22D, and URS-MW-24D) were also installed. In 2010, test boreholes were

completed at three locations that were used to redefine the conceptual site model (CSM) for groundwater movement in the subsurface. Between 2010 and 2016, 30 new bedrock wells (locations ECC-MW25 and EE-MW-43) were installed to delineate the extent of VOCs in the subsurface (in addition to the three existing bedrock wells mentioned above).

All sampling activities from 2008 to 2013 were performed by Environmental Chemical Corporation (ECC) in accordance with the *Field Sampling Plan* (FSP) *and Quality Assurance Project Plan* (QAPP) *of the Overburden Monitoring Well Installation Work Plan* (USACE 2008a) and the *Overburden and Bedrock Monitoring Well Installation, Testing, Sampling and Analysis Work Plan, Formerly Utilized Sites Remedial Action Program* (USACE 2010b). All sampling activities from 2014 to 2016 were performed by Ecology and Environment, Inc. (E & E) in accordance with the *Final Work Plan for the Groundwater Operable Unit – Additional Data Gathering for Completion of the Feasibility Study Report – August 2014* (USACE 2014) and the *Revised Final Work Plan Addendum for Additional Data Gathering for Completion of the Feasibility Study Report – August 2015*.

1.1 Objectives

The objective of the groundwater investigation for OU2 was to obtain post Soils OU-1 RA hydrogeological and analytical data as well as to evaluate the nature and extent of groundwater VOC contamination at the MSP site. The OU-1 RA is documented in *Final Preliminary Closeout Report* (PCOR), *Soils Operable Unit 1* (USACE 2008b) and *Final Post Remedial Action Report* (PRAR), *Soils Operable Unit 1* (USACE 2010a). With the removal of the sources of radiological and chemical contamination (USACE 2008b, 2010a), groundwater samples have been collected and analyzed to evaluate the total uranium and VOC groundwater contamination and natural attenuation conditions in the overburden and bedrock aquifers. Additional hydrogeological data and analytical results from this monitoring program will be used in the preparation of a FS to evaluate potential groundwater remedial alternatives by characterizing the nature, extent, source(s), and VOC concentration trends in both the overburden and bedrock aquifers. This GWITM summarizes and evaluates the groundwater analytical data collected at the MSP site during 16 SEs conducted from August 2008 to January 2016.

1.2 Report Organization

This GWITM consists of an executive summary followed by six sections with supporting tables, figures, and appendices.

Section 1 provides an introduction, scope of work (SOW), and the project objective. Section 2 provides a brief description of the MSP site; summarizes the site background, lists the environmental, regulatory, and cleanup history of the MSP site; and describes the hydrogeology

and nature and extent of groundwater contamination. Section 3 describes the field activities and data collection methods used during this investigation from 2008 through 2016. Section 4 presents the test data and analytical results from the investigation and MNA analyses conducted for 16 consecutive SEs and a summary of the Human Health Risk Assessment (HHRA) and Screening-Level Ecological Risk Assessment (SLERA). Section 5 presents a summary and conclusions based on the data and information obtained during the investigation. Section 6 presents references used in the report.

Appendix A includes the Supplemental HHRA report following soils removal and installation and sampling of additional MWs. Appendix B includes a technical memorandum by Michalski & Associates, Inc. (M&A) that discusses hydrogeologic and contaminant data for fractured bedrock at the site; re-assesses the bedrock as a leaky multi-unit aquifer; and provides recommendations for additional investigations for adequate bedrock characterization and delineation of groundwater contamination. The M&A memorandum describes the basis for the work described in this report. Appendix C includes borehole logs and well construction diagrams for the overburden MWs and bedrock MWs that have been monitored and/or sampled during the investigation. Appendix D presents copies of the acoustic, gamma, spontaneous potential, and resistivity geophysical logs for test holes and selected bedrock MWs. Appendix E includes the electrical conductance and temperature logs and the salt tracer testing results for the bedrock wells tested. Appendix F presents the laboratory reports for the depth-discrete and packer test samples that were collected from test holes and selected bedrock MWs. Appendix G presents the packer test data for the test holes. Appendix H presents the Quality Control Summary Report (QCSR) for SE 15 and SE 16.

2.0 SITE DESCRIPTION AND HISTORY

The following sections describe the site, site history, contamination history and sources, regional and local hydrogeology, and the nature and extent of groundwater contamination for the MSP site.

2.1 Site Description

The site is approximately 9.6 acres and is located at 239 Mountain Avenue in the Borough of Middlesex, New Jersey (Figure 1). The site is bordered to the east by residential and commercial properties, to the south by a small parcel of vacant land followed by residential property, and to the west and north by a railroad right-of-way and a scrap metal facility followed by commercial property. The former layout of the MSP (e.g., sump and pipe chase, boiler house slab, drainage ditch) is included on Figure 2. The site is currently vacant land with grass cover, and includes a gravel access road on the east side of the property. All of the original buildings (process building, garage, and administration building) associated with the use of the property described in Section 2.3 have been previously demolished (Figure 3). The site is fenced and public access is restricted. Site topography is relatively flat with surface elevations ranging from approximately 58 feet above mean sea level at the north end to 49 feet above mean sea level along the south end, with an average slope of approximately one percent.

Storm water flows over the site surface as sheet flow and is collected into drainage swales that carry it south where it is discharged off-site into the South Drainage Ditch (Figure 2). The property to the south consists of a marshy land and fields. The South Drainage Ditch carries surface water runoff from the site into the Main Stream and is approximately 1,150 feet long. The Main Stream flows intermittently in a southwesterly direction for approximately 2,100 feet where it discharges into Ambrose Brook.

2.2 Land Use

The area within 0.5 mile of the MSP is a mixture of residential homes, commercial and industrial properties, and undeveloped land. No environmentally sensitive areas exist within the fenced borders of the site. The MSP is zoned Industrial by the Borough of Middlesex Planning Commission. The MSP is bordered by a heavy industrial zone approximately 3,000 feet to the west, a commercial/light manufacturing/wholesale zone 200 feet to the north, and an attached residential cluster 2,100 feet to the east. The property to the south of the MSP is within Piscataway Township and is zoned Residential and Light Industrial. The master plans for the Middlesex and Piscataway Townships do not recommend changes in zoning for MSP and the vicinity. Recent residential development (condominiums) has occurred to the south of the MSP site.

The location of the adjacent salvage yard and current industrial zoning reduces the potential for residential development at the MSP site. With the recent construction of condominiums south of the MSP site, there is no available room for further development, south and southeast of the site. The MSP borders an area of residential zoning and experiences the pressures of expanding residential development.

2.3 History of the MSP Site

2.3.1 Operational History

Industrial operations at the MSP site began in 1910 with the construction of a plant for the manufacture of asphalt paint. At that time, the plant included a brick warehouse, a boiler house, a garage, an administrative building, a dye warehouse, and four smaller buildings (United States Department of Energy [USDOE] 1997). The original company (name unknown) was purchased in 1913 by the American Marietta Company with products sold under the American Asphalt Company label.

In October 1943, the Manhattan Engineering District (MED) leased the brick warehouse from American Marietta Corporation and converted it into the former Process Building to sample, store, test, and transfer ores containing uranium, thorium, and beryllium (as well as a chemical precipitate, magnesium diuranate, supplied by African Metals Corporation beginning in 1950). Between 1943 and 1955, uranium assay analysis, conducted by the United Lead Company (ULC) under contract with the Atomic Energy Commission (AEC), was the primary operation.

In 1946, MED was deactivated and MSP operations were continued under the direction of the AEC. The leased facility was purchased through condemnation by AEC from American Marietta Corporation, and various new buildings were constructed (USDOE 1997). These new structures included a replacement for the administrative building, a replacement garage, a thaw house, and a storage house. The former locations of the process building, garage, and administration building are included on Figure 3. A chain-link fence was installed around the site and approximately 7.9 acres of the 9.6 acres were paved with asphalt for use as a drum storage area.

Throughout the late 1940s and early 1950s, the site received and shipped various research and decontamination wastes. In addition, low-level combustible waste was incinerated on the site. The incinerated ashes and noncombustible scrap were reportedly placed in drums and transported off-site for disposal. The MSP was also used to prepare contaminated wastes for shipment and disposal at sea.

During 1951 and 1952, the MSP became the intermediate point for the shipment of uranium bars from the Lake Ontario Ordnance Works in Niagara Falls, New York, to the American Machine and Foundry Company in Brooklyn, New York, where the bars were experimentally machined into slugs. Scraps from this operation were then returned to the MSP for shipment to a uranium recovery processor. Before operations ceased, they also included assaying beryllium ore for shipment to Brush Beryllium in Luckey, Ohio.

During the years that the MSP was operational, the buildings, grounds, and nearby land parcels became contaminated with uranium and its associated decay progeny (radium). It is unlikely that the magnesium diuranate processing had significantly impacted the ground surface or adjacent properties due to the more controlled handling of the material. The handling of uranium ore sacks likely resulted in spillage, and subsequent migration mechanisms caused localized radiological contamination, both on- and off-site. It should be noted, however, that the facility management practices used at the MSP were standard industry techniques, considered appropriate at the time. Data obtained during the 2005 groundwater remedial investigation for VOCs indicated a source area located in the vicinity of the former garage, where solvents may have been used (Figure 2). The VOCs were detected within shallow bedrock, which, due to their potential to migrate downward, indicates that the release occurred on-site.

AEC terminated primary operations at the MSP in 1955. However, it continued to be used for storage and limited sampling of thorium residues. AEC activities at the site ended in September 1967, after decontamination of the structures and certification of the site for unrestricted release was completed. Decontamination activities included sandblasting, vacuuming, detergent and acid washing, concrete chipping, and equipment removal. In cases of severe contamination, parts of buildings were removed. In addition, a portion of the paved yard and underlying gravel and soil was transported by rail to the Nuclear Fuel Services licensed burial site at West Valley, New York (Ford, Bacon, and Davis 1979). In 1968, the AEC returned the MSP property to the General Services Administration, which transferred the site to the United States Department of the Navy. The site served as a United States Marine Corps reserve training center from 1969 to 1979.

2.3.2 Site Features

This section presents a summary of the former features at the MSP site as described in the Groundwater RI Report (USACE 2005a). Figure 2 presents the layout of the site with notable historical features. They include the buildings and pads (i.e., building structures, building and structure foundation slabs, and storage pile pads), and the storm water discharge system (termed the Pipe Chases) that includes the underground site storm water control system.

2.3.2.1 Buildings and Pads

The six site buildings that existed during the AEC's operations were the Process Building, Administration Building, thaw house, boiler house, equipment storage building, and garage (Figures 2 and 3). No buildings or evidence of the buildings remain at the site today. The Process Building was a brick warehouse in which sampling and assay of uranium ore was conducted. The thaw house was a concrete block building used to store ore that needed to be thawed prior to processing. The boiler for heating the Process Building was in the boiler house. The concrete block Administration Building contained offices, a laundry, shower, lunchroom, two locker rooms, a health and safety dispensary, and a waste disposal unit (solid waste incinerator). The equipment storage building was a Quonset hut made of steel and corrugated metal. The garage was a wood frame building covered with corrugated metal. During site operations, a seventh structure of concrete block was used as a dumping station for uranium ore onto the conveyor for transport to the assay equipment in the Process Building (Cahalane 1958).

The thaw house was demolished and buried on-site prior to construction of the Middlesex Municipal Landfill (MML) pile asphalt pad, and the equipment storage building was demolished in the early 1980s. A series of underground fuel tanks (gasoline) and surface pumps were near the center of the site east of the Process Building (Ford, Bacon, and Davis 1979a). These tanks and pumps were removed during construction activities in 1980. The Process Building and boiler house were demolished in 1996 but the slabs remained (USDOE 1996).

During site operations, a sump in the ore Process Building floor was used for the disposal of wastewater. The sump was 12 feet long by 6 feet wide by 10 feet deep and extended into the water table. As part of Process Building demolition in 1996, the sump was drained and plugged with concrete.

By 2008, the remaining building had been demolished and removed from the site. The site no longer contains any structures or evidence of structures on the property.

2.3.2.2 Pipe Chases (Subsurface Storm Water Drainage System)

Historically, surface storm water runoff (e.g., rainfall and snowmelt) at the MSP was diverted into a subsurface storm drainage system, which then directed it to the South Drainage Ditch. As is typical of subsurface drain systems, the pipes were surrounded by non-native bedding backfill material. This backfill was granular in nature and more porous than the surrounding soil. The USACE historically identifies this subsurface pipe and backfill feature on the site as the "Pipe Chase."

Prior to 1980, the site storm water system consisted of a 12- to 14-inch diameter below-grade line (hereafter called the Main Line) that extended through the approximate center of the site from the Administration Building southward to the southern property boundary. This Main Line

received roof runoff from the Administration Building and garage as well as runoff collected by a sump in the former ore Process Building. The sump in the ore Process Building was connected to the Main Line by an 8-inch diameter feeder line. A second 8-inch diameter feeder line joined the Main Line just north of the southern site boundary. This feeder line drained the area on the west side of the property, south of the former thaw house. A series of catch basins were also located at turns and bends along the feeder and lines. Water collected by this system was subsequently discharged through a concrete headwall into the South Drainage Ditch. Figure 2 illustrates the locations of the subsurface drainage lines before 1980.

In support of the vicinity properties (VPs) and MML clean-up actions, a portion of the above lines (Main line and feeder lines) were plugged and abandoned with concrete at both ends in 1980. The remainder of the site system was plugged in 1996. The former Process Building sump and most of the catch basins were also plugged and abandoned with concrete at that time. Replacement of the below-grade drainage lines in 1980 consisted of the installation of a surface trench drain system around the areas of the former VP and MML piles, and a settling basin and granular activated carbon filtration system were installed in the southern portion of the site. All subsurface stormwater conveyance features were removed during the Soils OU-1 RA completed in 2008 and stormwater is currently directed to the South Drainage ditch through surface swales and overland flow (USACE 2010a).

2.3.3 Remedial Activity History

In 1980, control was transferred to the USDOE, which began to remediate MSP VPs and the MML under the Formerly Utilized Sites Remedial Action Program (FUSRAP). The AEC, a predecessor to the USDOE, established FUSRAP in 1974 to identify, remediate, or otherwise control sites contaminated with residual radioactivity resulting from activities of the MED and early operations of the AEC. The goal of FUSRAP is remediation of sites contaminated as a result of the nation's early atomic energy program in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA). Responsibility for execution of response actions on sites included in FUSRAP was transferred from USDOE to USACE by Public Law 105-62, October 13, 1997, and long term programmatic authority was specifically provided to USACE in Public Law 106-60, Section 611, September 29, 1999. On February 18, 1999, MSP was added to the National Priorities List (NPL) in the Federal Facilities Section.

As a result of USDOE's remedial activities at the VPs and the MML, two waste piles were constructed on the MSP site for interim storage of waste material prior to off-site disposal. The VP waste pile, constructed in 1981, contained approximately 35,200 cubic yards (yd³) of radioactive soil and debris. The MML waste pile, constructed between 1984 and 1986, contained approximately 31,200 yd³ of waste containing residual radioactive material and lead

that had originally been disposed in the MML since the 1940's. Both piles were removed from MSP by the end of 1999.

Remedial investigations of soil and groundwater at the MSP were addressed in two OUs by the USACE from 1999 through 2005. OU-1 addressed radioactive and non-radioactive soil and debris contamination. Approximately 41,244 yd³ of radiological waste and 4,454 yd³ of non-radiological waste were excavated and transported to an off-site permitted disposal facility during the Soils OU-1 RA. Additionally, existing overburden groundwater MWs were removed and/or abandoned in place in accordance with New Jersey State regulations. The Soils OU-1 RA began in September of 2006. Excavation activities were completed in December 2007. Completion of transportation and disposal of contaminated soils occurred in June 2008.

After implementation of the Soils OU-1 RA, installation of a network of replacement overburden MWs, followed by sampling and analysis of groundwater was necessary in order to obtain post-soils remedial action groundwater data.

OU-2 initially addressed radioactive groundwater contamination. However, groundwater data indicated persistent elevated levels of VOCs in two of the three bedrock wells sampled. After evaluating this data, the USACE determined that additional bedrock MWs and sampling for VOCs was necessary to fully characterize the vertical and horizontal extent of MSP site contamination. A FS and a Proposed Plan (PP) for groundwater remedial action will be initiated based on the additional hydrogeological and VOC analytical data presented and evaluated in this GWITM.

A hydrogeologic study of the shallow bedrock aquifer system beneath the northern portion of the site was conducted during September and October 2010. This study refined the conceptual site model to better define the movement of groundwater flow in the bedrock aquifer and was used as the basis for designing the bedrock monitoring well network site installed between 2010 and 2016.

2.4 Geology

The regional and local geology of the MSP site is described in the following two sections. The bedrock geology greatly affects the hydrogeological character (movement of water through bedrock) of the MSP site, especially the interpretation of the deeper, bedrock site aquifers as described below.

2.4.1 Regional Geology

The bedrock beneath the site consists of late Triassic Passaic Formation, a major formation within the Newark basin in central New Jersey. The basin is a half-graben filled with thick lacustrine and fluvial deposits, predominantly mudstone, shales and sandstones, interbedded with

lava flows. Based on analyses of cores collected at several sites in New Jersey during the Newark Basin Coring Project (Olsen et al. 1996), the Passaic Formation has been divided into 40 members. Each member represents approximately 400,000 years of deposition, also known as a McLaughlin cycle, and generally includes 20 Van Houten cycles. A Van Houten cycle is a lithologic sequence starting with layered mudstone grading into massive or silty mudstone, with indicators of subaerial exposure near the top of the sequence. Each of the Van Houten cycles is approximately 10 to 30 feet thick and represents about 21,000 years of deposition (Olsen et al. 1996).

2.4.2 Local Geology

Site geology is divided into two units; overburden deposits and bedrock. The overburden deposits at the site consist of artificial fill, unconsolidated sediments (clayey fine sands to silty sands of eolian origin) with thickness ranging from 1.5 feet to more than 11 feet, and decomposed shale of the Passaic Formation. The northern soils were glacially derived which produced moderately well drained soils, while the southern soils formed from weathered bedrock which produced poorly drained soils.

In the MSP area, bedrock of the Passaic Formation strikes N 56° E and dip at 11° NW, based on the nearest dip and strike measurements shown on available regional geologic maps (Parker, 1993), as well as observation of bedrock outcrops in the railroad cut north of the site. Stratigraphically, the site bedrock section is positioned approximately 1,600 feet below the contact of the Passaic Formation with the overlying Orange Mountain Basalt. This is based on the dip angle, a horizontal distance of 8,000 feet from the site to the contact, and correcting for a higher elevation of the contact. The site bedrock is therefore within the "MM" member of the Passaic Formation. The dominant rock types of this member include red mudstone and red silty mudstone. The major lithologic types of the mudstone include: 1) laminated mudstone, 2) thinbedded mudstone, and 3) massive mudstone (Smoot 2010).

Site-specific values for the strike and dip of bedding were obtained by determining the attitude of a gamma marker bed that was identified by correlating gamma logs from the test holes installed in November 2010 and some of the existing wells. A strike of N 55° E (subparallel to the railroad tracks alignment) with a dip angle of 10.4° NW was measured for the gamma marker bed. These site-specific values are nearly the same as the initial values obtained for the study area.

2.5 Hydrogeology

The following two sections describe both the regional and MSP hydrogeological setting of the Passaic Formation aquifers present at the MSP site.

2.5.1 Regional Hydrogeology

The Passaic Formation is a major aquifer in the western part of Middlesex County and adjoining Essex County. The aquifer beneath the MSP site was originally described as a "single aquifer composed of unconsolidated material (both sediment and weathered bedrock) and fractured bedrock" (Agency for Toxic Substances and Disease Registry [ATSDR] 2002). More recent interpretations indicate that the aquifer in the area of the MSP site consists of a thin overburden unit (which includes the saturated overburden and highly decomposed bedrock) and a thick bedrock aquifer system.

The bedrock is conceptualized as a leaky, multiunit aquifer system (Michalski 1990, 2010a, 2010b), in which a few transmissive bedding fractures act as discrete aquifer units for beddingparallel groundwater flow and contaminant migration pathways. The leakage occurs through subvertical joints within the aquitard beds between the transmissive bedding fractures. The amount of leakage varies between the units and ranges from minor to significant. The dipping bedrock aquifer system is hydraulically connected to the overburden unit. In topographically elevated areas, the overburden groundwater recharges the transmissive bedding fractures (aquifer units) at their subcrops (the interface of the overburden and the underlying weathered bedrock surface). A downdip flow component is present within the bedding fractures in the recharge areas. The flow becomes more parallel with the strike of bedding in deeper reaches of the bedding fractures. An upward flow component develops in bedding locations adjacent to groundwater discharge zones.

Because of the dominance of groundwater flow parallel to the bedding of the bedrock, contaminants released into a given bedrock portion tend to remain within the impacted stratigraphic interval and follow the generic bedrock flow pathway. The flow within a particular bedrock zone can be monitored by installing piezometers/MWs screened across that zone.

2.5.2 Local Hydrogeology

The overburden water bearing unit is present between approximately two feet and eight feet below ground surface on-site. This water bearing unit is a perched unit sitting on top of the bedrock at the interface with the overburden and is up to several feet thick. A groundwater divide is formed in the northcentral portion of the site likely as the result of underlying bedrock structure. Groundwater flows to the north and south from this area near monitoring well MW-OB-8 and MW-OB-7R. North of this groundwater divide, overburden shallow groundwater flows in a north and northwesterly direction and may discharge to the railroad right of way, which is cut 8 to 10 feet into the subsurface. Groundwater flowing south of the site moves toward a wetland area and drainage ways within it.

A major task of the recent groundwater investigation was to re-evaluate the shallow bedrock as a leaky, multi-unit aquifer system. Based on results of several investigative methods used to identify and characterize transmissive bedrock fractures, three bedding-parallel bedrock aquifer units were identified and labeled Unit B, Unit C, and Unit D. The relationships between these units are shown on the cross-section in Figures 4a and 4b. Due to the large distances between on-site and off-site wells, a matchline (matchline 1) was added to Figures 4a and 4b to limit the size of the figures by decreasing the well distances. A breakline was also added to Figure 4b which eliminated 1,000 feet of the figure to limit the size. Figure 3 includes the location of the matchline. The characterization methodology and results are detailed in Section 4 with the groundwater elevation measurement results presented in Section 4.2.

2.6 Historical Groundwater Contamination Investigations/Monitoring

The following sections provide a summary of the historical investigations to determine the nature and extent of groundwater contamination at the MSP site. The results of previous remedial investigations at the MSP are presented in *Groundwater Operable Unit Remedial Investigation Report* (URS 2005) and *Soils Operable Unit, Final Remedial Investigation Report* (USACE 2005b). Details of previous RA-related investigations are discussed in the *Final Preliminary Closeout Report* (USACE 2008b) and *Final Post Remedial Action Report* (USACE 2010a).

2.6.1 Summary of Groundwater Monitoring Activity

Since the early 1980s, groundwater beneath the MSP site and in its immediate vicinity has been monitored to characterize the nature and extent of contamination. USDOE installed 18 on-site groundwater MWs and two downgradient off-site groundwater MWs during 1980-1981. Some of these wells were sampled sporadically to characterize contamination beneath the site and to track groundwater contaminant movement. Starting in 1982, the USDOE established a standardized groundwater surveillance program. Between 1982 and 1993, the USDOE sampled 19 of the 20 MWs (17 on-site and two off-site) quarterly for MSP FUSRAP contaminants (radium-226 and total uranium). In 1985, the USDOE also started sampling 12 MWs in the network for New Jersey priority pollutants (VOCs and semi-volatile organic compounds [SVOCs]). In 1990, the USDOE added metals and thorium-232 to the suite of analyses. After achieving consistent results over several years from the 19 wells in the monitoring network, the USDOE reduced the sampling effort to seven wells on an annual basis.

In 1994, the USDOE abandoned the 20 original MWs and upgraded the groundwater MW network by installing seven new shallow MWs (screened in the first water-bearing zone across the overburden and the weathered upper bedrock) near on-site waste areas. These included six on-site wells (B18W24S through B18W29S) and one downgradient off-site well (B18W30S).

All of the new wells were screened between 11 and 15 feet below ground surface (bgs). Between 1994 and the Soils OU-1 RA (soil removal actions between September 2006 and December 2007, documented in the *Preliminary Close Out Report, Soils Operable Unit* [USACE 2008b]), water samples were collected annually from these wells and analyzed for VOCs, SVOCs, metals, radium-226, radium-228, thorium-230, thorium-232, and total uranium. With the exception of B18W29S, all of these MWs were removed during the Soils OU-1 RA. Between August 2000 and September 2002, the USACE installed seven new bedrock MWs with open hole completion in Units B and C (URS-MW-1D, URS-MW-2D, URS-MW-3D, URS-MW-5D, URS-MW-9D, URS-MW-11D, and URS-MW-20D). Four additional bedrock MWs (URS-MW-21D, URS-MW-22D, URS-MW-23D, and URS-MW-24D) were installed in 2004.

Independent of the USDOE monitoring program, the ATSDR sampled two on-site MWs, one off-site MW, and 14 nearby private wells in February 2000 (ATSDR 2002). According to the Forward in the ATSDR Public Health Assessment Guidance Manual, "The mission of the ATSDR is to serve the public by using the best science, taking responsive public health actions and providing trusted health information to prevent harmful exposures and disease related to toxic substances. The ATSDR public health assessment process serves as a mechanism to help ATSDR sort through the many hazardous waste sites in its jurisdiction and determine when, where, and for whom, public health actions should be taken. Through this process, ATSDR finds out whether people living near or at a hazardous waste site are being exposed to toxic substances, whether that exposure is harmful, and what must be done to stop or reduce any exposure."

ATSDR re-sampled three of the private wells in April 2000, along with three additional private wells and all of the MSP MWs. Samples were analyzed for radium-226, radium-228, uranium-238, arsenic, chromium (total and hexavalent), lead, and manganese, and selected samples were analyzed for uranium-234 and uranium-235. ATSDR focused its evaluation of groundwater on radium, uranium, arsenic, chromium, and lead. As concluded in the Public Health Assessment (ATSDR 2002), the results of the investigations indicated that groundwater beneath MSP was contaminated with radium, uranium, metals (e.g., arsenic, chromium, and lead), and VOCs (e.g., benzene, and methyl tert-butyl ether [MTBE]). It also concluded that no exposures to contaminated groundwater immediately beneath the site are occurring or are expected to occur in the future.

In 2008 after completion of the Soils OU-1 RA (soil removal), the USACE re-established a monitoring well network at the MSP site by installing 13 shallow MWs (overburden wells MW-OB-1 through MW-OB-13); maintaining existing shallow monitoring well MW B18W29SR; and maintaining ten existing bedrock MWs to monitor groundwater levels and to collect groundwater samples from three of the bedrock MWs (URS-MW-2D, URS-MW-22D and URS-MW-24D).

USACE removed the groundwater sampling requirement for the other seven existing bedrock MWs due to a consistent history of analytical results that were below the cleanup criteria.

2.6.2 On-Site Groundwater Contamination

Radioactive Contamination

ATSDR reviewed the monitoring data for radionuclides in on-site groundwater and compared the detected concentrations to the United States Environmental Protection Agency (EPA) Maximum Contaminant Level (MCL) and/or USDOE exposure limits. Of the radioactive contaminants analyzed, total uranium is the only analyte detected at concentrations above EPA's MCL of 30 micrograms per liter (μ g/L). All the data for total uranium, reviewed by ATSDR, was reported in picocuries per liter (μ g/L), while recent and current data is reported in mass units of μ g/L. In order to compare historical data, which is presented in activity units (pCi/L), to recent data, which is recorded in mass units (μ g/L), the historical data is presented as originally reported in activity units (pCi/L) and also in mass units (μ g/L). The conversion from activity-based data to mass-based data requires knowledge of the isotope ratios. The isotope ratios were not reported with the historical data; therefore, the converted values are estimated. The data is being used to assess the general trend in total uranium concentrations before and after the soils removal; the data is not being used for compliance purposes. An EPA conversion factor of 1.49 (from pCi/L to μ g/L for uranium in groundwater) has been used (EPA 2002). EPA's MCL for total uranium (30 μ g/L) is, therefore, approximately equivalent to 20 pCi/L.

Prior to the abandonment of the 20 original MWs in 1994, elevated total uranium levels were consistently detected between 1982 and 1993 in MSP-11, which was located between the northern edge of the MML waste pile and the process building sump and in MSP-5, which was located near the southeastern edge of the MSP site. The maximum annual average at MW-11 was 143 pCi/L (approximately 213 μ g/L) and the maximum annual average at MW-5 was 192 pCi/L (approximately 286 μ g/L). Total uranium concentrations in these wells increased until the mid-to-late 1980s. The concentrations then decreased; however, the concentrations never fell below 30 μ g/L. Other radioactive constituents were detected infrequently and generally in low concentrations. With the exception of sporadic detections of radium-226 and thorium-232, most groundwater concentrations were well below screening levels.

Between 1994 and the OU-1 remediation in 2007, elevated levels of total uranium were detected in the northern portion of the MSP site. The total uranium concentration in one well (B18W24S) reached 276 pCi/L (approximately 411 μ g/L) in 1997, declined to 206 pCi/L (approximately 307 μ g/L) in 1998, and then rose to 391 pCi/L (approximately 583 μ g/L in 2000). In another well (B18W25S) located on the northwest perimeter, the total uranium concentration increased from

16.15 pCi/L (approximately 24 μ g/L) in 1997 to 178 pCi/L (approximately 265 μ g/L) in 1999, but dropped to 53 pCi/L (approximately 79 μ g/L) during the April 2000 sampling event.

The network of shallow overburden MWs discussed above were abandoned during the Soils OU-1 RA. In 2008, with the source soil of total uranium removed, further assessment of total uranium groundwater impact in the shallow overburden aquifer zone was initiated with the installation of a new network of 14 overburden MWs.

Volatile Organic Compound Contamination

VOCs (trichloroethylene [TCE], MTBE) also were detected along the western and southern boundaries of the site at concentrations above the ATSDR Comparison Values (CVs). VOCs were not linked to any specific on-site sources at that time. VOCs may have migrated from soil containing gasoline, solvents, lubricating fluids, or petroleum-based constituents, such as those found at nearby upgradient industrial facilities.

3.0 FIELD ACTIVITIES

The following subsections present summaries of the most recent groundwater investigation research and field activities completed by USACE at the MSP site to evaluate the bedrock aquifers for hydrogeological properties and to determine the source, extent, fate and transport of VOC contamination in the bedrock aquifers.

2010 - 2011

The 2010-2011 groundwater investigation was designed and implemented to determine hydrogeologic characteristics of the shallow bedrock as a leaky multi-unit aquifer system and delineate the vertical extent of the VOC contamination. These objectives were accomplished by installing bedrock test holes, conducting various borehole logs and tests, converting the test holes to MWs, installing additional bedrock MWs, and collecting depth discrete samples for analysis. After evaluating the results of the investigation, data gaps were identified on-site and further field work was recommended and approved.

2012

In May and November 2012, a groundwater investigation was implemented to determine whether carbon tetrachloride (CT) in the on-site groundwater originates on-site or off-site (or both) and, if an on-site source was confirmed, to delineate the extent and determine the fate and transport of the CT plume. During this phase of investigation test holes were installed, borehole logs and tests were conducted, one test hole was converted to a monitoring well, additional bedrock MWs were installed, and groundwater samples were collected and analyzed for VOCs. In May 2012, two bedrock MWs were installed to monitor Unit B and one bedrock MW was installed to monitor Unit D. In November 2012, five bedrock MWs were installed to monitor Unit C. After evaluating the results of the two phases of investigation, data gaps were identified on-site and further field work was recommended and approved.

2013

In February 2013, a groundwater investigation was implemented to delineate the down-gradient extent of the CT plume in Unit B and Unit C. During this phase of investigation additional bedrock MWs were installed on-site and groundwater samples were collected and analyzed for VOCs. One bedrock MW was installed to monitor Unit B and one bedrock MW was installed to monitor Unit C.

2014

From August to October 2014, an additional data gathering field program was conducted to further define the on-site source of the VOCs (primarily CT and TCE) at shallower depths and delineate the source within Unit B surrounding on-site well ECC-MW-30B. During this phase of investigation 13 temporary borings (GW-1 through GW-13) were installed with one or more groundwater screening samples collected from each. Groundwater screening samples are included in Appendix H. The groundwater screening samples were only analyzed for VOCs and were sent for quick turn analyses. Results from the screening samples were used to support decisions on placement of permanent MWs as well as screen depths within those wells. Two MWs were also installed on-site (EE-MW-40B and EE-MW-41S). Overburden wells MW-OB-7 and MW-OB-10 were abandoned because the filter packs were saturated with silt. MW-OB-7 was replaced with MW-OB-7R within 10 feet of the original location (MW-OB-10 was not replaced).

The off-site investigation was designed to focus on the extent of VOC migration off-site through Unit B. Borings were installed at four locations along Voorhees Avenue which were converted to permanent monitor wells EE-MW-36B through EE-MW-39B. After evaluating the results of the investigation, data gaps were identified and further field work was recommended and approved.

2015-2016

From September 2015 to January 2016, the additional data gathering field program was completed. The focus of the on-site portion of this investigation was to further delineate on-site contamination in the shallow bedrock above Unit B. Five on-site borings (GW-14 through GW-18) were completed in the top of the bedrock, and one groundwater screening sample was collected from each test hole. Groundwater screening samples are included in Appendix H. The groundwater screening samples were only analyzed for VOCs and were sent for quick turnaround analyses. Results from the screening samples were used to support decisions on placement of permanent MWs as well as screen depths within those wells. Two MWs were installed on-site at this time (EE-MW-44S and EE-MW-45S).

CT and TCE were detected in off-site groundwater screening and monitoring well samples during the 2014 investigation. Therefore, this investigation was designed to further delineate the maximum extent of VOC migration off-site through Unit B. Both of the off-site wells were installed in Unit B. EE-MW-42B was installed in an area downgradient (northwest of the site) and EE-ME-43B was installed side-gradient (northeast of the site).

3.1 Site Groundwater Sample Collection and Analysis

Sixteen (16) sampling events have been conducted at the MSP site from August 2008 (the first sampling event after the overburden MWs were installed) to January 2016. The SE activities included documenting groundwater levels and monitoring for the known contaminants of concern (total uranium and VOCs).

From 2008 to 2013, the SEs included determining the presence and concentrations of specific parameters that are indicators of natural attenuation. Groundwater samples from the overburden MWs were analyzed for MNA parameters during every SE from 2008 to 2013, except SE 3 (February 2009). MNA parameters were originally scheduled for only the first two SEs (USACE 2008b); however, MNA parameters were again included in the analytical scope for the overburden MWs after SE 3. MNA parameters have been analyzed in bedrock well samples beginning with SE 4 (December 2009). The MNA parameters are discussed in Section 4.5.

A summary of the wells sampled and the analyses conducted from August 2008 through January 2016 is presented in Table 1. Water level data collected during these SEs is presented in Table 2 and Table 3.

The individual SE activities included the following:

- Sampling Event 1 (SE 1) Groundwater samples were collected August 4-6, 2008 from 14 overburden MWs and analyzed for total uranium and select MNA parameters. Overburden well MW-OB-10 did not produce a sufficient volume of water to perform all required MNA analyses. Samples also were collected from three bedrock MWs and analyzed for VOCs. Static water levels (SWLs) were measured at the 14 overburden MWs and 10 bedrock MWs on August 1, 2008.
- Sampling Event 2 (SE 2) Groundwater samples were collected November 10-12, 2008 from 14 overburden MWs and analyzed for total uranium. Samples from 13 overburden MWs also were analyzed for select MNA parameters (overburden well MW-OB-10 did not produce a sufficient volume of water to perform the MNA analyses). Samples also were collected from 3 bedrock MWs and analyzed for VOCs. SWLs were measured at the 14 overburden MWs and 10 bedrock MWs on November 10, 2008.
- Sampling Event 3 (SE 3) Groundwater samples were collected February 10-12, 2009 from 14 overburden MWs and analyzed for total uranium. Samples also were collected from 3 bedrock MWs and analyzed for VOCs. SWLs were measured at the 14 overburden MWs and 10 bedrock MWs on February 10, 2009.
- Sampling Event 4 (SE 4) Groundwater samples were collected December 15-17, 2009 from 14 overburden MWs and analyzed for total uranium. Samples from 13 overburden MWs also were analyzed for select MNA parameters (overburden well MW-OB-10 did not produce a sufficient volume of water to perform the MNA analyses). Samples also

were collected from 3 bedrock MWs and analyzed for VOCs and select MNA parameters. SWLs were measured at the 14 overburden MWs and 10 bedrock MWs on December 14, 2009.

- Sampling Event 5 (SE 5) Groundwater samples were collected April 14-16, 2010 from 14 overburden MWs and analyzed for total uranium. Samples from 13 overburden MWs also were analyzed for select MNA parameters (overburden well MW-OB-10 did not produce a sufficient volume of water to perform the MNA analyses). Samples also were collected from 3 bedrock MWs and analyzed for VOCs and select MNA parameters. SWLs were measured at the 14 overburden MWs and 10 bedrock MWs on April 13, 2010.
- Sampling Event 6 (SE 6) Groundwater samples were collected November 15-18, 2010 from 14 overburden MWs and analyzed for total uranium. Samples from 13 overburden MWs also were analyzed for select MNA parameters (overburden well MW-OB-10 did not produce a sufficient volume of water to perform the MNA analyses). Samples also were collected from 9 bedrock MWs (3 existing wells and 6 new wells) and analyzed for VOCs and select MNA parameters. SWLs were measured at the 14 overburden MWs and 16 bedrock MWs (10 existing wells and 6 new wells) within a two-hour period on November 15, 2010.
- Sampling Event 7 (SE 7) Groundwater samples were collected May 24-27, 2011 from 14 overburden MWs and analyzed for total uranium. Samples from 13 overburden MWs also were analyzed for select MNA parameters (overburden well MW-OB-10 did not produce a sufficient volume of water to perform the MNA analyses). Samples also were collected from 12 bedrock MWs (9 existing wells and 3 new wells) and analyzed for VOCs and select MNA parameters. SWLs were measured at the 14 overburden MWs and 19 bedrock MWs (16 existing wells and 3 new wells) within a 3-hour period on May 23, 2011.
- Sampling Event 8 (SE 8) Groundwater samples were collected August 22-25, 2011 from 14 overburden MWs and analyzed for total uranium. Samples from the 14 overburden MWs also were analyzed for select MNA parameters. Samples also were collected from 12 bedrock MWs and analyzed for VOCs and select MNA parameters. SWLs were measured at the 14 overburden MWs and 19 bedrock MWs within a 3-hour period on August 22, 2011.
- Sampling Event 9 (SE 9) Groundwater samples were collected November 7-10, 2011 from 14 overburden MWs and analyzed for total uranium. Samples from the 14 overburden MWs also were analyzed for select MNA parameters. Samples also were collected from 15 bedrock MWs and analyzed for VOCs and select MNA parameters. SWLs were measured at the 14 overburden MWs and 19 bedrock MWs within a 3-hour period on November 7, 2011.
- Sampling Event 10 (SE 10) Groundwater samples were collected February 6-9, 2012 from 14 overburden MWs and analyzed for total uranium. Samples from the 14 overburden MWs also were analyzed for select MNA parameters. Samples also were collected from 12 bedrock MWs and analyzed for VOCs and select MNA parameters.

SWLs were measured at the 14 overburden MWs and 19 bedrock MWs within a 3-hour period on February 6, 2012.

- Sampling Event 11 (SE 11) Groundwater samples were collected June 19-22, 2012 from 14 overburden MWs and analyzed for total uranium. Samples from the 14 overburden MWs also were analyzed for select MNA parameters. Samples also were collected from 15 bedrock MWs (12 existing wells and 3 new wells) and analyzed for VOCs. Twelve of the wells were analyzed for select MNA parameters. SWLs were measured at the 14 overburden MWs and 22 bedrock MWs (19 existing wells and 3 new wells) within a 5-hour period on June 19, 2012.
- Sampling Event 12 (SE 12) Groundwater samples were collected August 20-23, 2012 from 14 overburden MWs and analyzed for total uranium. Samples from the 14 overburden MWs also were analyzed for select MNA parameters. Samples also were collected from 15 bedrock MWs and analyzed for VOCs and select MNA parameters. SWLs were measured at the 14 overburden MWs and 22 bedrock MWs within a 5-hour period on August 20, 2012.
- Sampling Event 13 (SE 13) Groundwater samples were collected November 26-30, 2012 from 13 overburden MWs and analyzed for total uranium (overburden well MW-OB-10 was dry and a groundwater sample was not collected). Samples from the 13 overburden MWs also were analyzed for select MNA parameters. Samples also were collected from 21 bedrock MWs (15 existing wells and 6 new wells) and analyzed for VOCs. MNA parameters also were analyzed at 12 of the bedrock wells. SWLs were measured at the 14 overburden MWs and 28 bedrock MWs (22 existing wells and 6 new wells) within a 3-hour period on November 26, 2012.
- Sampling Event 14 (SE 14) Groundwater samples were collected February 19, 2013 from 3 bedrock MWs (1 existing well and 2 new wells) and analyzed for VOCs. SWLs were measured at the 14 overburden MWs and 30 bedrock MWs (28 existing wells and 2 new wells) within a 2-hour period on February 19, 2013.
- Sampling Event 15 (SE 15) Groundwater samples were collected October 6-9, 2014. A total of 11 overburden MWs and analyzed for total uranium and VOCs (overburden wells MW-OB-9 and MW-OB-12 were found to be dry during the event so no samples were collected). Groundwater samples were also collected from 29 bedrock MWs and analyzed for VOCs. On October 6, 2014, SWLs were measured within a 4-hour period at the 13 overburden MWs, 29 bedrock MWs (23 existing wells and six new wells), and six additional on-site wells that were not sampled during this SE.
- Sampling Event 16 (SE 16) Groundwater samples were collected January 9-13, 2016, except for wells ECC-MW-35B (sampled December 2, 2015), ECC-MW-35C (sampled December 3, 2015), and EE-MW-42B (sampled January 19, 2016). A total of 13 overburden MWs and analyzed for total uranium and VOCs. Groundwater samples were also collected from 29 bedrock MWs, two newly installed on-site shallow bedrock MWs, and two newly installed off-site Unit B MWs, which were all analyzed for VOCs. SWLs were measured within an 8-hour period on December 15, 2015 at the 13 overburden MWs, 34 bedrock MWs (24 existing wells and 10 new wells), and six additional on-site

wells that were not sampled. The SWLs for the three wells ECC-MW-35B, ECC-MW-35C, and EE-MW-42B were collected twice, prior to GW sample collection and on December 15, 2015.

3.2 Off-Site Potable Well Investigation, Sample Collection and Contaminated Sites in the Vicinity of MSP

Previous MSP reports were reviewed for information on the extent of VOC contamination in the bedrock within the vicinity of MSP. Figure 2-4 from the 2005 Groundwater OU RI Report (URS 2005) indicated the presence of a domestic well located on a residential property adjacent to the MSP site. On August 16, 2010, a groundwater sample was collected from the domestic well and analyzed for VOCs. Concentrations of CT, tetrachloroethene (PCE), TCE, and 1,1-dichloroethene (1,1-DCE) were detected above the New Jersey Department of Environmental Protection (NJDEP) Health Based Groundwater Criteria (HBGWC) and EPA's MCLs. Other VOCs were detected at concentrations below the HBGWC and EPA's MCLs. Table 4a summarizes the analytical results for the August 16, 2010 groundwater sample collected from the domestic well. The USACE subsequently made the appropriate notifications to EPA and NJDEP, and installed a Point of Entry Treatment carbon filter treatment system. In February 2011 the residence was connected to a public water supply, and the Point of Entry Treatment system was removed. The discovery prompted an investigation of other potable wells within a half-mile radius of the MSP site.

The USACE used several resources to identify and locate supply wells that may still be in service for providing potable water to residents or local business. The on-line NJDEP well search resource was used to identify registered wells within a half-mile of the MSP site, which resulted in the identification of 12 properties with records of existing potable water wells. To investigate additional properties within the search area that may exist but were not registered with the state, the USACE consulted with the Middlesex Department of Health to request a list of properties with either a water well or a record of on-site contamination. This resulted in a small number of properties already on the list obtained from NJDEP.

In order to provide a more comprehensive assessment, Middlesex tax maps were searched to identify all addresses within a half-mile radius of the MSP site that could potentially be impacted by contamination from or nearby the MSP site. Over 300 properties were identified. After cross-checking the address list with the New Jersey-American Water Company to eliminate properties on public water supply, 42 properties could not be verified as being supplied by a public water source and, therefore, might have a potable well. A field reconnaissance was conducted to investigate these 42 properties, which included drive-by inspections and door-to-door interviews to inquire whether or not the property had a potable well.

The document search and field reconnaissance resulted in a list of eight properties (in addition to the property mentioned above adjacent to the MSP site) that were potential candidates for collecting groundwater samples form potable domestic wells. Table 4b lists seven properties where samples were collected, along with the sampling dates and the VOC analytical detections. The eighth property, located adjacent to the MSP site, is only located on Table 4a. A property located southeast of MSP is not included on Table 4a or 4b because samples were not collected, but is included on Figure 5. Figure 5 shows the locations of the properties where groundwater samples were collected. All samples collected from these seven properties exhibited VOC detections below the NJDEP drinking water criteria, and, therefore, are not discussed further in this report. Table 4a presents the adjacent property Domestic Well analytical results for August 2010, September 2010, and October 2010.

Adjacent and Nearby Contaminated Sites

In 2010, a limited study was conducted for groundwater contamination at adjacent and nearby properties using the NJDEP Office of Record Access. Several properties near the MSP site had been investigated in the past by others and contained varying degrees of VOC contamination. NJDEP information on soil and groundwater contamination was obtained.

File information from a report by Arcadis on the Middlesex Industrial Site (MIS) located immediately west of MSP, now known as Absolute Auto Salvage, and dated August 27, 2001, indicated six sites within 0.5 mile of the MIS with documented contamination. The six sites were:

- 1) The Phoenix Gasket and Packaging Manufacturing property immediately northwest of the MIS and MSP sites along the Lehigh Railroad tracks;
- 2) The MSP site;
- 3) A Union Carbide Corporation property southwest of the MIS and MSP sites;
- 4) The Union Carbide Possumtown Road Landfill site southwest of the MIS and MSP sites;
- 5) The Jersey Petroleum site immediately north of the MIS and MSP sites; and
- 6) The Lincoln Fuel Company site northeast of the MSP site.

A URS Surrounding Properties Location Map for the MIS site (immediately west of the MSP site) dated October 27, 2008, highlighted seven nearby properties with potential contamination. The seven sites were:

1) Total Dry Cleaners at 600 Williams Street, approximately 350 feet east of the MSP site;

- 2) Rure Associates at 200 Mountain Avenue, about 350 feet northeast of the MSP site;
- 3) A Kendal Group property at 107 Egel Avenue (also known as the Richie's Auto property), immediately northeast of the MSP site, which appears to be the Lincoln Fuel site identified in the Arcadis report;
- 4) A second Kendal Group property at 420 Mountain Avenue, north of the MSP site and across the Lehigh Railroad tracks;
- 5) A third Kendal Group property at 646 Lincoln Boulevard, about 450 feet northwest of the MSP site and across the Lehigh Railroad tracks;
- 6) The S&G Property immediately southeast of the 646 Lincoln Blvd site and immediately across the Lehigh Railroad tracks from the MSP site; and
- 7) The Pastor Properties between 544 and 600 Lincoln Boulevard, northwest and across the Lehigh Railroad tracks from the MSP site, which appears to be the Phoenix Gasket and Packaging site identified in the Arcadis report.

Only data from properties immediately adjacent to or within a few hundred feet of the MSP site were reviewed. Significant groundwater contamination was identified at the following three properties:

- 1) MIS;
- 2) The former Pastor Enterprises across the railroad tracks to the west; and
- 3) Richie's Auto at 107 Egel Avenue.

Figure 6 shows the nearby properties where groundwater contaminated with one or more VOCs has been detected and could either be impacting the groundwater at MSP or impacted by the past activities at MSP. Groundwater VOC analytical data is posted from the various report sources described above.

The MIS site is immediately west of the MSP and has five shallow groundwater MWs with analytical data available. MWs MW-3, MW-4, and MW-5 were completed as "shallow" wells screened between 18 and 43 feet bgs and are all south and west of the MSP. MWs MW-1 and MW-2 were completed as "shallow" wells (MW-1 was screened between 18 and 43 feet bgs; MW-2 was screened between 15 and 40 feet bgs) and are west of the MSP. Although well samples were analyzed for metals, no uranium values were reported for any wells. Samples collected in July 2000 resulted in the following VOC results:

- MW-1 cis-1,2-dichloroethene(cis-1,2 DCE; 420 µg/L) and TCE (4,400 µg/L);
- MW-2 CT (3.3 µg/L) and PCE (0.8 µg/L);

- MW-3 benzene (3.6 μg/L) and TCE (2.3 μg/L);
- MW-4 benzene (31.0 μ g/L), PCE (4.9 μ g/L), and TCE (11.0 μ g/L); and
- MW-5 non-detects.

Although the TCE concentration in MW-1 was high, the well is at least 650 feet west of the MSP site boundary and in a side-gradient to downgradient position from the MSP site. The screened interval in MW-1 (between 18 and 43 feet bgs) is within a bedrock zone which is stratigraphically higher than the bedrock zones being monitored by the MSP site bedrock MWs. Therefore, the high TCE concentrations found in shallow bedrock well MW-1 cannot be from the MSP site, and must have originated from a source located at the MIS site.

The only VOCs detected at MW-2 were CT and PCE; the concentrations of both parameters were below their respective MCLs, although the CT concentration did exceed the NJDEP Specific Ground Water Quality Criteria for Class IIA Aquifers. MW-2 is the nearest (approximately 150 feet) MIS well to the MSP site and is located between ECC-MW-29B and ECC-MW-26B (Figure 6). MW-2 is downgradient of the MSP site and the screened interval is between 15 and 40 feet bgs. The screened interval at ECC-MW-26B (66-76 feet bgs) and the screened interval at ECC-MW-29B (80-90 feet bgs) are within the same bedrock hydrostratigraphic unit (designated as Unit B). Therefore, MW-2 is screened in a bedrock unit which is stratigraphically higher than the bedrock units being monitored at the MSP site.

Although VOCs were detected in MW-3 and MW-4, these two MWs are approximately 820 feet and 430 feet, respectively, away from the MSP site and in a side-gradient direction (Figure 6). MW-5 is relatively close (approximately 200 feet) to the MSP site; however, no VOCs were detected in MW-5.

The former Pastor Enterprises site is located northwest and across the Lehigh Railroad tracks from the MSP site (Figure 6), which is structurally down-dip and hydraulically side-gradient from the MSP site. Analytical data is available from numerous shallow groundwater MWs within the site. MWs 105 (sealed), 101, 102, 109, 110, 112, and 113 are all either abandoned or screened between 2 and 7 feet bgs. These shallow wells are not considered to be relevant to the MSP because the screened depths of the MWs are projected to be above the bedrock zones of interest at the MSP. In October 1991, a temporary well at the former Pastor Enterprises site was noted with significant 1,1,1-TCA contamination (74,000 μ g/L) from an assumed spill near former Pastor Enterprises well MW-104. The spill site was downgradient from the MSP. Deeper MWs (MW-104, MW-106, MW-107, MW-108, MW-111, and MW-114) at the former Pastor Enterprises site were screened between 125 and 150 feet bgs and most samples contained some VOC detections. TCE was observed in wells MW-102, MW-104, and MW-106 at

concentrations between 99-160 μ g/L. The screened depths of these MWs correlate to the zone of bedrock aquifer Units beneath the MSP site (Figures 4a and 4b); however, the source of the VOCs in these wells has not been determined.

The Richie's Auto site at 107 Egel Street is approximately 100 feet northeast of the MSP entrance and cross-gradient of the MSP site. This site has five MWs completed to approximately 20 feet bgs, and one deeper MW (URS-MW-2D) completed to approximately 96 feet bgs. A significant spill apparently occurred at this property because "free product" was reported in MW-1 and in 2003, MW-2 samples had high detections of vinyl chloride (2,100 μ g/L), cis-1,2- DCE (30,000 μ g/L), PCE (67,000 μ g/L), and TCE (2,200 μ g/L). In 2008, the sample from MW-2 had detections of *cis*-1,2-DCE (48 μ g/L), PCE (60 μ g/L), and TCE (11 μ g/L). This site is upgradient of the northern portion of the MSP site and has had significant historic VOC contamination in shallow and deep MWs. The source of the VOC contamination observed in bedrock MWs at the northern end of the MSP site could be the Richie's Auto site.

Although no site-specific data for the Total Dry Cleaners were determined during this limited study for groundwater conditions at the Total Dry Cleaners site, the same types of chlorinated compounds found at the MSP site are used in typical dry cleaning operations. The site is located hydraulically upgradient of the MSP site and near the projected fracture zone subcrop or intersection with overburden soils (Figure 6). Fracture zone subcrops can be primary pathways for recharge along with contaminant introduction and migration along those fracture zones. Potential releases at the Total Dry Cleaners site could be impacting groundwater conditions at the MSP site.

3.3 Bedrock Groundwater Characterization Activities

Based on the previous review of potential contaminant sources around MSP, a comprehensive evaluation of the existing network of bedrock MWs at MSP was necessary. This review indicated that the existing bedrock MWs at MSP were inadequate to provide a complete assessment of the vertical and horizontal extent of bedrock contamination. Most of the existing bedrock wells installed during the OU-2 Remedial Investigation were installed to a similar depth (approximately 45 to 60 feet below ground surface) and were constructed with either a long open-hole interval of 25 feet (USACE 2005a).

The project team developed a supplemental bedrock characterization program to achieve the following objectives;

• Re-assess the bedrock as a multi-unit aquifer dominated by bedding-parallel flow;

- Extend the depth of the bedrock exploration, characterization and monitoring to vertically delineate the VOC contamination;
- Investigate the horizontal extent of the VOC-impacted groundwater in discreet aquifer units;
- Determine the source(s) of the VOC contamination; and
- Refine the CSM.

Recommendations and detailed testing procedures to achieve the above objectives were presented by Dr. Michalski in a technical memorandum, dated March 8, 2010. A copy of the memorandum is provided in Appendix B. The Work Plan approved for field work was based on Dr. Michalski's memorandum.

3.3.1 2010-2011 – Bedrock Characterization

This initial characterization program was completed as proposed in the memo (Michalski 2010a), and included the following elements;

- Installation of three temporary test holes;
- Borehole geophysical logging;
- Borehole vertical flow measurements using salt tracer to identify locations of inflow and outflow fractures within the entire open-hole segments;
- Borehole depth-discreet sampling to evaluate the level VOC contamination contribution from the identified inflow fractures;
- Borehole packer tests to measure hydraulic heads, collect groundwater samples, and determine transmissivity values of the packer-isolated zones within the borehole;
- Conversion of three test holes to bedrock MWs;
- Conversion of a private water supply well to a bedrock MW; and
- Installation of two new bedrock MWs.

Further descriptions of each of these testing elements are presented in the following sub-sections.

Three temporary test holes (TTH-25, TTH-26 and TTH-27) were installed at locations beyond the site boundaries between September 2 and 9, 2010. TTH-25, TTH-26, and TTH-27 were converted during November 2010 to bedrock MWs ECC-MW-25D, ECC-MW-26D and ECC-MW-27D, respectively, to monitor Unit D; the locations of the bedrock MWs are shown on Figure 3. The test holes were installed using air rotary drilling and were temporarily completed as six-inch diameter open holes to an approximate total depth below grade ranging from 150 feet

at TTH-25 and TTH-26, to 170 feet at TTH-27. The greater completion depth of TTH-27 (ECC-MW-27D) was due to its down-dip location relative to TTH-25 (ECC-MW-25D) and TTH-26 (ECC-MW-26D) (see Figure 4a). TTH-25 was installed east of Mountain Avenue and was intended to be an upgradient off-site location relative to the MSP site based on the anticipated northwesterly direction of groundwater flow in discrete bedrock aquifer units. Borehole lithologic logs of these three test holes are included in Appendix C.

3.3.1.1 Borehole Geophysical Logging

The following set of borehole and geophysical logs was conducted in each test hole:

- Fluid temperature and electrical conductivity,
- Fluid conductivity,
- Acoustic televiewer (ATV),
- Natural gamma,
- 3-arm caliper,
- Spontaneous potential (SP), and
- Electrical resistivity.

ATV and natural gamma logs also were obtained at two existing bedrock MWs (URS-MW-22D and URS-MW-24D) to establish baseline bedrock conditions at MSP. The fluid temperature, electrical conductivity, fluid conductivity, ATV, natural gamma, caliper, SP, and electrical resistivity logs are provided in Appendix D. The acoustic and resistivity logs, together with observation of the cuttings during test hole drilling, provided a means of lithostratigraphic and fracture characterization of the penetrated bedrock section. Gamma logs were used to establish a gamma-based stratigraphic correlation between the test holes and to determine strike and dip of bedding. Figure 7 presents the natural gamma logs and the interpreted position of a gamma marker; the selection of the gamma marker is described in Section 4.1.2. Figure 7 also presents structure contours based on the gamma marker.

In addition, specific electrical conductance (EC) and fluid temperature logging were conducted in each test hole with a hand-held downhole probe. These two logs were used to corroborate possible locations of hydraulically active (transmissive) bedrock fractures and to select depths for salt tracer injections. EC, fluid temperature and salt tracer logs are provided in Appendix E.

3.3.1.2 Salt Tracer Tests

Nine salt tracing tests were conducted in the three test holes in order to identify hydraulicallyactive (transmissive) fractures within the bedrock section penetrated by the open holes and to measure vertical cross-flows between the fractures. The testing procedure is described in Appendix E.

A slug of salt tracer solution was emplaced at a pre-selected depth, and subsequent migration of the tracer within the hole was tracked by repeated EC logging over time. To interpret flow tracing test data, the EC values and depths (including the baseline EC) were transferred into a spreadsheet, and the data from individual EC logging runs were plotted. The resulting plots are presented in Appendix E. The locations of water inflow and outflow, and the type of inflow and outflow (discrete versus diffuse) were interpreted from changes in the shape and the size of the sequence of data plots.

The size of the tracer images is determined by an area between a current log run and the baseline EC run. This area is proportional to the mass of the salt tracer still remaining in the hole. Typical signature of a fracture with outflow from the borehole is recognized by a decreasing size and disappearance of the tracer image at the fracture (the loss of salt tracer mass from the hole), and/or by slower tracer velocity beyond the fracture location. Typical signatures of a fracture with inflow on the graphs may include persisting disturbance of the sequential tracer images at the inflow location (an indication of a discrete inflow), and a faster tracer migration (e.g., a steeper slope of the EC plot) downstream of the inflow location.

Local tracer velocity value was calculated from the vertical distance traveled by a selected reference point on two sequential tracer images and the elapsed time difference. Vertical flow was then calculated as a product of the local velocity and the cross-sectional area of the hole, or a unit volume of the test hole (1.47 gallons/foot for a 6-inch diameter hole). The selected velocity reference point was selected so that it did not cross any inflow fractures. This salt tracer technique is an excellent method to identify significant fractures at depth that transmit water through a multi-unit aquifer system.

3.3.1.3 Depth-Discrete Vertical Flow Sample Collection and Analysis

Depth-discrete vertical groundwater flow samples were collected and analyzed to obtain a rapid screening-level assessment of the concentrations of VOC contaminants of concern in individual inflow fractures/zones that were identified during the tracer testing. Information on vertical contaminant distribution obtained from the depth-discrete samples was used to infer the location of potential source(s) of the contamination within the boreholes.

In general, the sampling depths were selected half-way between identified adjacent fractures, in order to avoid mixing zones at the confluence of the fracture and the hole. The samples were analyzed for VOCs. The laboratory reports for these samples are provided in Appendix F. The sampling depths selected in the test holes are provided in Figure 8 and have been labeled sequentially from the deepest sample (GW-01) to the shallowest sample (GW-04). A

submersible pump was lowered to the deepest sampling location and operated at a low rate to properly purge the tubing prior to collecting an analytical sample. The pump was raised to the next sample depth and operated at a low rate to purge the tubing and collect a sample. This sequence was repeated for the remaining sampling depths.

Concentration of a contaminant of interest in an inflow fracture (C_f) was determined using the following formula (Michalski 2010a):

$$C_f = (Q_bC_b - Q_aC_a) / (Q_b - Q_a)$$

where: **Q**_a is the vertical flow measured via salt tracing above the fracture;

- **Q**_b is the vertical flow measured via salt tracing below the fracture;
- **C**_a is the contaminant concentration in the depth-discrete flow sample collected above the inflow fracture; and
- **C**_b is the contaminant concentration in the depth-discrete flow sample collected below the inflow fracture.

This formula is derived from the principle of contaminant mass preservation upon simple mixing under an assumed steady state vertical flow in the hole.

In general, representative water quality samples were collected during packer testing (see Section 3.3.1.4) only from test hole fracture zones known or suspected (based on results of salt tracing tests) to produce inflows into the open hole.

3.3.1.4 Packer Tests

Packer tests were conducted for selected zones in each of the three test holes. These tests were intended to:

- Measure vertical hydraulic head differences between the tested zones and water levels of the open holes (head profiling);
- Determine transmissivity values for the test zones; and
- Obtain groundwater samples from the isolated test zones.

Packer testing procedures followed those outlined by Michalski (Michalski 2010a).

The straddle packer assembly consisted of two inflatable packers spaced 9.5 feet apart. Pressure transducers were placed within the test zone, above the test zone and below the test zone to measure pressure changes. The packer assembly was lowered to the selected test zone and the water column was allowed to stabilize. Prior to inflating the packers, all three pressure transducer readings were reset to zero. After inflating the packers, but prior to any pumping, transducer readings in the test zone were allowed to stabilize. The stabilized pressure reading

corresponded to the hydraulic head value in the test zone and was recorded (this pressure was relative to the ambient water level in the open hole when the transducers were reset to zero). The ambient water level was actually a composite of the heads in all transmissive fractures involved in vertical cross-flows.

A small submersible pump was lowered into the test zone through a 2-inch diameter pipe. A constant-rate pumping test of the packed-off fracture interval was used to calculate the transmissivity (\mathbf{T}) of the test interval based on the following steady-state (Thiem) equation (National Research Council 1996; Cedergren 1989, p. 53):

$T = (Q/2\pi s) ln(L/r)$

where:

- L is the length of the test interval;
- **r** is the radius of the test hole;
- **s** is the stabilized drawdown value; and
- ${\boldsymbol{\mathsf{Q}}}$ is the constant pumping rate.

The pumping rate was frequently measured by manually recording the time to fill a one-quart calibrated container. Near the end of the pumping test, after purging of approximately 2 to 3 volumes of the isolated test zone and/or stabilization of EC and temperature for the discharging water, a sample of the discharge water was collected directly from a 3/8-inch diameter discharge tubing for laboratory analyses of water quality.

Four test zones per hole were selected for packer testing. The selection was based primarily on the results of salt tracer tests and the correlation of stratigraphic units between the holes developed from the geologic and geophysical data described in earlier sections of this report. Table 5 specifies the selected test zones, the depth ranges/intervals for each test, and a summary of packer-testing results for each of the three test holes.

Representative groundwater quality samples were collected during the packer tests, but only from the fracture zones that produced inflows into the open hole and showed higher-thanambient head following inflation of the packers. Outflow zones were not sampled because the water quality in such a zone was impacted by the water flowing from other zones within the borehole; therefore, the water was not representative of the outflow fracture zone. Groundwater quality for an outflow zone was determined after converting the borehole to a permanent monitoring well that was screened in such a zone.

3.3.1.5 Water Level Monitoring During Packer Tests

During the packer testing in the three test holes (TTH-25, TTH-26 and TTH-27), pressure transducers were placed in three existing on-site MWs (URS-MW-22D, ECC-MW-23D and URS-MW-24D). The goal of this monitoring was to observe water-level responses in the selected wells to precipitation events, possible pumping effects caused by the 233 Mountain Avenue domestic well, and short-term responses to pumping during the packer tests. The observed responses of the existing MWs provided a means to verify the site conceptual model of the bedrock as a leaky, dipping multiunit aquifer with bedding fractures acting as aquifer units.

Continuous monitoring of water levels in the selected on-site MWs started at noon on September 27, 2010 and ended at midnight on October 4, 2010. Figure 9 provides plots of water level elevations in these wells during the entire monitored period. Also shown on Figure 9 are precipitation events and hourly precipitation data recorded in nearby New Brunswick, New Jersey (http://climate.rutgers.edu/njwxnet). Approximately 5 inches of rain fell during three precipitation events between September 27, 2010 and October 4, 2010.

3.3.1.6 Conversion of Test Holes to Bedrock Monitoring Wells and Installation and Sampling of Additional Bedrock Monitoring Wells

After the packer tests were completed, the test holes were converted to bedrock MWs (ECC-MW-25D, ECC-MW-26D and ECC-MW-27D), with ten-foot screen intervals, to monitor aquifer Unit D. TTH-27 needed to be deepened to penetrate Unit D. Well completion details are provided in Table 2 and the locations of ECC-MW-25D, ECC-MW-26D and ECC-MW-27D are shown on Figure 3.

Separate MWs targeting aquifer Unit C (ECC-MW-25C, ECC-MW-26C and ECC-MW27C) were installed at the test-hole locations (Figure 3). Completion data for these Unit C wells are also provided in Table 2. Top of casing (TOC) and ground elevations for the six new wells were surveyed by a surveyor licensed by the State of New Jersey.

Static water levels were measured in the six new bedrock MWs and all existing MWs on November 15, 2010. Depth to water and water level elevations are presented in Table 3. Initial groundwater samples were collected from the six new bedrock MWs in November 2010 (SE 6) and analyzed for VOCs and monitored natural attenuation (MNA) parameters. Sample analytical results are summarized in Table 6. The laboratory analytical report for the sample results is included in Appendix F.

3.3.1.7 Domestic Well Testing and Sample Collection

The 233 Mountain Avenue Domestic well was taken out of service on March 4, 2011, when the house was connected to a municipal water supply. Following the removal of the domestic

pumping equipment from the well on March 9, 2011, several tests were conducted. These tests included a suite of borehole geophysical logs (caliper, temperature, electrical conductivity, natural gamma, SP, resistivity, and ATV) and a salt tracing test to determine ambient vertical flow. Several depth-discrete vertical flow samples also were collected from the well for VOC analysis.

Borehole Geophysics

On March 14 and 16, 2011, geophysical logging of the former domestic well at 233 Mountain Avenue was conducted. These logs are provided in Appendix D. The geophysics show that this 6-inch diameter well is 105 feet deep and the surface casing terminates at a depth of 17 feet bgs. The caliper log shows major well bore enlargements at 25, 44, 54, 67 and 80 feet bgs, which are likely related to fractures. The SP log shows an anomaly near 80 feet bgs. Numerous fractures are apparent on the ATV log.

Salt Tracing Test

Prior to conducting an in-well salt tracing test in the former domestic well at 233 Mountain Avenue on March 15, 2011, baseline logs of the fluid specific EC and temperature were obtained in order to select a salt injection depth. No strong inflections were apparent on these logs (Appendix E); however, minor inflections, indicative of possible minor inflows were identified at 21, 34, and 56 feet bgs.

Based on these data, and an assumed downward flow in the well, a depth of 30 feet was selected for injection of the saline slug. Approximately two ounces of common salt was dissolved in ¹/₄ gallon of fresh water and emplaced at the selected depth via a small-diameter tube. The salt solution was followed by ¹/₄ gallon of fresh-water chaser. A downhole EC probe was used to obtain EC-T logs over time producing sequential images of the injected salt tracer (Appendix E).

Depth-Discrete Sampling

On March 17, 2011, depth-discrete vertical groundwater flow samples were collected from the former domestic well at depths of 90, 65, 45 and 30 feet bgs. The selected sampling depths were positioned between the minor transmissive fractures identified in the well. Low-flow sampling equipment was used to collect these depth-discrete samples, with purging limited to evacuation of several sample tubing volumes prior to collection of the water samples. The samples were analyzed for VOCs. The laboratory report for these samples is provided in Appendix F. Analytical results for selected chlorinated VOCs of concern are also included in Figure 10. No chlorinated VOCs were detected in the upper two samples (30 feet and 45 feet) collected above the Unit B fracture. Trace-level concentrations of CT, PCE, TCE and 1,2-DCE were detected in

the lower two samples collected below the Unit B fracture. The Unit B fracture contributed a small amount of inflow (0.002 gallon per minute [gpm]) into the wellbore (Figure 10); these results suggest that the Unit B fracture is the uppermost contaminated fracture in the well. The low concentrations of the contaminants detected below the Unit B fracture are not representative of their true concentrations in the Unit B fracture, because of the overwhelming impact of vertical flow originating from the shallow fracture above Unit B. True water quality in Unit B fracture at that location was determined after converting the former domestic well into a Unit B monitoring well.

Also included at the bottom of Figure 10 are analytical results for the selected chlorinated VOCs in a tap water sample collected on October 12, 2010 from the 233 Mountain Avenue domestic well. The tap water results show concentrations an order of magnitude higher than the trace-level concentrations in depth-discrete samples. These two sets of samples were collected under different flow regime in the domestic well. One can estimate that approximately 200 gallons a day was pumped from this well during its use period. The bulk of the water pumped originated from Unit C, as the transmissivity of this unit is greater than other units, as documented by packer-testing results conducted in test holes TTH-25, 26 and 27 (Table 5). The packer testing also showed that Unit C in the upgradient test hole TTH-25 was contaminated with 1,1-DCE (Table 5) at concentrations higher than the domestic well tap water sample.

After the cessation of pumping from the domestic well, the hydraulics of this wellbore became dominated by a weak downward flow of approximately 0.013 gpm (Figure 10), as measured by the salt tracing test (Appendix E). The bulk of this downward flow is believed to consist of clean water originating from a shallow fracture at 21 feet bgs, which is well above the Unit B fracture (Figure 10). This flow was sampled during the depth-discrete sampling.

3.3.1.8 2011 Bedrock Monitoring Well Installation and Sample Collection

Two additional bedrock MWs targeting Unit B (ECC-MW-26B and ECC-MW-29B) were installed during May 2011 at the locations shown on Figure 3. The domestic well discussed above was converted in May 2011 to a monitoring well (ECC-MW-28B) screened in Unit B. Completion data for these Unit B wells are provided in Table 2. TOC and ground elevations for the new wells were surveyed by a licensed surveyor. Static water levels were measured in the new bedrock wells and all existing wells on May 24, 2011 (Table 3). Groundwater samples were collected from the new bedrock MWs beginning with the May 2011 SE (SE 7) and analyzed for VOCs and MNA parameters. VOC analytical results are summarized in Table 6.

3.3.2 2012 – Contaminant Source and Delineation Investigation

The 2012 characterization program included the following elements;

- Installation of three temporary test holes;
- Borehole geophysical logging;
- Borehole vertical flow measurements using salt tracer to identify locations of inflow and outflow fractures within the entire open-hole segments;
- Borehole depth-discreet sampling to evaluate the level VOC contamination contribution from the identified inflow fractures;
- Conversion of two test holes to bedrock MWs; and
- Installation of seven additional bedrock MWs.

Further descriptions of each of these testing elements are presented in the following sub-sections.

Three test holes (TH-22B, TH-24B, and TH-30B) were installed during May 2012 within the site boundaries. Test holes TH-24B and TH-30B were converted during May 2012 to bedrock MWs ECC-MW-24B and ECC-MW-30B, respectively, to monitor Unit B. TH-22B was plugged and abandoned after testing activities were completed due to low VOC concentrations in the depth-discrete samples.

3.3.2.1 Borehole Geophysical Logging

The following set of borehole and geophysical logs was conducted in each test hole:

- Fluid temperature and electrical conductivity,
- ATV,
- Natural gamma,
- SP, and
- Electrical resistivity.

The fluid temperature, electrical conductivity, ATV, natural gamma, SP, and electrical resistivity logs are provided in Appendix D.

In addition, specific EC and fluid temperature logging was conducted in the test hole with a hand-held downhole probe. These two logs were used to corroborate possible locations of hydraulically active (transmissive) bedrock fractures and to select depths for salt tracer injections. EC, fluid temperature, and salt tracer logs are provided in Appendix E.

3.3.2.2 Salt Tracer Tests

Four salt tracing tests were conducted in the three test holes in order to identify hydraulicallyactive (transmissive) fractures within the bedrock section penetrated by the open holes and to measure vertical cross-flows between the fractures. The testing procedure is described in Appendix E. The resulting plots are presented in Appendix E. The locations of water inflow and outflow, and the type of inflow and outflow (discrete versus diffuse) were interpreted from changes in the shape and the size of the sequence of data plots.

3.3.2.3 Depth-Discrete Vertical Flow Sample Collection and Analysis

Four depth-discrete vertical groundwater flow samples were collected and analyzed from each test hole to obtain a rapid screening-level assessment of the concentrations of VOC in individual inflow fractures/zones that were identified during the tracer testing. Information on vertical contaminant distribution obtained from the depth-discrete samples were used to infer the location of potential source(s) of the contamination within the boreholes.

In general, the sampling depths were selected half-way between identified adjacent fractures, in order to avoid mixing zones at the confluence of the fracture and the hole. The samples were analyzed for VOCs. The laboratory reports for these samples are provided in Appendix F.

CT concentrations for the four discrete samples collected from TH-30B were high (5,200 to 5,900 μ g/L). This concentration is indicative of a nearby on-site CT source. An on-site source of CT was also indicated by results from test hole TH-22B, which was installed near existing well URS-MW-22D, approximately 210 feet upgradient from ECC-MW-30B. The analytical results for the depth-discrete samples collected from TH-22B did not have any VOC detections above EPA MCL criteria and CT and TCE detections were at or just above their respective NJDEP criteria.

3.3.2.4 Conversion of Test Holes to Bedrock Monitoring Wells and Installation and Sampling of Additional Bedrock Monitoring Wells

After the depth-discrete samples were collected, test holes TH-24B and TH-30B were converted to bedrock MWs ECC-MW-24B and ECC-MW-30B, respectively, with ten-foot screen intervals, to monitor Unit B. TTH-22 was plugged and abandoned. An additional MW (ECC-MW-30D) was completed to monitor Unit D. Well completion details are provided in Table 2 and the locations of ECC-MW-24B, ECC-MW-30B, and ECC-MW-30D are shown on Figure 3. TOC and ground elevations for the new wells were surveyed by a licensed surveyor. Static water levels were measured in the new bedrock wells and all existing wells on June 19, 2012 (Table 3). Groundwater samples have been collected from the new bedrock MWs beginning with the June 2012 SE (SE 12) and analyzed for VOCs and MNA parameters. VOC analytical results for the

November 2012 SE (SE 13) are summarized in Table 7; SE 13 was the most recent SE that included all previously sampled bedrock MWs.

Five additional bedrock MWs targeting Unit B (ECC-MW-27B, ECC-MW-31B, ECC-MW-32B, ECC-MW-33B, and ECC-MW-34B) and one additional bedrock MW targeting Unit C (ECC-MW-32C) were installed during November 2012 at the locations shown on Figure 2. ECC-MW-31B, ECC-MW-32B, ECC-MW-32C, ECC-MW-33B, and ECC-MW-34B were installed to investigate another possible source of CT, chloroform (CF), and TCE. ECC-MW-27B was installed to delineate the down-gradient extent of the CT plume in Unit B. Completion data for these wells are provided in Table 2. TOC and ground elevations for the new wells were surveyed by a licensed surveyor. Static water levels were measured in the new bedrock wells and all existing wells on November 26, 2012 (Table 3). Groundwater samples have been collected from the new bedrock MWs beginning with the November 2012 SE (SE 13) and analyzed for VOCs and MNA parameters. VOC analytical results for the November 2012 SE (SE 13) are summarized in Table 7.

Depth-discrete samples also were collected from URS-MW-2D in October 2012 and analyzed for VOCs. The laboratory analytical report for the sample results is included in Appendix F.

3.3.3 2013 – Contaminant Source and Delineation Investigation

Additional MWs were required to delineate the down-gradient extent of the CT plume. The 2013 characterization program included the following elements;

- Installation of one temporary test hole;
- Borehole geophysical logging;
- Borehole vertical flow measurements using salt tracer to identify locations of inflow and outflow fractures within the entire open-hole segments;
- Borehole depth-discreet sampling to evaluate the level VOC contamination contribution from the identified inflow fractures;
- Conversion of test hole to a bedrock MW; and
- Installation of an additional bedrock MW.

Further descriptions of each of these testing elements are presented in the following sub-sections.

One test hole (TH-35) was installed during January 2013 at a location beyond the site boundaries. Test hole TH-35 was converted during February 2013 to bedrock MW ECC-MW-35C to monitor Unit C (Figure 3).

3.3.3.1 Borehole Geophysical Logging

The following set of borehole and geophysical logs were conducted in the test hole:

- Fluid temperature and electrical conductivity,
- ATV,
- Natural gamma,
- SP, and
- Electrical resistivity.

The fluid temperature, electrical conductivity, ATV, natural gamma, SP, and electrical resistivity logs are provided in Appendix D.

In addition, specific EC and fluid temperature logging was conducted in the test hole with a hand-held downhole probe. These two logs were used to corroborate possible locations of hydraulically active (transmissive) bedrock fractures and to select depths for salt tracer injections. EC, fluid temperature and salt tracer logs are provided in Appendix E.

3.3.3.2 Salt Tracer Tests

Three salt tracing tests were conducted in the test hole in order to identify hydraulically-active (transmissive) fractures within the bedrock section penetrated by the open hole and to measure vertical cross-flows between the fractures. The testing procedure is described in Appendix E. The resulting plots are presented in Appendix E. The locations of water inflow and outflow, and the type of inflow and outflow (discrete versus diffuse) were interpreted from changes in the shape and the size of the sequence of data plots.

3.3.3.3 Depth-Discrete Vertical Flow Sample Collection and Analysis

Five depth-discrete vertical groundwater flow samples were collected and analyzed from the test hole to obtain a rapid screening-level assessment of the concentrations of VOC contaminants of concern in individual inflow fractures/zones that were identified during the tracer testing. Information on vertical contaminant distribution obtained from the depth-discrete samples were used to infer the location of potential source(s) of the contamination within the boreholes.

3.3.3.4 Conversion of Test Hole to Bedrock Monitoring Well and Installation and Sampling of Additional Bedrock Monitoring Wells

After the depth-discrete samples were collected, the test hole was converted to a bedrock MW (ECC-MW-35B) with a ten-foot screen interval, to monitor Unit B. An additional bedrock MW

(ECC-MW-35C) was completed to monitor Unit C. Well completion details are provided in Table 2 and the locations of ECC-MW-35B and ECC-MW-35C are shown on Figure 3. TOC and ground elevations for the new wells were surveyed by a licensed surveyor. Static water levels were measured in the new bedrock wells and all existing wells on February 19, 2013 (Table 3). Groundwater samples were collected from the new bedrock MWs during the February 2013 SE (SE 14) and analyzed for VOCs and MNA parameters. VOC analytical results for the November 2012 SE (SE 13) are summarized in Table 7. The laboratory analytical report for the sample results is included in Appendix F.

3.3.4 2014 – Additional Data Gathering

An additional investigation of groundwater was completed to verify/further delineate both the potential source area and downgradient off-site impacts from VOCs, specifically contaminants of concern CT and TCE through Unit B. The 2014 additional data gathering investigation included the following elements;

- Installation of 13 temporary on-site groundwater monitoring wells (GW-1 through GW-13) and collection of groundwater screening samples;
- Plugged and abandoned temporary on-site groundwater monitor wells (GW-1 through GW-13) except for GW-5 and GW-10 which were converted into groundwater MWs EE-MW-40B and EE-MW-41S, respectively;
- Abandonment of groundwater monitor wells MW-OB-7 and MW-OB-10;
- Installation of groundwater monitor well MW-OB-7R. MW-OB-7 was replaced with MW-OB-7R within 10 feet of the original location (MW-OB-10 was not replaced);
- Installation of four off-site groundwater MWs (EE-MW-36B through EE-MW-39B) and collection of groundwater screening samples; and
- Gamma logging was completed in the open off-site borings to identify the gamma marker bed.

Further descriptions of each of these testing elements are presented in the following subsections.

3.3.4.1 Borehole Geophysical Logging

Gamma logging was conducted in open bedrock borings to identify the gamma marker bed for the Unit B fractured bedding plane and are provided in Appendix D. Gamma logging was used as needed to locate the gamma marker bed approximately 5 feet above Unit B to provide additional confidence that the proper zone was being sampled.

3.3.4.2 Packer Screening Sample Collection and Analysis

A packer assembly was installed to seal off maximum 10-foot open hole zones or as appropriate, based on lithology. Each boring had the first packer assembly straddling Unit B for sampling, followed by 10-foot intervals above the initial sample for a 50-foot total interval. The samples were collected from each boring to obtain a rapid screening-level assessment of the concentrations of VOC contaminants of concern prior to well installation. Low-flow methods were used to determine the potential vertical contaminant distribution of VOCs within the bedrock. A total of 20 depth-discrete vertical groundwater flow samples were collected from the off-site wells EE-MW-36B through EE-MW-39B. These 20 samples consisted of five samples collected at 10-foot intervals starting at the bottom of each borehole/Unit B, continued by sampling upward. A list of the intervals where these groundwater samples were collected is included as Table 1 in the Draft Final-Updated Data Summary Report (USACE 2016).

3.3.4.3 Conversion of Borings to Bedrock Monitoring Wells and Installation and Sampling of Additional Bedrock Monitoring Wells

After the depth-discrete samples were collected, the borings were converted to bedrock MWs (EE-MW-36B through EE-MW-39B) with 10-foot screen intervals, to monitor Unit B. Well completion details are provided in Table 2 and the locations of EE-MW-36B through EE-MW-39B are shown on Figure 3. TOC and ground elevations for the new wells were surveyed by a licensed surveyor. Static water levels were measured in the new bedrock wells and all existing wells on October 6, 2014 (Table 3). Groundwater samples were collected from the new bedrock MWs during the October 2014 SE (SE 15) and analyzed for VOCs which are summarized in Tables 6 and 7. The laboratory analytical report for the sample results is included in Appendix F.

3.3.5 2015/2016 – Additional Data Gathering

An additional data gathering investigation to further delineate the maximum extent of VOC migration off-site through Unit B and on-site contamination in shallow bedrock above Unit B. The 2015/2016 investigation included the following elements:

- Installation of five on-site borings (GW-14 through GW-18) and collection of groundwater screening samples;
- Plugged and abandoned temporary on-site groundwater monitor wells (GW-14, GW-16, and GW-18). GW-15 and GW-17 were converted into groundwater MWs EE-MW-44S and EE-MW-45S, respectively;
- Installation of two on-site groundwater MWs (EE-MW-44S and EE-MW-45S);
- Installation of two off-site groundwater MWs (EE-MW-42B and EE-MW-43B);

- Gamma logging was completed on the open off-site boreholes to identify the gamma marker bed; and
- Completion of a geophysical investigation of test hole EE-MW-42B using an optical televiewer to identify fractures, and a heat pulse meter to identify flow characteristics within the borehole.

Descriptions of each of these testing elements are presented in the following subsections.

3.3.5.1 Borehole Geophysical Logging

Gamma logging was conducted in open bedrock borings to identify the gamma marker bed for the Unit B fractured bedding plane and are provided in Appendix D. Gamma logging was used as needed to locate the gamma marker bed approximately 5 feet above Unit B to provide additional confidence that the proper zone was sampled.

3.3.5.2 Packer Screening Sample Collection and Analysis

A packer assembly was installed to seal off maximum 10-foot open hole zones or as appropriate, based on lithology, straddling Unit B for sampling. The samples were collected from each test hole to obtain a rapid screening-level assessment of the concentrations of VOC contaminants of concern prior to well installation. Low-flow methods were used to determine the potential vertical contaminant distribution of VOCs within the bedrock.

A total of 21 depth-discrete vertical groundwater flow samples were collected from the off-site wells EE-MW-42B (PS-42B) and EE-MW-43B (PS-43B). A total of 12 depth-discrete vertical groundwater flow samples were collected from the on-site borings GW-10 (converted to MW-41S), GW-11, GW-12, GW-13, and URS-MW-2D. A list of the intervals where these groundwater samples were collected is included as Table 1 in the Draft Final-Updated Data Summary Report (USACE 2016). All samples were analyzed for VOCs using 24-hour or less turnaround time.

3.3.5.3 Conversion of Borings to Bedrock Monitoring Wells and Installation and Sampling of Additional Bedrock Monitoring Wells

After the depth-discrete samples were collected, the borings were converted to bedrock MWs EE-MW-42B and EE-MW-43B with screen intervals of 25 feet and 10 feet, respectively, to monitor Unit B. Well completion details are provided in Table 2 and the locations of EE-MW-42B and EE-MW-43B are shown on Figure 3. TOC and ground elevations for the new wells were surveyed by a licensed surveyor. Static water levels were measured in the new bedrock wells and all existing wells on December 15, 2015 (Table 3). Groundwater samples were collected from the new bedrock MWs during the November 2015 through January 2016 SE (SE

16) and analyzed for VOCs which are summarized in Tables 6 and 7. The laboratory analytical report for the sample results is included in Appendix F.

4.0 INVESTIGATION FINDINGS

This section presents data from the following sources:

- 1) Data obtained during the installation of 25 borings and 30 new bedrock MWs both on-site and off-site; and
- 2) Data from 16 on-site MSP SEs completed between August 2008 and January 2016.

A combined QCSR and Data Summary Report (DSR) were generated after each SE presenting the groundwater monitoring and analytical results. The QCSR for SE 15 and SE 16 is included as Appendix H. Each QCSR and DSR contains appendices with chain-of-custody records, groundwater collection field sheets, Daily Quality Control Reports (DQCRs), synoptic water level measurements and the laboratory analytical results (on compact disk). The documents present detailed results of the data validation for each sampling event, including data qualifiers, complete data summary tables, and laboratory data packages.

The QCSRs and DSRs for SEs 1 through 16 are as follows:

- Final Quality Control Summary Report and Data Summary, August 2008 Groundwater Sampling Event (USACE 2009a);
- Quality Control Summary Report and Data Summary, November 2008 Groundwater Sampling Event (USACE 2009b);
- Quality Control Summary Report and Data Summary, February 2009 Groundwater Sampling Event (USACE 2009c);
- Quality Control Summary Report and Data Summary, December 2009 Groundwater Sampling Event (USACE 2010c);
- *Quality Control Summary Report and Data Summary, April 2010 Groundwater Sampling Event* (USACE 2010d);
- Quality Control Summary Report and Data Summary, November 2010 Groundwater Sampling Event (USACE 2011a);
- *Quality Control Summary Report and Data Summary, May 2011 Groundwater Sampling Event* (USACE 2011b);
- Quality Control Summary Report and Data Summary, August 2011 Groundwater Sampling Event (USACE 2011c);
- Quality Control Summary Report and Data Summary, November 2011 Groundwater Sampling Event (USACE 2012a);
- Quality Control Summary Report and Data Summary, February 2012 Groundwater Sampling Event (USACE 2012b);

- *Quality Control Summary Report and Data Summary, June 2012 Groundwater Sampling Event* (USACE 2012c);
- Quality Control Summary Report and Data Summary, August 2012 Groundwater Sampling Event (USACE 2012d);
- Draft Quality Control Summary Report and Data Summary, November 2012 Groundwater Sampling Event (USACE 2013); and
- Draft Final-Updated Data Summary Report for Additional Data Gathering for Completion of Feasibility Study Report Groundwater Operable Unit (USACE 2016).

The Analytical Laboratory Report for each SE is included in the QCSR/DSR for that SE.

4.1 Test Hole Geophysical, Tracer and Packer Test Results

As described in Section 3.3, three temporary test holes (TTHs) were installed at locations beyond the MSP site boundaries in September 2010. These TTHs were logged geophysically, subjected to salt tracer tests, and sampled as TTHs and later as completed bedrock MWs. A private well was taken out of service in March 2011, after which this well was logged geophysically, subjected to salt tracer tests, and sampled. This subsection presents analyses for the MSP off-site deep aquifer geophysical logs, salt tracer testing data, and VOC sampling results.

Each of the three aquifer units includes a conductive bedding fracture that dips at 11° to the northwest, and have hydraulic characteristics of minor transmissive fractures within a low-transmissivity bedrock sequence penetrated by the test holes.

High-angle transmissive fractures were only mapped near the top of the bedrock in TTH-27 where they provide an upward flow path to the exposed slope in the railroad cut north of the MSP site. The high-angle fractures (joints) provide for vertical leakage in a multi-unit bedrock that otherwise exhibits groundwater flow parallel to the bedding planes.

4.1.1 Acoustic Televiewer and Resistivity Logs

The ATV and resistivity logs, together with limited observation of cuttings during drilling indicated that red massive mudstone and thin-bedded mudstone are the dominant lithologic types. Based on the ATV logs, a weathered bedrock zone extends to depths of 50 feet to 70 feet bgs.

4.1.2 Gamma Logs

Natural gamma borehole logs obtained from the initial three test holes (TTH-25, TTH-26 and TTH-27) and two existing MWs (URS-MW-22D and URS-MW-24D) are presented on Figure 7.

Although the natural gamma signal is attenuated by casing in a completed well, the relative strength of the signal is preserved within the cased-off section. No strong "gamma marker" is apparent on the logs; however, a correlation between the logs has been established based on the observed cyclical nature of the gamma counts, which is related to the Van Houten cycles (see Section 2.4). A referenced gamma marker was selected and is shown on Figure 7. By interpolating elevations of the selected gamma marker in the three test holes and the two pre-existing wells (URS-MW-22D and URS-MW-24D), a map depicting the planar surface of the marker has been generated (Figure 7). The map shows a strike of the gamma marker (bedding plane) of N 57° E and a dip angle of 10.4° NW. These values are very close to the preliminary estimates of N 56° E for the strike and 11° NW for the dip angle of the bedrock units established from regional studies. This conceptual model was used throughout the remainder of the additional data collection to identify the gamma marker bed and water bearing units below it.

4.1.3 Tracer Tests and Depth Discrete Sample Results

The baseline EC and temperature logs and plots of sequential EC profiles and tracer images over time for each of the nine salt tracer tests conducted in TTH-25, TTH-26 and TTH-27 are provided in Appendix E. Also shown on the plots are calculations of local tracer velocity for reference markers selected on the tracer images. The synthesis of salt tracing test results for each test hole, including the calculated flow values (ambient flow), is provided on Figure 8. Locations of the transmissive fractures, as well as direction and relative size of measured vertical flows, also are shown on Figure 8.

Depth-discrete groundwater samples were collected from TTH-25, TTH-26, TTH-27 and the domestic well. The concentrations of CT, CF, PCE, TCE and 1,1-DCE detected in the samples are presented on Figure 8 (TTH-25, TTH-26, and TTH-27) and Figure 10 (domestic well). The analytical laboratory reports for depth-discrete samples are provided in Appendix F. Figure 8 also provides the contaminant concentrations in the groundwater from inflow fractures as calculated with the formula presented in Section 3.3.1.3. Contaminant concentrations were not calculated for the groundwater from inflow fractures in the domestic well.

TTH-25

The baseline EC and temperature logs for test hole TTH-25 (Appendix E) indicated a possible transmissive fracture at a depth of 90 feet. In Tracer Test 1, a saline slug was released at 35 feet bgs to assess ambient flow in the upper portion of the water column. Some of the tracer was observed to spread downward, driven by an interpreted inflow from a fracture at 39 feet. This inflow kept much of the tracer above this depth. A downward flow velocity of 0.07 feet per minute (ft/min), corresponding to a downward flow of 0.11 gpm, was calculated for the test hole segment below 39 feet bgs (Figure 8).

In Tracer Test 2, the tracer slug was released at a depth of 130 feet. Some of the salt tracer was pushed upward during the release; however, the bulk of the tracer migrated downward under ambient flow. Some of the tracer exited through a fracture at 137 feet bgs. This main exit fracture was designated as bedrock hydrostratigraphic Unit D and is identified on Figure 8. The remainder of the tracer migrated toward the bottom of the test hole at a decreasing velocity that corresponded to a downward flow of less than 0.01 gpm.

In Tracer Test 3, the tracer slug was released at 80 feet bgs, which was 10 feet above a transmissive fracture interpreted from the baseline EC and temperature logs at 90 feet bgs. The signature of this hydraulically active fracture included a small indentation of EC profiles at the inflow fracture depth. This fracture was designated as bedrock hydrostratigraphic Unit C and is identified on Figure 8. A downward tracer velocity of 0.015 ft/min, corresponding to a downward flow of 0.023 gpm, was calculated below 90 feet. The lowermost portion of the Test 3 plots also includes images of the earlier tracer slug released in Test 2 at 130 feet.

The synthesis of wellbore hydraulics of TTH-25 compiled from the salt tracing test results (Figure 8) documents a downward, discharging pattern of ambient vertical flows. This pattern is indicative of decreasing hydraulic head with depth in this test hole.

The ambient flow regime in TTH-25 featured only one inflow fracture zone near the top of the open hole and all other fractures were outflow zones (Figure 8). The formula presented in Section 3.3.1.3 is not applicable for calculating contaminant concentrations in an outflow zone. Sample GW-01, which was collected below Unit C, showed the highest concentrations of 1,1-DCE (63 μ g/L) and TCE (18 μ g/L), indicating that the contaminant concentrations in the lower portion of this test hole. The chlorinated VOC contaminant concentrations in the uppermost sample (GW-04) are several times lower than in sample GW-01. The upper samples likely measured the quality of residual development water not yet completely purged by the slow downward flow prior to the sampling date. Because of this flow, the measured contaminant concentrations may underestimate actual concentrations in the lower zones.

TTH-26

The baseline EC plot indicated higher EC values in the upper portion of the water column and possible transmissive fractures at depths of 45 feet and 73 feet (Appendix E). Three salt tracer injection tests were completed in this hole. In Tracer Test 1, the tracer slug was released at a depth 36 feet bgs. The slug migrated downward at a slow velocity of 0.017 ft/min (flow of 0.025 gpm). The velocity increased to 0.053 ft/min (flow of 0.075 gpm) below the fracture at 45 feet bgs, indicating an inflow of 0.05 gpm from this fracture. The flow exited through a fracture at

72 feet. This bedding fracture correlates with hydrostratigraphic Unit B on Figure 8. The domestic well was in use during the salt tracing tests.

In Tracer Test 2, the saline slug was released at 130 feet bgs. Subsequent images of this tracer slug indicated a stagnant condition in the hole below 145 feet bgs and a very slow upward flow above this depth (Appendix E). A fracture at 145 feet bgs correlates with hydrostratigraphic Unit D on Figure 8.

In Tracer Test 3, the saline tracer was released at 90 feet bgs. Images of this tracer slug indicated that an inflow from a fracture at 94 feet bgs divided the slug, causing a larger portion of the tracer to migrate downward, and a smaller portion to migrate upward. This fracture is designated as hydrostratigraphic Unit C on Figure 8. The calculated tracer velocities were 0.04 ft/min (flow of 0.06 gpm) for the downward migration and 0.005 ft/min (flow of 0.08 gpm) for the upward migration. The lowermost portion of the Tracer Test 3 plots includes images of the earlier tracer slug released during Tracer Test 2 at 130 feet bgs.

As revealed by the salt tracing results, the hydraulics of cross-flows in TTH-26 is atypical as it featured two exit zones at different depths (Figure 8). The ambient flow regime in TTH-26 featured one inflow fracture zone at a depth of 94 feet bgs and another inflow fracture zone at a depth of 145 feet bgs (Figure 8). Two other fracture zones (72 and 126 feet bgs) were outflow zones. The formula presented in Section 3.3.3 is not applicable for calculating contaminant concentrations in an outflow zone. CT was a principal contaminant detected in depth-discrete samples from TTH-26 (Figure 8). The fracture at 94 feet bgs (Unit C) showed the highest calculated concentration of CT (74 μ g/L). TCE (calculated concentration: 8.3 μ g/L) and CF (calculated concentration: 5.3 μ g/L) also were detected in the sample from 94 feet bgs. A CT concentration of 21 μ g/L also was calculated for the inflow fracture at 45 feet (Figure 8).

TTH-27

Three salt tracer tests were completed in TTH-27, with tracer release depths at 36, 150, and 90 feet bgs for Tracer Tests 1, 2, and 3, respectively (Appendix E). Ambient hydraulics of this hole featured a consistent upward flow in all three tests. The measured upward flow increased from 0.01 gpm in the lower portion of the hole to 0.20 gpm in the upper portion of the open hole. The largest inflow of 0.15 gpm was from a fracture at 94 feet bgs, which correlates with hydrostratigraphic Unit B from the other two test holes. A fracture at 120 feet bgs is designated as hydrostratigraphic Unit C on Figure 8. TTH-27 was not deep enough to penetrate hydrostratigraphic Unit D. The flow exited through sub-vertical fractures at 47 feet bgs and 40 feet bgs, as interpreted from the baseline EC and temperature logs and ATV data.

The ambient flow regime in TTH-27 featured inflow fracture zones throughout the depth of the borehole (Figure 8) and a consistent upward flow. CT was the principal contaminant in TTH-27, with the highest calculated concentration of 182 μ g/L in the fracture zone at 94 feet bgs (Unit B). The calculated concentration of CT in the sample from the fracture at 120 feet bgs (Unit C) was 55 μ g/L. TCE and CF also were detected in the samples from both fracture zones and the calculated concentrations were as follows: TCE – 15 μ g/L (Unit B) and 13 μ g/L (Unit C); CF – 16 μ g/L (Unit B) and 4 μ g/L (Unit C).

Domestic Well

The results of the salt tracer test in the former domestic well showed a slow downward flow within the well towards an outflow zone at 80 feet bgs, designated on Figure 10 as Unit C. The baseline EC plot for the domestic well indicated minor inflections, indicative of possible minor inflows, at 21, 34, and 56 feet bgs (Appendix E). Based on these data, and an assumed downward flow in the well, a depth of 30 feet was selected for injection of the saline slug. The images indicate a slow downward migration of the tracer under ambient flow in the well originating above the tracer emplacement depth, presumably from the "fracture" at 21 feet bgs. After 24 hours, the receding limb of the tracer image only moved 12 feet downward. The tracer exited the well via "fractures" at 80 feet bgs and below.

From the tracing data, downward flow in this well was calculated to be 0.013 gpm above the "fracture" at 54 feet bgs and increased to 0.015 gpm below this fracture. The fracture at 54 feet bgs correlates with hydrostratigraphic Unit B and the fracture at 80 feet bgs correlates with hydrostratigraphic Unit C on Figure 10. Figure 10 also provides a diagram of ambient vertical flow in the domestic well, as calculated from the salt tracing test data.

A tap water sample collected in October 2010 from the domestic well had VOC concentrations as follows: CT (14 μ g/L); CF (1.2 μ g/L); PCE (13 μ g/L); TCE (8.3 μ g/L); and 1,1-DCE (65 μ g/L) (Figure 10). Depth-discrete samples collected in the well indicate the contaminants are coming from the fracture zone at 54 feet bgs (Unit B).

4.1.4 Packer Tests

Pressure transducer records for each packer-tested zone of the three test holes are provided as graphs in Appendix G. These records also provide additional information on hydraulic relations of the packer-isolated fractures to other transmissive fractures, including degree of vertical leakage (or confinement) and recharge conditions during the pumping and subsequent recovery period.

Table 5 provides a summary of the measured hydraulic heads, transmissivity values calculated from the pumping rates (Q) and drawdown (s) data, and stabilized EC values. Table 5 also

provides concentrations of the VOCs that exceed comparison criteria (CT, CF, TCE, PCE, and 1,1-DCE) for the test zones in TTH-25, TTH-26 and TTH-27.

Hydraulic Heads

The head readings reported in Table 5 were obtained by averaging several sequential readings and rounding the averages to 0.1 foot of water. Although a direct comparison of the measured heads between the holes may be impacted by testing the holes on different dates, the higher head values measured in TTH-25 (Table 5) are consistent with an upgradient/background location of that test hole relative to TTH-26 and TTH-27. When comparing the heads measured in specific test zones, the hydrostratigraphic position of such zones within a sequence of dipping beds needs to be accounted for. For example, packer tested Zone IV in TTH-25 is equivalent to Zone III in TTH-26 and Zone III in TTH-27; however, they all straddled hydrostratigraphic Unit B. The higher hydraulic head value of 40.8 feet above mean sea level (amsl) measured in Zone IV of TTH-25, when compared to 36.8 feet amsl measured in Zone III of TTH-26 and TTH-27, documents an upgradient position of Unit B in TTH-25 relative to the other two holes.

The pattern of vertical head distribution in each of the test holes (Table 5) is consistent with that inferred from the vertical flow salt tracer tests. In TTH-25, the highest heads, indicative of inflow zones, were measured in the upper portion of the hole, and the lowest heads (indicative of outflow zones) were measured in Zones I and III. Zone III corresponds to the outflow zone (fracture) at 90 feet bgs, and Zone I corresponds to an outflow zone near the bottom of the test hole (Figure 8).

In TTH-26, the lowest head was measured in Zone III, which straddled a principal water outflow fracture at 72 feet bgs (Figure 8). In TTH-27, the highest head was measured in Zone I and decreased upward through Zone IV, consistent with an upward flow measured throughout the open-hole section of this test hole (Figure 8).

Transmissivity Values

The sum of the calculated transmissivity values for all test zones was 78 gallons per day per foot (gpd/ft) in TTH-25, 93 gpd/ft in TTH-26, and 233 gpd/ft in TTH-27 (Table 5). For comparison, a single major bedding fracture (aquifer unit) in the Passaic formation typically exhibits a transmissivity value greater than 1,000 gpd/ft (Michalski 1990). Therefore, the low transmissivity values measured for the entire open-hole section of the test holes indicate that no major aquifer unit was penetrated by any of the test holes. The section of Passaic formation penetrated by these test holes can be considered a regional aquitard. However, the measured transmissivity values are not uniformly distributed in the test holes. The bulk of these values are associated with specific zones that are parts of the minor bedrock hydrostratigraphic units

designated as Units B, C and D (Table 5 and Figure 8). The packer testing results also show that the thick bedrock section between Unit D and Unit C is a tighter aquitard.

Analytical Results for Packer Samples

Analytical laboratory reports on groundwater samples collected during the packer tests are provided in Appendix F. Concentrations of the key chlorinated volatile contaminants of concern (CT, CF, TCE, PCE and 1,1-DCE) detected in these samples are presented on Figure 8 and summarized in Table 5. These results are generally similar to the depth-discrete sampling results, which also are presented on Figure 8.

Different sources for the individual contaminants detected in the samples are indicated by their highest concentrations in different test zones (Table 5). The highest concentration of TCE (85 μ g/L) was detected near the bottom (Zone I) of TTH-25 (Figure 8), which is an upgradient off-site location. Zone I in TTH-25 corresponds to hydrostratigraphic Unit D. The highest concentrations of PCE (30 μ g/L) and 1,1-DCE (140 μ g/L) were detected in Zone III (Unit C) of the same upgradient test hole (TTH-25). The highest concentrations of CT (84 μ g/L) and CF (7.1 μ g/L) were detected in Zone II (Unit B) of downgradient test hole TTH-26 (Figure 8). CF is considered to be a breakdown product of CT and 1,1-DCE may be a breakdown product of 1,1,1-TCA.

Water Level Monitoring During Packer Pump Testing

Distinct drops of water levels, interpreted as drawdown due to periodic pumping at the domestic well, are apparent in the plots for URS-MW-22D and URS-MW-24D on Figure 9, but not for ECC-MW-23D. Examples of such synchronous sharp responses to the domestic well pumping are at 6 p.m. on September 28, 2010 and around 8 a.m. on October 2, 2010 (Figure 9). This type of response is indicative of a direct hydraulic connection between the domestic well and MWs URS-MW-22D and URS-MW-24D. ECC-MW-23D did not respond to the domestic well pumping during these two events, indicating the lack of a direct hydraulic connection between these two wells.

The only significant direct response to packer testing recorded in ECC-MW-23D (Figure 9) was to test pumping of Zone IV in TTH-26. Indirect responses were observed in ECC-MW-23D to packer testing of Zone IV in TTH-27 and, to a lesser degree, to packer testing of Zone IV (Unit B) in TTH-25. Well URS-MW-24D responded directly to pumping of Zone III (Unit B) and IV in TTH-27. URS-MW-24D also directly responded to pumping of Zone III (Unit B) and IV of TTH-26. The strongest drawdown response recorded at well URS-MW-22D was to pumping of Zone III (Unit C) in TH-25.

4.2 **Potentiometric Surfaces**

Based on the measured groundwater elevations in the MWs for December 15, 2015 (Table 3), potentiometric surface contours were prepared for the shallow overburden water bearing unit (Figure 11). As discussed in Section 2.5, the groundwater divide is present in the northcentral portion of the site with groundwater flowing both north and south from this topographic high point.

Based on the measured groundwater elevations in the MWs for October 6, 2014, and December 15, 2015 (Table 3), potentiometric surface contours were prepared for the bedrock hydrostratigraphic Unit B (Figures 12a and 12b). The bedrock potentiometric surfaces on Figures 12a and 12b show groundwater flow to the northwest. This flow direction is subparallel to the dip of the bedding. From the limited amount of wells available for Unit C and Unit D, the groundwater flow direction appears to mimic the flow direction of Unit B wells.

The overburden groundwater unit recharges the bedrock aquifer as exhibited by the significant downward vertical gradient between the average elevation of the overburden unit and the bedrock aquifer using water level measurements collected since 2008 (49.47 and 38.49 feet AMSL, respectively). The vertical gradient observed between bedrock Units B, C, and D, as observed in cluster well locations, is predominantly downward although minor upward vertical gradient has been noted in measurements.

4.3 Analytical Results and Trends for Bedrock Monitoring Wells

This section presents the analytical results and trends for the bedrock MWs at the MSP site over 16 SEs from August 2008 to January 2016. Laboratory reports of the analytical results for the SEs are provided in the QCSRs and DSRs for the individual SEs (see Section 3.1). Figures 13a, 13b, and 13c show the TCE, CT, and 1,1-DCE trends, respectively, in the bedrock well samples over the 16 SEs. Figure 13d shows the TCE, CT, and CF trends in on-site Unit B bedrock MWs (MW-30B and MW-41S) near the source area.

Table 6 presents a summary of the detections for the VOCs in the bedrock MW samples from August 2008 to January 2016. Detections that exceed the New Jersey State Specific Ground Water Quality Criteria (SGWQC) for Class IIA aquifers (NJDEP 2010) and/or the EPA MCLs are highlighted in the table. The SGWQC for the VOCs at the MSP site included on Table 6 include:

- $CF 70 \ \mu g/L;$
- 1,1-DCE 1 μg/L;
- $CT 0.4 \ \mu g/L;$

- PCE 0.4 μ g/L; and
- TCE $-1 \mu g/L$.

Based on the bedrock hydrostratigraphy and groundwater flow directions within Unit B (Figures 12a and 12b), and contaminant distribution, bedrock MWs completed in Unit B are categorized as follows:

- EE-MW-40B is an upgradient well;
- EE-MW-41S and ECC-MW-30B on-site wells near the source area;
- URS-MW-2D, ECC-MW-31B, ECC-MW-32B, ECC-MW-33B, ECC-MW-34B, EE-MW-40B, and EE-MW-44S on-site wells that were installed to define the source area but were determined not to be in the source area;
- ECC-MW-24B, URS-MW-24D, ECC-MW-28B, and EE-MW-45S on-site and off-site side-gradient wells;
- ECC-MW-26B, ECC-MW-27B, ECC-MW-29B, ECC-MW-35B, EE-MW-36B, EE-MW-37B, EE-MW-38B, EE-MW-39B off-site down-gradient wells;
- EE-MW-42B off-site down-gradient control well; and
- EE-MW-43B and EE-MW-36B off-site side-gradient control wells.

These wells are used for the evaluation of VOC contaminant concentration trends and the potential for natural attenuation of the VOC contamination. Trends are discussed below for the five predominant VOCs (TCE, 1,1-DCE, CT, CF, and PCE).

4.3.1 Unit B Analytical Results

The VOC detections for the Unit B bedrock wells during the 16 SEs are presented in Table 6 and are interpreted as follows:

- <u>URS-MW-2D</u>: The VOC results for on-site well URS-MW-2D show a consistent presence of TCE and CT above the NJDEP and EPA criteria; and low concentrations below the NJDEP and EPA criteria to non-detects for CF, 1,1-DCE, and PCE.
- <u>ECC-MW-24B</u>: Five SEs (11, 12, 13, 15 and 16) have been recorded for side-gradient on-site well ECC-MW-24B. The results show a consistent presence of TCE and CT above the NJDEP and EPA criteria; a consistent presence of CF below the NJDEP and EPA criteria; and a consistent presence of PCE and 1,1-DCE at low concentrations above the NJDEP criteria except for SE 16 when PCE was below the NJDEP criteria, and SE 15 and SE 16 when 1,1-DCE was above the NJDEP and EPA criteria.

- <u>URS-MW-24D</u>: The results for side-gradient off-site well URS-MW-24D show consistent concentrations of TCE and CT above the NJDEP and EPA criteria; a gradual decrease in the concentration of CF below the NJDEP and EPA criteria; and a decrease in the concentrations of PCE and 1,1-DCE to concentrations below the NJDEP and EPA criteria.
- <u>ECC-MW-26B</u>: The results for down-gradient off-site well ECC-MW-26B show nondetects for PCE and 1,1-DCE; low concentrations for TCE and CF; and a downward trend for CT (SE 16 was only above the NJDEP and EPA criteria). The analytical results for down-gradient off-site well ECC-MW-26B show the presence of TCE, CT, and CF at levels approximately one order of magnitude less than in side-gradient off-site well URS-MW-24D.
- <u>ECC-MW-27B</u>: Three SEs (13, 15 and 16) have been recorded for down-gradient offsite well ECC-MW-27B and the results show a low concentration of CF below the NJDEP and EPA criteria; low concentrations of CT, TCE, and 1,1-DCE above the NJDEP and EPA criteria; and a low concentration of PCE above the NJDEP criteria.
- <u>ECC-MW-28B</u>: The analytical results for up-gradient off-site well ECC-MW-28B show low concentrations for PCE, TCE, 1,1-DCE, and CF, and a consistent CT presence above the NJDEP and EPA criteria.
- <u>ECC-MW-29B</u>: The results for down-gradient off-site well ECC-MW-29B show the consistent presence of all five VOCs, with TCE and CT above the NJDEP and EPA criteria, CF below the NJDEP and EPA criteria, and PCE and 1,1-DCE above the NJDEP criteria (except for SE 16 which was above both NJDEP and EPA criteria for 1,1-DCE).
- <u>ECC-MW-30B</u>: Six SEs (11 through 16) have been recorded for on-site well ECC-MW-30B near the source area. The results show a the presence of CT, CF, and TCE above the NJDEP and EPA criteria except in SE 16 when CF was only above the NJDEP criteria; and non-detects for PCE and 1,1-DCE. A significant trend for this well is consistent reductions in concentrations of these compounds each time this well has been sampled since installation.
- <u>ECC-MW-31B</u>: Three SEs (13, 15, and 16) have been recorded for on-site well ECC-MW-31B; the results show non-detects for the NJDEP and EPA criteria for all of the VOCs.
- <u>ECC-MW-32B</u>: Four SEs (13, 14, 15, and 16) have been recorded for on-site well ECC-MW-32B. The results show non-detects for the NJDEP and EPA criteria for all of the VOCs.
- <u>ECC-MW-33B</u>: Four SEs (13, 14, 15, and 16) have been recorded for on-site well ECC-MW-33B. The results show non-detects for the NJDEP and EPA criteria for all of the VOCs.
- <u>ECC-MW-34B</u>: Three SEs (13, 15, and 16) have been recorded for on-site well ECC-MW-34B and the results show non-detects in SE 13 and SE 15. Concentrations for SE

16 were above NJDEP and EPA criteria for 1,1-DCE, CT, and TCE; concentrations for PCE were above NJDEP criteria, and CF was non-detect.

- <u>ECC-MW-35B</u>: Three SEs (14, 15, and 16) have been recorded for down-gradient offsite well ECC-MW-35B and the results show a low concentration of CF below the NJDEP and EPA criteria; low concentrations of TCE above the NJDEP and EPA criteria; low concentrations of 1,1-DCE above the NJDEP criteria, low concentrations of CT which was above the NJDEP and EPA criteria for SE 14 but only above NJDEP criteria in SE 15 and SE 16, and a low concentration of PCE, which was above NJDEP criteria in SE 15 but was non-detect in SE 15 and SE 16.
- <u>EE-MW-36B</u>: Two SEs (15 and 16) have been recorded for off-site well EE-MW-36B. Concentrations of TCE were above NJDEP criteria for both SEs. All remaining VOCs (CF, 1,1-DCE, CT, and PCE) were non-detect for both SEs.
- <u>EE-MW-37B</u>: Two SEs (15 and 16) have been recorded for off-site well EE-MW-37B. Concentrations of CT were above NJDEP and EPA criteria for SE 15 then decreased to above NJDEP criteria only in SE 16. Concentrations of PCE and TCE were above NJDEP criteria in SE 15 then decreased to non-detect in SE 16. CF and 1,1-DCE were non-detect in both SEs.
- <u>EE-MW-38B</u>: Two SEs (15 and 16) have been recorded for off-site well EE-MW-38B. Concentrations of CT were above NJDEP and EPA criteria, and above NJDEP criteria for TCE, although these concentrations have decreased from SE 15 to SE 16. Concentrations of PCE were above NJDEP criteria in SE 15 then decreased to non-detect in SE 16. CF and 1,1-DCE were non-detect in both SEs.
- <u>EE-MW-39B</u>: Two SEs (15 and 16) have been recorded for off-site well EE-MW-39B. Concentrations of CT were above NJDEP and EPA criteria, and above NJDEP criteria for PCE and TCE, although these concentrations have decreased from SE 15 to SE 16. CF and 1,1-DCE were non-detect in both SEs.
- <u>EE-MW-40B</u>: Two SEs (15 and 16) have been recorded for on-site well EE-MW-40B; the VOC concentrations were non-detect.
- <u>EE-MW-41S</u>: Two SEs (15 and 16) have been recorded for on-site well EE-MW-41S near the source area. The results show a presence of CT above the NJDEP and EPA criteria in both SEs, but decreased at a level approximately two orders of magnitude from SE 15 to SE 16. Both CF and TCE had concentrations above both NJDEP and EPA criteria in SE 15, but decreased to non-detect in SE 16. PCE and 1,1-DCE also had non-detects for both SEs.
- <u>EE-MW-42B</u>: One SE (16) has been recorded for off-site well EE-MW-42B, the VOC concentrations were non-detect.
- <u>EE-MW-43B</u>: On SE (16) has been recorded for off-site well EE-MW-43B. A concentration was detected above the NJDEP and EPA criteria for 1,1-DCE. The remaining concentrations were non-detect.

- <u>EE-MW-44S</u>: One SE (16) has been recorded for on-site well EE-MW-44S. Concentrations were only detected above NJDEP criteria for CT. The remaining concentrations were non-detect.
- <u>EE-MW-45S</u>: One SE (16) has been recorded for on-site well EE-MW-45S. Concentrations were only detected above NJDEP and EPA criteria for CT. The remaining concentrations were non-detect.

Overall, trends that were noted were significant decreases in concentration of site-related contaminants (primarily CT and TCE) in source area wells ECC-MW-30B and EE-MW-41S. Also, concentrations of site-related contaminants reduced consistently in recently installed downgradient off-site wells EE-MW-37B through EE-MW-39B. Other Unit B bedrock wells on-site have exhibited rather consistent concentrations of site related compounds (CT and TCE).

4.3.2 Unit C Analytical Results

The VOC detections for the Unit C bedrock wells during the 16 SEs are presented in Table 6 and are interpreted as follows:

- <u>URS-MW-22D</u>: The analytical results for on-site well URS-MW-22D show increases in TCE ranging from non-detects to low concentrations above the NJDEP criteria; low concentrations above the NJDEP and EPA criteria for 1,1-DCE; sporadic detects for CF and PCE below the NJDEP and EPA criteria; and non-detects for CT.
- <u>ECC-MW-25C</u>: The results for side-gradient off-site well ECC-MW-25C show a consistent concentrations of CT, PCE, TCE and 1,1-DCE above the NJDEP and EPA criteria, and CF at low concentrations below the NJDEP and EPA criteria. It should be noted that this off-site well consistently contains the highest concentrations of both PCE and 1,1-DCE in MSP wells.
- <u>ECC-MW-26C</u>: The results for down-gradient off-site well ECC-MW-26C show consistent concentrations for PCE, TCE, and 1,1-DCE above the NJDEP and EPA criteria; decreasing concentrations for CT above the NJDEP and EPA criteria; and low concentrations for CF below the NJDEP and EPA criteria.
- <u>ECC-MW-27C</u>: The results for down-gradient off-site well ECC-MW-27C show concentrations for TCE, CT, and 1,1-DCE above the NJDEP and EPA criteria; concentrations for PCE above the NJDEP criteria; and low concentrations for CF below the NJDEP and EPA criteria.
- <u>ECC-MW-32C</u>: Three SEs (13, 15 and 16) have been recorded for on-site well ECC-MW-32C; the results show low concentrations below the NJDEP and EPA criteria to non-detects for CF and PCE; low concentrations above the NJDEP criteria for 1,1-DCE; and low concentrations for CT and TCE above the NJDEP and EPA criteria.
- <u>ECC-MW-35C</u>: Three SEs (14, 15, and 16) have been recorded for down-gradient offsite well ECC-MW-35C and the results show low concentrations of CT and CF below the NJDEP and EPA criteria; and concentrations of TCE above the NJDEP and EPA criteria.

Concentrations of PCE and 1,1-DCE ranged from above the NJDEP criteria, below NJDEP criteria, to non-detect.

Overall, the concentrations of site-related contaminants (primarily CT and TCE) are relatively stable in Unit C wells with the exception of the concentration of CT in ECC-MW-26C, which has been consistently reducing over time. Also, concentrations of CT and TCE are typically lower in Unit C wells when compared to Unit B wells.

4.3.3 Unit D Analytical Results

The VOC detections for the Unit D bedrock wells during the 16 SEs are presented in Table 6 and are interpreted as follows:

- <u>ECC-MW-25D</u>: The analytical results for side-gradient off-site well ECC-MW-25D show non-detect to low concentrations below the NJDEP and EPA criteria for CF and CT; concentrations for TCE and 1,1-DCE above the NJDEP and EPA criteria; and low concentrations of PCE generally above the NJDEP criteria.
- <u>ECC-MW-26D</u>: The results for down-gradient off-site well ECC-MW-26D show nondetect to low concentrations below the NJDEP and EPA criteria for CF and 1,1-DCE; low concentrations above the NJDEP criteria for CT and PCE (CT and PCE were below the NJDEP criteria in SEs13, 15, and 16); and consistent concentrations for TCE above the NJDEP and EPA criteria.
- <u>ECC-MW-27D</u>: The results for down-gradient off-site well ECC-MW-27D show nondetects for 1,1-DCE; non-detect to low concentrations below the NJDEP and EPA criteria for CF and PCE; low concentrations above the NJDEP criteria for CT; and concentrations for TCE above the NJDEP and EPA criteria.
- <u>ECC-MW-30D</u>: Five SEs (11, 12, 13, 15, and 16) have been recorded for the source area on-site well ECC-MW-30D; the results show low concentrations below the NJDEP and EPA criteria for CF; concentrations ranging from non-detect to above NJDEP criteria for CT and PCE; and concentration above NJDEP and EPA criteria for 1,1-DCE and TCE.

Overall, concentrations of site related contaminants (CT and TCE) have been relatively consistent over time and are typically lower in concentration than Unit B or Unit C wells at cluster locations.

4.4 Analytical Results and Trends for Overburden Monitoring Wells

This section presents the analytical results and trends for the overburden MWs at the MSP site over 16 SEs from August 2008 to January 2016. Laboratory reports of the analytical results for the SEs are provided in the QCSRs and DSRs for the individual SEs (Section 3.1).

4.4.1 Distribution and Concentration Trends of Total Uranium in Overburden Monitoring Wells

A total of 13 post-RA overburden MWs (MW-OB-1 through MW-OB-13), were installed in 2008 at the MSP site after radiological remediation activities were completed. These wells along with pre-RA monitoring well, B18W29SR, were used for the evaluation of total uranium concentration trends and the potential for natural attenuation of total uranium. MW-OB-7 and MW-OB-10 were abandoned in 2014 because the filter packs were saturated with silt, reducing the yield and sample quality. MW-OB-7R was installed in 2014 as a replacement well for MW-OB-7, and MW-OB-10 was not replaced because groundwater was monitored by adjacent well MW-OB-12. MW-OB-11 was abandoned in July 2016 because a property owner needed it removed to access their property. This well is not scheduled for replacement.

Based on the hydrogeology and groundwater flow directions within the overburden with respect to the local groundwater divide, total uranium contamination history, and contaminant distribution, overburden MWs are categorized as follows:

- MW-OB-1 background well;
- MW-OB-2, MW-OB-5, and MW-OB-6 side-gradient wells south of the groundwater divide;
- MW-OB-9 side-gradient well north of the groundwater divide;
- MW-OB-7R and MW-OB-8 wells within the former source area south of the groundwater divide;
- MW-OB-3, MW-OB-4, MW-OB-11, and B18W29SR down-gradient wells south of the groundwater divide; and
- MW-OB-10, MW-OB-12, and MW-OB-13 down-gradient wells north of the groundwater divide.

The total uranium detections for the overburden MWs during the 16 SEs (August 2008 – January 2016) are summarized in Table 8:

Total uranium exceeded the MCL (30 μ g/L) in samples from overburden wells in the former source area (MW-OB-7 and MW-OB-8), and from down-gradient wells MW-OB-10 and MW-OB-12 as follows:

• Total uranium detections from MW-OB-7 samples exceeded the MCL during SE 1 (35.1 μ g/L), SE 2 (36.1 μ g/L), SE 3 (38.1 μ g/L), SE 6 (41.1 μ g/L), SE 10 (32.3 μ g/L), and SE 13 (44 μ g/L). The detections from OB-7 samples were below the MCL during SE 4, SE 5, SE 7, SE 8, SE 9, SE 11, and SE 12. MW-OB-7 was abandoned during SE 15 and

replaced with well MW-OB-7R. MW-OB-7R was below the MCL during SE 15 and SE 16.

- Total uranium detections from MW-OB-8 samples only exceeded the MCL during SE 1 (34.2 μg/L), which was collected a few months after the soil piles were removed from the MSP site. Subsequent detections from MW-OB-8 samples have been below the MCL (SE 2 through SE 16).
- Total uranium detections from MW-OB-10 samples, which is down-gradient (north of divide) of the former source area, was below the MCL during SE 1 through SE 10. The detections from MW-OB-10 exceeded the MCL during SE 11 (51 μg/L) and SE 12 (40 μg/L). MW-OB-10 was dry during SE 5 and SE 13, then abandoned prior to SE 15.
- Total uranium detections from MW-OB-12 samples, which is down-gradient (north of divide) of the former source area, was below the MCL during SE 1 through SE 6, and during SE 8 through SE 16. The detection from MW-OB-12 exceeded the MCL only during SE 7 (43.5 μ g/L).

Total uranium trends for the overburden MWs are presented in Figures 14a through 14d. The trend for background well OB-1 (Figure 14a) is stable with very low detections of total uranium between 0.317 and 3.63 μ g/L.

The total uranium trends for side-gradient wells MW-OB-2, MW-OB-5, and MW-OB-6 (Figure 14b), located south of the groundwater divide, are stable with low detections of total uranium (<10.0 μ g/L). The total uranium trend for side-gradient well MW-OB-9 (Figure 14b), located north of groundwater divide, shows a decrease to levels below 10 μ g/L after SE 3.

The trend for former source area well MW-OB-7 (Figure 14c) after SE 3 is cyclic with maximums in SE 6 (41.1 μ g/L), SE 10 (32.3 μ g/L), and SE 13 (44 μ g/L). The low levels between maximums may be attributable to residual total uranium from the source area being naturally attenuated. The replacement well MW-OB-7R contained total uranium concentrations below the MCL in SE 15 (8.64 μ g/L) and SE 16 (9.14 μ g/L) (Figure 14c). The overall trend for former source area well MW-OB-8 (Figure 14c) also is decreasing with an anomalous increase in SE 6 (25.80 μ g/L), decreasing in SE 7 (1.7 μ g/L) and SE 8 (non-detect), slight increase in SE 12 (18 μ g/L), and decreasing again in SE 15 (3.39 μ g/L) and SE 16 (2.78 μ g/L).

Down-gradient wells south of the groundwater divide (MW-OB-3, MW-OB-4, MW-OB-11, and B18W29SR) all have total uranium concentrations less than the MCL with a stable trends in MW-OB-3, MW-OB-4, MW-OB-11, and B18W29SR (Figure 14d).

4.4.2 Distribution and Concentration Trends of VOCs in Overburden Monitoring Wells

The overburden MWs (MW-OB-1 through MW-OB-13) and the pre-RA monitoring well, B18W29SR, were not sampled for VOCs from 2008 to 2012. In 2014 and 2015, a total of 13

overburden wells were sampled for VOCs. MW-OB-7 and MW-OB-10 were abandoned in 2014 and were not sampled for VOCs. The VOC detections for the overburden MWs during the two SEs (15 and 16) are summarized in Table 9.

VOCs were detected in samples collected from the following overburden wells during SE 15 and SE 16:

- PCE concentrations were detected in off-site well MW-OB-13 (located on the adjacent Absolute Auto property), which exceeded the New Jersey Groundwater Standard of 0.4 μ g/L during SE 15 (1.44 μ g/L) and SE 16 (1.7 J μ g/L). These detections were both below the MCL of 5 μ g/L.
- MTBE concentrations were detected in well MW-OB-1 during SE 15 (0.37 J μ g/L). This concentration was below the New Jersey Groundwater Standard and the MCL. The sample results collected during SE 16 were non-detect.
- MTBE concentrations were detected in well MW-OB-6 during SE 15 (4.60 μ g/L) and SE 16 (2.6 J μ g/L). These concentrations were below the New Jersey Groundwater Standard and the MCL.
- MTBE concentrations were detected in well MW-OB-7R during SE 15 (0.38 J μ g/L) and SE 16 (0.48 J μ g/L). These concentrations were below the New Jersey Groundwater Standard and the MCL.

The lack of VOCs in the overburden GW samples confirm that no sources of contaminants are in the overburden, which was expected as the result of the removal of on-site soils from the OU-1 RA.

4.5 Monitored Natural Attenuation Parameters

The EPA defines natural attenuation as, "a variety of physical, chemical, or biological processes that, under favorable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in-situ processes include biodegradation; dispersion; dilution; sorption; volatilization; radioactive decay; and chemical or biological stabilization, transformation, or destruction of contaminants" (Wilhelm 2006). Natural attenuation is a passive, non-invasive remediation method that relies on natural processes to cleanup or attenuate pollution in soil or groundwater. Monitoring these natural processes over time is referred to as MNA. The primary objective of MNA is to demonstrate that natural processes will reduce contaminant concentrations in soil or groundwater to levels below regulatory standards before a point of compliance is reached.

The MNA parameter suite for the overburden (shallow) wells is different than the MNA parameter suite for the bedrock (deep) wells, although nine parameters are common to both

suites (total iron, hydrogen, nitrate, nitrite, sulfate, sulfide, alkalinity, carbon dioxide, and total organic carbon). Overburden well MNA parameters which are not included in the MNA suite for the bedrock wells are chloride, volatile fatty acid, biological oxygen demand (BOD), and chemical oxygen demand (COD). Bedrock well MNA parameters which are not included in the MNA suite for the overburden wells are ferrous iron, methane, ethane, and ethene. The specific analyses included in the MNA parameter suites for overburden MWs and bedrock MWs are identified in Section 1.0 of this document. All detections for MNA parameters are listed in Tables 10a through 10k. The general biogeochemical parameters are discussed in Section 4.5.1. Geochemical parameters specifically related to the distribution of electron acceptors are discussed in Section 4.5.2.

4.5.1 Chlorinated Solvents Natural Attenuation Evaluation

MNA refers to the remedial option that relies on naturally occurring attenuation processes to achieve site-specific remediation goals within a reasonable time frame. Natural attenuation processes that reduce contaminant concentrations in groundwater include destructive (biodegradation and chemical reactions with other subsurface constituents) and nondestructive mechanisms (dilution, dispersion, volatilization, and adsorption).

Biodegradation is typically the most significant destructive attenuation mechanism. Chlorinated solvents, such as TCE and CT, attenuate predominantly by reductive dechlorination under anaerobic conditions.

The primary reductive dechlorination pathway for TCE to non-toxic ethene (or ethane) is as follows:

TCE \rightarrow *cis*-1,2-DCE \rightarrow Vinyl Chloride (VC) \rightarrow ethene (\rightarrow ethane)

The primary reductive dechlorination pathway for CT to non-toxic methane is as follows:

 $CT \rightarrow CF \rightarrow dichloromethane \rightarrow methyl chloride \rightarrow methane$

The extent and rate of reductive dechlorination processes depend on many factors, including: 1) an adequate supply of electron donors; 2) the absence of competing electron acceptors, such as oxygen, nitrate/nitrite, ferric iron, or sulfate; 3) the number of chlorine atoms attached to the molecule; and 4) the subsurface microbial ecology.

In the reductive dechlorination process, TCE and *cis*-1,2-DCE serve as the electron acceptor in the TCE reductive dechlorination pathway; CT and CF serve as the electron acceptor in the CT reductive dechlorination pathway. Other electron acceptors (e.g., oxygen, nitrate/nitrite, ferric iron, sulfate) at sufficient concentrations can compete with TCE and CT for electron donor and

inhibit the dechlorination process. Based on an appreciable level of reduction potential, the electron donor will react with available oxygen first. As oxygen is depleted, the electron donor will react with nitrate/nitrite. As nitrate/nitrite are depleted, the electron donor will react with ferric iron, followed by sulfate, and then carbon dioxide under methanogenic conditions. TCE can be reduced to *cis*-1,2-DCE under iron/sulfate reducing conditions. Reduction of *cis*-1,2-DCE and VC generally occurs under sulfate reducing to methanogenic conditions.

TCE is more susceptible to anaerobic dechlorination than VC because it is more oxidized compared to VC. Also, the lack of a special group of bacteria containing *Dehalococcoides spp*. (DHC) can cause the reductive dechlorination process to stall at *cis*-1,2-DCE. By analyzing the geochemistry data, distribution of electron acceptors, metabolic by-products, and the contaminant distribution and time-trend, it is possible to determine whether active biodegradation of the chlorinated solvents is occurring through reductive dechlorination processes. Other than reductive dechlorination, *cis*-1,2-DCE and VC can be biodegraded under aerobic conditions via aerobic co-metabolic degradation, direct oxidation, and abiotic oxidation.

To facilitate the evaluation of natural attenuation with an emphasis on biodegradation of chlorinated VOCs under anaerobic conditions, EPA published the Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water - EPA/600/R-98/128 (the Protocol) (EPA 1998). The Protocol provides a method of scoring the geochemical and biodegradation environment and is used as a guideline in this report for evaluating the significance of biodegradation and biotransformation processes. Table 11 presents the results of the MNA scoring evaluation.

4.5.1.1 Geochemical Environment for Intrinsic Biodegradation

The presence of PCE and TCE breakdown products (*trans*-1,2-DCE, *cis*-1,2-DCE) in groundwater can indicate that anaerobic biodegradation via reductive dechlorination is occurring at this site.

The questions are:

- What conditions or factors contribute to reductive dechlorination of chlorinated volatile organic compounds (CVOCs) to occur at this site?
- Is biodegradation of CVOCs happening under current site conditions?
- Will natural attenuation of CVOCs via destructive mechanism(s), if occurring, be sustainable at the site?

The objectives of the MNA evaluation are to answer these questions and to provide recommendations for the remediation and management of the site contamination. To evaluate

the intrinsic biodegradation as the key mechanism for natural attenuation, groundwater geochemical parameters (Section 4.5.1.2 and Section 4.5.1.3) are assessed first, followed by the discussion on the trend of reductive dechlorination (Section 4.5.2) over time. Groundwater geochemical parameters were analyzed for the evaluation of groundwater conditions that can affect the presence and activity of microbial populations and the extent of biodegradation. The results for these parameters are presented in Tables 10a through 10k.

4.5.1.2 General Groundwater Geochemistry

Temperature

Groundwater temperature directly affects the rate of microbial metabolic activity. Biodegradation rates roughly double for every 10 degrees Celsius (°C) increase in temperature, between the temperature range of 5° C and 25° C (EPA 1998). At temperatures below 5° C, metabolic rates are generally too low to be significant, while temperatures greater than 35° C are generally inhibitory to most groundwater microbial populations. Table 10a presents the temperature measurements collected during 13 SEs. Groundwater temperature at the site ranged between 7° C and 18° C for the bedrock MWs. Although this temperature range is not ideal for biological activities, it is suitable. However, 18° C does not meet the Protocol's preliminary screening goal of 20° C for positive weighting in the MNA scoring evaluation.

Alkalinity

Table 10b presents the alkalinity values collected during 13 SEs. Alkalinity is a measure of the ability of a solution to neutralize acids to the equivalence point of carbonate and bicarbonate. Carbon dioxide can be generated during the process of biodegradation of contaminants, which can increase the alkalinity. The Protocol (EPA 1998) indicates that alkalinity values more than twice the background level can be the result of interaction between carbon dioxide and the aquifer minerals. Alkalinity levels greater than two times background levels indicate conditions are favorable for reductive dechlorination.

Alkalinity in the background bedrock monitoring well (URS-MW-22D) for Unit C varied from 80 milligrams per liter (mg/L) (SE 6) to 720 mg/L (SE 5). Alkalinity in Unit C downgradient bedrock monitoring well (ECC-MW-27C) ranged from 80 mg/L (SE 6 and SE 13) to 240 mg/L (SE 7). The consistency in the analytical results between URS-MW-22D and ECC-MW-27C does not indicate that reductive dechlorination is occurring in Unit C. Background alkalinity for Unit B and Unit D has not been measured.

pН

EPA's Protocol (EPA 1998) specifies a pH between 5 and 9 as the optimal range for reductive dechlorination and studies have shown that for complete reductive dechlorination, pH greater

than 6.5 is preferable. Non-optimal pH conditions may slow down the reaction rates but do not necessarily stop biological activity. The pH measurements (Table 10c) in the background bedrock monitoring well (URS-MW-22D) for Unit C ranged between 7.03 (SE 3) and 8.01 (SE 4). The pH readings in the Unit C downgradient bedrock MW (ECC-MW-27C) was 9.45 (SE 6) and 7.47 (SE 10). A pH greater than 9 is unfavorable for complete reductive dechlorination of TCE to ethene and is expected to retard biological activities. pH values greater than 9 warrant a negative weighting in the MNA scoring evaluation presented in the Protocol.

Total Organic Carbon

Total organic carbon is a measure of the electrons that may be available for biological reductive dechlorination. Elevated total organic carbon concentrations can promote the development of anaerobic groundwater conditions and facilitate the degradation of CVOCs via reductive dechlorination. With sufficient total organic carbon concentrations, microbiological reactions will sequentially reduce available electron acceptors (oxygen, nitrate/nitrite, ferric iron, sulfate), changing the aquifer to favorable conditions for anaerobic biodegradation of CVOCs including TCE, (cis-, trans-, 1,1-)DCE, and VC. TCE and DCE are electron acceptors in competition with oxygen, nitrate, ferric iron, and sulfate for available electrons. Optimal conditions for reductive dechlorination of TCE to DCE occur under sulfate-reducing and methanogenic conditions, but the TCE to DCE dehalogenation process also may be observed under nitrate and ferric iron reducing conditions. However, reductive dechlorination of DCE and VC require sulfate reducing and methanogenic conditions. If total organic carbon levels are insufficient, then electron acceptors such as nitrate and ferric iron will not be depleted and complete reductive dechlorination will not occur. Each site is unique, there is no universal guideline of minimum total organic carbon concentrations to facilitate anaerobic dechlorination. The Protocol (EPA 1998) suggests that total organic carbon concentrations greater than 20 mg/L can drive dechlorination.

Table 10d presents the total organic carbon results for the bedrock MWs during SE 4 through SE 13. All total organic carbon results were below the 20 mg/L benchmark listed in the Protocol (EPA 1998). Total organic carbon concentrations in the background bedrock monitoring well URS-MW-22D varied from 0.74 mg/L (SE 10) to 1.6 mg/L (SE 8); total organic carbon concentrations in the other bedrock MWs ranged from 0.37 to 3.0 mg/L. In general, the low total organic carbon concentrations have most likely limited and will continue to limit sustainable biological reductive dechlorination at the site.

4.5.1.3 Distribution of Electron Acceptors and Oxidation-Reduction Potential

At certain concentrations, dissolved oxygen (DO), nitrate/nitrite, ferric iron and sulfate can compete with CVOCs as electron acceptors and thus impede biological reductive dechlorination. Distribution of electron acceptors and field oxygen reduction potential (ORP) results are

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discussed in this section to evaluate if suitable conditions exist or existed for biological reductive dechlorination at this site.

Dissolved Oxygen

Table 10e presents the DO concentrations measured in the field for the bedrock MWs during 13 SEs. Generally, a DO concentration less than 0.5 mg/L indicates anoxic or anaerobic conditions. DO concentrations have been above 0.5 mg/L at all bedrock well locations prior to SE 7. Although three older bedrock wells (URS-MW-2D, URS-MW-22D, and URS-MW-24D) have had consistent DO concentrations less than 0.5 mg/L from SE 7 through SE 13, the majority of data collected to date indicate consistent DO levels above optimal levels. These data indicate that the DO levels in the bedrock zones are generally unfavorable to biological reductive dechlorination.

Oxidation-Reduction Potential

Distribution of electron acceptors in groundwater can be reflected in groundwater ORP readings. EPA's Protocol indicates that the anaerobic reductive dechlorination pathway becomes possible at ORP less than 50 millivolts (mV). Furthermore, anaerobic reductive dechlorination is likely to occur at ORP values less than -100 mV, which corresponds to iron reducing conditions. Analytical results of electron acceptors and biological degradation products typically provide a more accurate representation of the actual groundwater reducing conditions than the field ORP measurements.

Table 10f presents the ORP readings collected for the bedrock MWs during 13 SEs. ORP readings in the background bedrock monitoring well (URS-MW-22D) were less than 50 mV during 7 SEs and below -100 mV during 3 SEs, which indicates conditions are favorable for reductive dechlorination. The results of the sampling events indicate that the groundwater aquifer may currently be under slightly anaerobic conditions, but that those conditions are not optimal for the reductive dechlorination pathway.

Nitrate

Table 10g presents nitrate concentrations detected for the bedrock MWs during SE 4 through SE 13. Nitrate should be depleted to create the suitable groundwater conditions for reductive dechlorination to occur. Nitrate concentrations in background bedrock monitoring well URS-MW-22D ranged from non-detect to 0.94 mg/L. Nitrate concentrations in the other bedrock MWs fluctuated over time, ranging from 0.091 mg/L to 16 mg/L. Therefore, the nitrate concentrations in the bedrock MWs are favorable to reductive dechlorination.

Nitrate concentrations in bedrock MWs ECC-MW-25D, ECC-MW-27C, and ECC-MW-27D were similar to the background well concentrations that are conducive to reductive dechlorination. Overall, the low nitrate concentrations in the bedrock indicate that nitrate will not significantly compete with the chlorinated VOCs for available electron donors.

Ferrous Iron

Table 10h presents the ferrous iron concentrations measured for the bedrock MWs in the field during SE 4 through SE 13. An increase of ferrous iron concentration from background level is an indication of iron reducing conditions, which can support the reductive dechlorination of TCE to DCE.

Ferrous iron concentrations for the background bedrock monitoring well (URS-MW-22D) ranged from non-detect (SE 4) to 0.54 mg/L (SE 6). Ferrous iron concentrations in the other bedrock MWs (with the exception of ECC-MW-32C, ECC-MW-33B and ECC-MW-34B) ranged from non-detect to 0.86 mg/L. These data indicate that the bedrock groundwater has not been under iron reducing conditions.

Sulfate and Sulfide

Table 10i presents the sulfate concentrations measured for the bedrock MWs during SE 4 through SE 13. According to the Protocol (EPA 1998), sulfate at concentrations greater than 20 mg/L may compete with chlorinated VOCs within the reductive pathway and a sulfide (i.e., reduced form of sulfate) concentration greater than 1 mg/L indicates reductive dechlorination is likely to occur. Complete reductive dechlorination to ethene generally occurs under sulfate reducing or methanogenic conditions.

Sulfate concentrations in the background bedrock monitoring well (URS-MW-22D) ranged from 6.8 mg/L to 20 mg/L. Sulfate concentrations in the other bedrock MWs have varied and ranged from 7.0 mg/L to 120 mg/L. During SE 6, most sulfate concentrations were less than 40 mg/L, but more than twice the background level. However, during SE 7, the majority of the sulfate detections were less than twice the background concentrations and less than 20 mg/L (the concentration below which the anion does not compete with the reductive pathway), with the exception of URS-MW-2D and ECC-MW-28B. Sulfide has not been detected in any of the bedrock monitoring well samples to date. With limited electron donor presence (low total organic carbon concentrations), sulfate at concentrations exceeding 20 mg/L would serve as a competitive electron acceptor in the reductive dechlorination pathway.

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Methane

Table 10j presents the methane results for the bedrock MWs during SE 4 through SE 13. According to the Protocol, methanogenic conditions are indicated by methane concentrations greater than 500 μ g/L, and are important for facilitating the dechlorination of DCE to VC, then to ethene. Therefore, a methane concentration of 500 μ g/L is used as a bench mark for this evaluation. Methane concentrations in the bedrock MWs were all well below 500 μ g/L thereby suggesting that methanogenic conditions are not prevalent. Consequently, the absence of highly reducing methanogenic conditions indicates a very limited potential for the reduction of DCE to VC and VC to ethane.

4.5.2 Chlorinated Solvents Natural Attenuation Trend Analysis

The trends of natural attenuation can also be analyzed through the trends of chlorine number changes over time at any given well and the trends of CVOCs changes over distance from the source area.

Decreases in the TCE to DCE molar ratio, decreases in the CT to CF molar ratio, and decreases of chlorine number are clear indications of reductive dechlorination. The chlorine number represents the average chlorination level of all chlorinated ethenes in a sample and is calculated by dividing the total normality of chlorine by the total molar concentration of chlorinated ethenes. For most of the MW results (Table 6), the concentrations of DCE have not increased above the concentrations of TCE and the concentrations of CF have not increased above the concentrations of CT.

Assuming a TCE \rightarrow *cis*-1,2,-DCE \rightarrow VC \rightarrow ethene (\rightarrow ethane) pathway, VC would be expected to accumulate given the slowing of the dehalogenation process due to the decreased number of chlorine functional groups and the resulting lower oxidation state. VC has never been detected through the 14 SEs.

Assuming a $CT \rightarrow CF \rightarrow$ dichloromethane \rightarrow methyl chloride \rightarrow methane pathway, methyl chloride would be expected to accumulate given the slowing of the dehalogenation process due to the decreased number of chlorine functional groups and the resulting lower oxidation state. Methyl chloride has never been detected through the 14 SEs.

Ethane, ethene, and methane are final degradation products of chlorinated VOCs. Ethene measurements from 13 rounds of groundwater sampling are presented in Table 10k. Ethene was only detected (between 0.32 and 3.2 μ g/L) in the following wells in specified rounds: ECC-MW-25C in SEs 6 and 8; ECC-MW-26B in SEs 8, 9, 10, and 11; ECC-MW 26C in SEs 7, 8, and 10; ECC-MW-26D in SEs 6, 7, 8, 9, 10, and 11; ECC-MW-27C in SE 6; ECC-MW-27D in SEs 6, 7,

and 8; ECC-MW-28B in SEs 8 and 9; and ECC-MW-24B in SE 11. Ethane has not been detected in any MWs at the site.

The very low levels of ethane, ethene, and methane concentrations indicate that complete reductive dechlorination via anaerobic biological degradation has not been a significant process at the site. This might be caused by the low total organic carbon concentrations and a general lack of optimized influencing factors as detailed in Section 4.5.1.

DCE and VC may be subject to oxidation under aerobic conditions. Because oxidation of DCE and VC is a difficult process to quantify (i.e., the metabolic byproducts of these reactions are carbon dioxide, water, and/or reduced iron at very low concentrations), no attempt has been made to quantify these processes. However, the TCE, DCE, and VC results do not point to attenuation at similar rates, as would be expected in the mixed behavior scenario wherein a mixture of aerobic and anaerobic conditions within the contaminated zone result in reductive dechlorination is coupled with the oxidation of VC resulting in a terminal degredation product of carbon dioxide.

4.5.3 Uranium Natural Attenuation Evaluation

Uranium natural attenuation is contingent upon the maintenance of optimal aquifer geochemical and groundwater chemical conditions for a desired attenuation mechanism. Aquifer conditions that are reducing and phosphate-rich and/or silica-rich are the most effective for uranium attenuation (Criteria 1 and 2), and under attenuation mechanism Criteria 2, a rise in oxidative conditions, pH, and/or alkalinity all decrease the aquifer capacity for uranium attenuation. Aquifer conditions that are oxidizing and have low carbonate are ideal for attenuation mechanism Criteria 3. Natural attenuation conditions for aqueous total uranium are evaluated using the guidelines provided in the EPA guidance document, *Monitored Natural Attenuation of Inorganic Contaminants in Water* – Volume 3 (EPA 600-R-10093) (EPA 2010).

The long-term stability of attenuated uranium depends on the maintenance of either (EPA 2010):

- Criteria 1: Groundwater chemistry that prevents solubilization of hexavalent uranium (U[VI]) precipitates,
- Criteria 2: Sufficiently low reduction potentials to prevent oxidation and consequent solubilization of U(IV) solids, or
- Criteria 3: Stability of the sorbent mineral and sufficiently low concentrations of competing ions that could displace the sorbed U(VI).

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Groundwater Geochemistry and Aquifer Conditions

For natural attenuation to occur, conditions must exist wherein uranium sorption and/or precipitation will occur, and then the geochemical driving forces (presence of phosphates/silicates, reducing conditions, low levels of competing ions, pH, and the presence of surface sites) must be maintained to prevent the remobilization of attenuated uranium. In the subsections below, natural attenuation parameters are evaluated for their efficacy in facilitating and maintaining uranium attenuation.

Dissolved Oxygen

Table 10e presents the DO concentrations measured in the field for the overburden MWs during 13 SEs. Generally, a DO concentration less than 0.5 mg/L indicates reducing conditions are present. Historically, DO concentrations have been above 0.5 mg/L at the majority of overburden well locations. The majority of data collected to date indicate consistent DO levels above the range that is optimal for reducing conditions, oxidizing conditions could predominate in the long term, and uranium attenuation by the formation and precipitation of U(VI) species may not be the primary attenuation mechanism (Criteria 2). Dissolved uranium in oxidizing environments is predominantly U(VI), and U(VI) is the only uranium species typically observed at uranium sites to occur at levels of environmental concern (EPA 2010). The uranium analytical method does not report specific isotopes, but rather total uranium. The predominant U species on-site is not definitively known; however, based upon the geochemical parameters, it most likely is U(VI). High DO levels indicate an oxidizing environment and stability of the sorbent minerals, which may lead to U(VI) sorption as an attenuation mechanism (Criteria 3).

Nitrate

Table 10g presents nitrate concentrations detected for the overburden MWs during 13 SEs. Nitrate concentrations in background overburden well MW-OB-1 ranged from 7.14 mg/L to non-detect over the course of 13 SEs. Nitrate concentrations in the other overburden wells have fluctuated over the 13 SEs, ranging from non-detect to 35 mg/L. High nitrate levels indicate an oxidizing environment and stability of the sorbent minerals, which may lead to U(VI) sorption as an attenuation mechanism (Criteria 3).

Alkalinity

Table 10b presents the alkalinity values collected during 13 SEs. Alkalinity measures the ability of a solution to neutralize acids to the equivalence point of carbonate and bicarbonate. For environmental groundwater systems, alkalinity is then typically a measure of the carbonate/ bicarbonate levels due to dissolution of carbonate minerals and/or dissolved atmospheric carbon dioxide. U(VI) exhibits a high affinity for sorption to iron oxyhydroxides and aluminosilicates,

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and alkalinity influences the degree of sorption of U(VI) onto iron oxyhydroxides (EPA 2010). High levels of carbonates can displace U(VI) from sorbent minerals resulting in remobilization and, conversely, low carbonate levels result in greater U(VI) sorption. In an oxidizing environment, sorption of U(VI) onto iron oxyhydroxides may be the most important attenuation mechanism, as forming stable U(VI) precipitates may be limited by the relatively low concentration of phosphates and vanadates (EPA 2010).

Alkalinity concentrations in the background overburden monitoring well (MW-OB-1) ranged from 100 mg/L to 300 mg/L over the 13 SEs. Alkalinity concentrations in the other overburden MWs ranged from 64.8 mg/L to 720 mg/L, and total uranium has exhibited decreasing trends with these levels of carbonate in the aquifer (Criteria 3).

pН

The pH measurements (Table 10c) in the background overburden monitoring well (MW-OB-1) ranged between 6.69 to 7.53 and the pH range for the remaining overburden MWs was consistent over 13 SEs. The solubility of uranium species in systems containing carbonate and silica or phosphate increases moderately in environments between a pH of 7 and 8 and increases rapidly between a pH of 8 and 10. In these systems, total uranium solubility, hence mobility, is lowest in pH environments between 6 and 7 (Criteria 1).

Total Organic Carbon

Complexation of U(VI) by organic ligands in solid humic materials may also serve to remove uranium from groundwater (EPA 2010). Low aqueous total organic carbon levels suggest that the aquifer contains little humic material. Total organic carbon was not collected for overburden wells during SEs 3 and 5 through 13.

Ferrous Iron

Table 10h presents the ferrous iron concentrations measured for the OB MWs in the field during SE 5 through SE 13. These data indicate that the groundwater has not been under iron reducing conditions and that iron oxyhydroxides surfaces capable of adsorbing U(VI) should be stable (i.e., not dissolving and releasing adsorbed total uranium). Stable iron oxyhydroxides are a potential adsorption-site for total uranium (Criteria 3).

Oxidation Reduction Potential

The ORP readings in the background overburden monitoring well (MW-OB-1) through 13 SEs ranged from -17.8 to 293 millivolts. For the remaining overburden MWs, ORP readings

fluctuated over time ranging from -165 to 359 millivolts. SE 7 had the highest reported readings to date ranging from 267 to 359 millivolts. The historical and current ORP trends do not indicate optimally low levels for uranium attenuation as precipitated U(IV) solids; however, an oxidizing environment is ideal for the stability of iron oxyhydroxides, as shown by the low ferrous iron levels in Table 10h. Stable iron oxyhydroxides are a potential adsorption-site for total uranium (Criteria 3).

4.5.4 Uranium Trend Evaluation

The following section provides an evaluation of the analytical data from the 13 SEs (August 2008 through November 2012) for trends and evidence of uranium attenuation.

Overburden wells were examined for uranium attenuation in the following area designations:

- MW-OB-1 background well;
- MW-OB-2, OB-5, and OB-6 side-gradient wells, south of groundwater divide;
- MW-OB-9 side-gradient well, north of groundwater divide;
- MW-OB-8, OB-7 former source area wells;
- MW-OB-3, MW-OB-4, MW-OB-11, and B18W29SR down-gradient wells, south of groundwater divide, and
- MW-OB-10, MW-OB-12, and MW-OB-13 down-gradient wells, north of groundwater divide.

Figures 14a through 14d depict uranium concentrations over time for the overburden well groupings listed above. In the background overburden well (OB-1), low-level concentrations were detected over time, with a decrease in concentration from 3.63 μ g/L (SE 1) to non-detect (SE 9) to 1.2 μ g/L (SE 13). The data for OB-1 establishes the background levels of uranium for the site.

Down-gradient Overburden Wells

Down-gradient overburden MWs MW-OB-4, MW-OB-11, and MW-OB-13 showed generally decreasing total uranium concentrations (7.15 μ g/L to non-detect) over time. Total uranium concentrations in down-gradient overburden MW B18W29SR were variable over time with a concentration ranging from 14 μ g/L (SE 2) to 0.82 μ g/L (SE 12). Down-gradient overburden monitoring well MW-OB-12 showed increases in total uranium concentration to a maximum of 43.5 μ g/L (SE 7) and then a decrease to 7.8 μ g/L (SE 13). Down-gradient overburden monitoring well MW-OB-3 total uranium concentrations decreased from 14 μ g/L (SE 2) to 3.0 μ g/L (SE 13). Down-gradient overburden monitoring well MW-OB-3 total uranium concentrations decreased from 14 μ g/L (SE 2) to 3.0

SE 1 to SE 10 with a maximum total uranium concentration of 23.6 μ g/L (SE 3); however, the concentration has increased to 51 μ g/L (SE 11) and 40 μ g/L (SE 12). OB-10 was not sampled during SE 13 due to insufficient water. Geochemical parameters (pH, alkalinity, nitrate, DO) showed little change over the 13 SEs, which indicate a stable environment with little potential for total uranium mobilization due to dissolution of iron oxyhydroxides.

In an active uranium attenuation system, downgradient wells should exhibit a decrease in concentration over time. All of the downgradient overburden wells south of the groundwater divide (MW-OB-3, MW-OB-4, MW-OB-11, and B18W29SR) have decreasing trends and many are comparable to background total uranium levels. Downgradient wells north of the divide have a decreasing trend to background total uranium levels, with the exception of well MW-OB-10. The MNA data suggest natural attenuation is occurring by adsorption on to stable sorbent mineral surfaces (Criteria 3).

Former Source-Area Wells

The overall trend for former source area well MW-OB-7 (Figure 14c), located south of the groundwater divide, has cycled between levels approximately 1/3 of the MCL to levels 30% above the MCL; the results do not show a decreasing trend. The overall trend for former source area well MW-OB-8 (Figure 14c), located south of the groundwater divide, has declined over the 13 SEs. Other geochemical parameters (pH, alkalinity, nitrate, DO) showed little change over the 13 SEs, which suggest a stable environment with little potential for total uranium mobilization due to dissolution of iron oxyhydroxides. Figure 14c shows uranium concentrations over time for the former source area overburden MWs. The MNA data suggest natural attenuation is occurring by adsorption on to stable sorbent mineral surfaces (Criteria 3).

Side-Gradient Wells

Concentrations for side-gradient overburden MWs MW-OB-2, MW-OB-5, MW-OB-6, and MW-OB-9 showed a decreasing trend for total uranium detections throughout the 13 SEs. This is consistent with what would be expected in an aquifer with active natural attenuation. The MNA data suggest natural attenuation is occurring by adsorption on to stable sorbent mineral surfaces (Criteria 3). Figure 14b provides trend graphs for the side-gradient wells. Geochemical parameters (pH, alkalinity, nitrate, DO) showed little change over the 13 SEs, which suggest a stable environment with little potential for total uranium mobilization due to dissolution of iron oxyhydroxides.

4.6 Human Health Risk Assessment Summary

This section presents summaries for two HHRAs that were conducted for MSP groundwater. The baseline HHRA was performed in 2005 as part of the Groundwater OU RI (USACE 2005a). The Supplemental HHRA includes data collected during the 2014 through 2016 investigations and presents the Risk Assessment Guidance for Superfund Part D tables. The entire HHRA report is included in Appendix A.

Current EPA guidelines for acceptable exposures are a reasonable maximum individual lifetime excess cancer risk in the range of 1×10^{-4} to 1×10^{-6} (corresponding to a 1 in 10,000 to 1 in 1,000,000 increase in the probability of cancer as opposed to a 1 in 3 normal background risk). For non-cancer health effects, a hazard index (HI) is calculated. An HI represents the sum of the individual exposure levels compared to their corresponding reference doses. The key concept for a non-cancer HI is that a "threshold level" (measured as an HI of 1) exists below which non-cancer health effects are not expected to occur.

It should be noted that groundwater that is susceptible to FUSRAP contamination is not currently used as a potable water source or for any other purpose. Thus, the risks estimated for groundwater exposure are hypothetical. There are no known plans to use the groundwater in the future.

In addition, a screening level ecological risk assessment was not performed because recent investigations revealed that site-related VOCs are migrating off-site via bedrock bedding planes that do not discharge into surface water systems. The most contaminated bedding plane is at a depth of more than 75 feet below ground surface at the site boundary. Therefore, there is no pathway to ecological receptors. In addition, no ecological habitats have been identified at the MSP site.

4.6.1 Baseline Human Health Risk Assessment

The Baseline HHRA evaluated the risks from contaminants (radionuclides, VOCs, SVOCs, and metals) in on-site groundwater to hypothetical future residential receptors at the site. The COPCs that were carried through the Baseline HHRA process included nine radionuclides, six VOCs, two SVOCs, and 13 metals. This risk assessment was performed in 2005 prior to the soil removal action as part of the OU-1 remedial action and concentrations of uranium in groundwater have decreased significantly since this action. The results of the Baseline HHRA are summarized below:

• The potential cancer risk associated with groundwater use by a hypothetical future on-site resident was approximately 1×10^{-4} for a site-wide average concentration, which is equal to the upper limit of EPA's acceptable risk range. Uranium contributed 7×10^{-5} of the risk and radium contributed 2×10^{-5} of the risk. Chemical exposure from VOCs comprised 2×10^{-5} of the risk. The potential cancer risk at the well showing the highest radioactive

contamination, well B18W24S, was approximately $6x10^{-4}$, primarily due to ingestion of uranium in drinking water.

- Hazard indices exceeded 1 for the resident (HI of 5) and child resident (HI of 14) for average site-wide groundwater exposure. The exceedance of the non-cancer benchmark was primarily based on the concentration of manganese. For the well with the highest radioactive contamination (B18W24S), the HI for the child resident was 15 due to the uptake of uranium. For the well with the highest chemical risk (URSMW2D), the HI for the child resident was 6, primarily due to CT concentrations.
- Exposure to sediments and surface water at the MSP posed a cancer risk of 2 x 10⁻⁵, which is within EPA's acceptable risk range. Non-cancer health effects from sediments and surface water are unlikely.

Based on the risks and hazards calculated for the COPCs, the following contaminants were identified as chemicals of concern (COCs) in the 2005 baseline HHRA: total uranium (as a toxic metal); uranium-238 and uranium-234 (as radioactive contaminants); CT; and manganese. The detected concentrations of the radium isotopes were comparable to background concentrations and below the established drinking water standards; therefore, they were not classified as COCs. Manganese was identified in the risk assessment as posing a non-cancer health hazard but is not a site contaminant. Historical records of site activities do not indicate its use or possible use. Elevated manganese has been documented for groundwater in the Newark Group (Serfes 1994). Therefore, manganese is considered to be part of the natural background at this site rather than a result of government activities at the site.

4.6.2 Supplemental Human Health Risk Assessment

The Supplemental HHRA for the MSP site (Appendix A) evaluated the risks associated with VOCs in groundwater to hypothetical future on-site workers and hypothetical future off-site residential receptors. Sample results from five wells within the core of the plume were used for the risk assessment. The groundwater data used in the risk assessment included VOC data collected from those wells during two sampling events conducted in 2014 and 2015. The results of the Supplemental HHRA are summarized below:

- For the adult worker exposure to groundwater, the reasonable maximum exposure (RME) cancer risk exceeded EPA's acceptable risk range. The total cancer risk of 1.4 x 10⁻³ was primarily due to CT. The central tendency exposure (CTE) cancer risk was within the acceptable risk range at 9.0 x 10⁻⁵. The HI for the adult worker exposure to groundwater was 17.3 for the RME scenario primarily due to CT and TCE. The HI for the CTE scenario was 4.2, primarily due to CT.
- For the child residential exposure to groundwater, the RME cancer risk exceeded EPA's acceptable risk range. The total cancer risk of 1.2 x 10⁻³ was primarily due to CT. The

CTE cancer risk also exceeded the acceptable risk range at 2.5 x 10^{-4} . The HI for the child resident exposure to groundwater was 59.1 for the RME scenario primarily due to CT, chloroform, and TCE. The HI for the CTE scenario was 17.9 due to CT and TCE.

• For the adult residential exposure to groundwater, the RME cancer risk exceeded EPA's acceptable risk range. The total cancer risk of 3.4 x 10⁻³ was primarily due to CT and chloroform. The CTE cancer risk also exceeded the acceptable risk range at 4.6 x 10⁻⁴. The HI for the adult resident exposure to groundwater was 48.6 for the RME scenario primarily due to CT, chloroform, and TCE. The HI for the CTE scenario was 15.9 due to CT and TCE.

Based on the risks and hazards calculated for the COPCs, the following contaminants were identified as COCs in the Supplemental HHRA: CT, chloroform, and TCE. Low levels of VOCs were detected in the site background well indicating that off-site, upgradient sources of VOCs could be impacting groundwater conditions at the MSP site. However, in most instances, the concentrations of COPCs from within the core of plume were significantly higher than the background values.

5.0 SUMMARY AND CONCLUSIONS

This section presents the summary and conclusions of the groundwater investigation, including geophysical and hydrogeological testing, and delineation data from the 16 SEs (August 2008 to January 2016). This data supplements the information presented in the *Final Groundwater Operable Unit Remedial Investigation Report Middlesex Sampling Plant* (USACE 2005a). Data from these reports will be used to develop the FS for MSP. Information from the 2005 Final Remedial Investigation Report and this GWITM were used to assess the risk to human health and the environment, in context of the contaminant pathways identified.

Section 5.1 summarizes the hydrogeology; Section 5.2 summarizes the nature and extent of groundwater contamination for VOCs and total uranium; and Section 5.3 presents the conclusions.

5.1 Hydrogeology

The site hydrogeology includes a perched saturated overburden unit atop of a leaky multiunit bedrock aquifer system. The overburden unit flows over top of less transmissive weathered zone of the bedrock at depths generally between 2 to 10 feet below the surface and a thickness of a foot to several feet during wet periods and may be dry in places during dry periods. The overburden unit is hydraulically connected to the bedrock aquifer and provides recharge in the subcrop zones and likely through vertical leakage along minor fractures and other bedding partings. A zone of unsaturated weathered bedrock, between 5 to 12 feet thick, lies between the overburden groundwater unit and the water table surface for the bedrock aquifer. The difference in potentiometric surface elevation between the saturated overburden unit and the bedrock aquifer averages nearly 11 feet.

The bedrock system includes three parallel minor bedding plane aquifer units, designated as Unit B, Unit C, and Unit D. These units are associated with bedding fractures that are relatively more transmissive than the intervening low-permeability mudstone. These bedding fractures dip to the northwest at approximately 11 degrees.

Groundwater level data collected from MWs were used to interpret the direction of groundwater flow and hydraulic gradients. In general, groundwater in the overburden flows from an elongated groundwater mound or divide located in the northern portion of the site (Figure 11). The mound causes the shallow groundwater to flow to the northwest and to the south. Groundwater flow in the bedrock is to the northwest (subparallel to the dip of the bedrock bedding), primarily within the bedrock fracture zones.

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The initial principal flow pathway within each aquifer Unit (B, C, and D) is downdip to the northwest. Based on the potentiometric surfaces presented in Figures 12a and 12b, the typical average horizontal hydraulic gradient values in bedrock aquifer Unit B ranged from 0.003 to 0.007 from 2014 and 2015. These low hydraulic gradient values result from the relatively higher transmissivity of the bedrock aquifer units (fracture zones) compared to the low-permeability mudstone members of the bedrock. The entire section of bedrock investigated at the MSP can be considered an aquitard, with minor groundwater flow occurring in secondary porosity predominantly along bedding planes, facilitated by fractures. Vertical fractures provide some communication between these more transmissive bedding planes and flow between each is primarily downward. Based on the well survey conducted, the shallow bedrock aquifer in the vicinity of the MSP is not widely used as a water supply source, limiting human health exposure. Of the potable wells identified and sampled, only the well located at 233 Mountain Avenue, on a lot adjacent to the MSP, was impacted by VOCs in the bedrock. This well was subsequently removed from service and the resident was provided with a public water supply.

5.2 Nature and Extent of Groundwater Contamination

One of the objectives of the groundwater investigation has been to define the nature and extent of groundwater contamination at the MSP. Groundwater samples have been collected from off-site private wells, test holes, shallow MWs, and bedrock MWs. Samples have been collected for 16 SEs (August 2008 to November 2015) from the shallow MWs for total uranium analysis. Samples have been collected for 16 SEs (August 2008 to January 2016) from the bedrock MWs for VOCs analysis.

Figures 13a through 13c present the trends of VOCs in the bedrock MWs for SE 1 through SE 16. Figures 14a through 14d present the trends of total uranium in the overburden MWs for SE 1 through SE 16. Figure 15 presents the VOC and total uranium sampling results for SE 15 and SE 16. Figure 16 presents an iso-concentration contour of CT and TCE results in Unit B from the SE 16 sampling event.

5.2.1 Total Uranium in the Overburden

The overburden wells and total uranium contaminant concentrations for the two most recent SEs (SE 15 and SE 16) are presented on Figure 15 and listed in Table 9. These results indicate that the Soils OU-1 RA has greatly improved MSP groundwater quality. Prior to the RA, total uranium concentrations in some of the MSP MWs exceeded the MCL criteria by a factor of 10 (see Section 2.6). Since completion of the RA, total uranium exceedances have been limited to four wells (MW-OB-7, MW-OB-8, MW-OB-10, and MW-OB-12) with results marginally above criteria since the RA.

Total uranium in former source area well MW-OB-8, marginally exceeded the EPA criteria during the first sampling event following the soils removal and since has remained below the EPA criteria. Total uranium in MW-OB-7, also located in the former source area, marginally exceeded criteria during the first three sampling events, dropping below the criteria in SE 4, SE 5, SE 7, SE 8, SE 9, SE 11, and SE 12, with an increase above the criteria in SE 6, SE 10, and SE 13. MW-OB-7 was abandoned in 2014 because the filter pack has been saturated with silt, reducing the yield and sample quality. MW-OB-7 was replaced with MW-OB-7R within 10 feet of the original location. MW-OB-7R was sampled during SE 15 and SE 16, sample results were below the criteria in both events.

Since the RA, all overburden MWs side-gradient and down-gradient south of the potential source area (south of the ground water divide) have been below the MCL and are tending towards background levels or non-detections. Overburden wells north of the groundwater divide that are either side-gradient and/or down-gradient of the former source area have had total uranium detects below EPA criteria, except for MW-OB-12 with a result above the EPA criteria in SE 7 (43.5 μ g/L) and MW-OB-10 with results above the EPA criteria in SE 11 (51 μ g/L) and SE 12 (40 μ g/L).

For all overburden wells, the geochemical parameters indicate favorable conditions for natural attenuation by sorption onto iron oxyhydroxides, as indicated by the high ORP values and low ferrous iron levels (Criteria 3).

5.2.2 VOCs in the Overburden and the Bedrock

CT and TCE are the most prevalent VOCs detected at MSP and the surrounding area, although other chlorinated compounds, breakdown components of these, and petroleum-related compounds have been detected in samples collected from the monitoring well network. The presence of chloroform and dichloroethene (1,1 and 1,2-cis) in site MWs is likely the result of degradation of CT and TCE, respectively. Shallow wells containing CT on-site and bordering the site have typically exhibited a much higher concentration of CT than TCE. No other VOCs were detected in on-site monitoring wells at concentrations that indicated a potential that they had been released to the environment on-site.

No shallow sources of CT and/or TCE were detected on-site in overburden groundwater screening or monitoring well samples. Although soils were removed to the top of bedrock at the site as part of the soils OU-1 RA, residual contaminants in Unit B and shallow bedrock wells have had the highest concentration of these VOCs detected.

The Unit B bedrock MWs, CT/TCE concentrations, and CT/TCE iso-concentration contours for the most recent sampling event (SE 16) are presented on Figure 16. The highest concentrations

of CT and TCE have been detected in ECC-MW30B but they have been decreasing consistently and significantly since this well was first sampled in 2012. The concentration of CT and TCE were CT 13,000 µg/L and TCE 430 µg/L during SE 11 and have decreased to CT 1,200 µg/L and TCE 50 µg/L during SE 16 in 2015 (see Table 6). EE-MW-41S showed a similar trend between the only two times this well was not sampled (SE 15 and SE16). The concentrations detected in this well were CT 2,460 µg/L and TCE 62 µg/L during the first sampling event and then dropped to CT 32 J µg/L and TCE 0.61 J µg/L in the following event. Both of these wells, ECC-MW-30B and EE-MW-41S, were installed within the bedrock aquifer beneath the overburden unit to depths of 53 feet bgs and 30 feet bgs, respectively, with 10-foot well screens. Wells installed at these depths would be expected to be lower in concentration of VOCs than shallower or upgradient samples more near release areas (surface). Upgradient screening samples in Unit B and overburden groundwater did not exhibit these volatile compounds in significant concentration. Based on this, the likely source area resides just south of EE-MW-41S where the sump within the former Process Building was located. This structure was 12 feet long, 6 feet wide, and 10 feet deep, and built to except wastewater from the building and a likely disposal point for other wastes. The location of the sump is included on Figure 2.

Trends for CT and TCE in other site bedrock wells are relatively stable. Concentrations of VOCs detected in Units C and D at the same location of Unit B are lower as the result of minor downward vertical leakage through fractures.

5.3 Conclusions

In general, VOC concentrations on the site are relatively low and do not indicate that a significant and widespread source of contaminants is present at the MSP site. The VOC detected with the highest concentrations on-site is CT. TCE is typically detected in samples that contain CT but at much lower concentrations. MSP is located in an industrial area where there are multiple contributors of contaminants to the bedrock aquifer. Contribution of CT and TCE in the MSP off-site MW network from off-site sources unrelated to MSP activities in groundwater is possible. Other VOCs detected in on-site wells were not found at concentrations that indicate an on-site source is present. Instead, it appears that some VOCs are migrating beneath the site in groundwater as best indicated by the presence of MTBE in on-site monitoring wells, a gasoline additive introduced in 1979, after site operations had already ceased. Other VOCs detected in on-site and off-site wells that do not appear to be site related are Freon 11, Freon 113, MTBE, 1,1,1-TCA, 1,1-DCA, 2-butanone, and chlorobenzene.

The release area for the CT and TCE appears to be limited to a small sump that was located in the former Process Building (Figure 2). This sump was used for disposal of wastewater and could have been used for disposal of non-water residuals although site records do not indicate the use of solvents as part of site operations. This sump was 12 feet long, by 6 feet wide, by 10 feet

deep and had a feeder line leading from it to the main pipe chase line. Records indicated that the sump was open and in communication with groundwater (overburden). The bottom of the sump would have been near the interface of the overburden groundwater unit and on top of the unsaturated weathered bedrock providing a migration pathway directly to the bedrock aquifer. Residuals disposed of at this depth would have spread downward and outward from this point along fractures and partings within the unsaturated bedrock before reaching the water table. CT and TCE were not detected in groundwater samples collected from the overburden wells or overburden screening samples during the most recent sampling events SE 15 and SE 16.

CT and TCE have had the most impact on groundwater in the Unit B bedding plane. The monitoring well network has delineated the extent of CT and site related TCE migration in the Unit B portion of the bedrock aquifer. The contaminant contours show that the extent of TCE in the aquifer is slightly greater than the extent of CT, indicating that other sources of TCE are likely present in the bedrock aquifer (Figure 16). These contaminants are present in Units C and D in lower concentrations as the result of minor downward vertical leakage through fractures.

Uranium was not detected in overburden wells above the EPA MCL for total uranium in SE 15 and SE 16. The lack of CT, TCE, and uranium in the overburden confirms no sources of contaminants in the overburden, which was expected as the result of the removal of on-site soils (OU-1 remedial action).

The concentrations of CT and TCE in MWs have remained relatively stable over the course of the sampling history with two exceptions, the ECC-MW-30B and the EE-MW-41S bedrock wells. The significant reduction of CT and TCE concentrations observed in these on-site wells indicate that the initial elevated concentrations of these contaminants may have been a secondary effect of drilling through minor residual contaminants in the unsaturated portion of the weathered bedrock, beneath the limits of the remedial excavation of site soils (OU-1 remedial action). Thus, groundwater MW samples collected from Unit B and the top of the bedrock aquifer (shallow bedrock wells) indicate that residual materials may remain in the unsaturated portion of the site around ECC-MW-30B, EE-MW-41S, and the former sump of the Process Building.

An evaluation of MNA parameters indicates that reductive dechlorination does not occur at the site; therefore, continued collection and evaluation of MNA parameters associated with dechlorination is not warranted at this time. However, other mechanisms associated with MNA (e.g., dispersion and adsorption) may still provide a means to reducing contaminant concentrations. Therefore, inclusion of MNA for VOCs could still be a component of a remedy presented in the FS.

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The extent of CT and TCE in the most highly contaminated bedding plane/fracture zone (Unit B) has been delineated off-site and is deemed sufficient to proceed with the completion of an FS.

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TABLES

		SE 1							A	Analys	es						
		(Aug 2008)				sb											
Well ID	Well Type	Date Sampled	Total Uranium	VOCs	Iron	Volatile Fatty Acids	Hydrogen	Nitrate	Nitrite	Sulfate	Sulfide	Chloride	Alkalinity	Carbon Dioxide	BOD	COD	TOC
MW-OB-1	Overburden	8/4/2008	•		٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠
MW-OB-2	Overburden	8/5/2008	•		•	•	•	٠	٠	٠	٠	٠	٠	•	•	•	•
MW-OB-3	Overburden	8/4/2008	•		٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠
MW-OB-4	Overburden	8/5/2008	•		٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠
MW-OB-5	Overburden	8/5/2008	•		٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠
MW-OB-6	Overburden	8/5/2008	•		٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠
MW-OB-7	Overburden	8/5/2008	•		•	•	•	٠	٠	٠	٠	٠	٠	•	•	•	•
MW-OB-8	Overburden	8/5/2008	•		•	•	•	٠	٠	٠	٠	٠	٠	•	•	•	•
MW-OB-9	Overburden	8/5/2008	•		•	•	•	•	•	٠	•	•	•	•	•	•	•
MW-OB-10	Overburden	8/6/2008	•		٠			٠	٠	٠	٠	٠	٠		٠	٠	•
MW-OB-11	Overburden	8/5/2008	•		•	•	•	•	•	٠	•	•	•	•	•	•	•
MW-OB-12	Overburden	8/6/2008	•		•	•	•	٠	٠	٠	٠	٠	٠	•	•	•	•
MW-OB-13	Overburden	8/6/2008	•		•	•	•	٠	٠	٠	٠	٠	٠	•	•	•	•
B18W29SR	Overburden	8/6/2008	•		٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠	٠
URS-MW-2D	Bedrock	8/4/2008		٠													
URS-MW-22D	Bedrock	8/4/2008		٠													
URS-MW-24D	Bedrock	8/4/2008		•													

Notes:

• = Requested for the indicated analyses.

ID = Identification

VOCs = Volatile Organic Compounds

TOC = Total Organic Carbon

COD = Chemical Oxygen Demand

BOD = Biological Oxygen Demand

		SE 2							A	Analys	es						
		SE 2 (Nov 2008)				ds											
Well ID	Well Type	Date Sampled	Total Uranium	VOCs	Iron	Volatile Fatty Acids	Hydrogen	Nitrate	Nitrite	Sulfate	Sulfide	Chloride	Alkalinity	Carbon Dioxide	BOD	COD	TOC
MW-OB-1	Overburden	11/10/2008	•		٠	٠	٠	•	٠	•	٠	٠	•	•	٠	٠	•
MW-OB-2	Overburden	11/10/2008	٠		٠	٠	•	•	•	٠	٠	٠	•	•	•	•	٠
MW-OB-3	Overburden	11/10/2008	•		•	•	•	•	•	•	•	•	•	•	٠	•	•
MW-OB-4	Overburden	11/10/2008	•		٠	٠	٠	٠	٠	٠	٠	٠	٠	•	٠	٠	٠
MW-OB-5	Overburden	11/11/2008	•		٠	•	٠	•	٠	٠	٠	٠	٠	•	٠	٠	٠
MW-OB-6	Overburden	11/11/2008	•		•	•	٠	•	٠	٠	٠	٠	٠	•	٠	٠	٠
MW-OB-7	Overburden	11/11/2008	•		•	•	•	•	•	٠	٠	٠	•	•	•	•	٠
MW-OB-8	Overburden	11/12/2008	•		•	•	•	•	•	٠	٠	٠	•	•	•	•	٠
MW-OB-9	Overburden	11/11/2008	•		•	•	•	•	•	•	•	•	•	•	•	•	•
MW-OB-10	Overburden	11/11/2008	•														
MW-OB-11	Overburden	11/12/2008	•		•	•	•	•	٠	٠	•	٠	٠	•	٠	٠	•
MW-OB-12	Overburden	11/11/2008	•		٠	٠	٠	٠	٠	٠	٠	٠	٠	•	٠	٠	٠
MW-OB-13	Overburden	11/11/2008	•		٠	٠	•	•	•	٠	٠	•	•	•	•	•	•
B18W29SR	Overburden	11/12/2008	•		•	•	•	•	•	٠	٠	٠	•	•	•	•	٠
URS-MW-2D	Bedrock	11/10/2008		•													
URS-MW-22D	Bedrock	11/10/2008		٠													
URS-MW-24D	Bedrock	11/10/2008		•													

Notes:

• = Requested for the indicated analyses.

ID = Identification

VOCs = Volatile Organic Compounds

TOC = Total Organic Carbon

COD = Chemical Oxygen Demand

BOD = Biological Oxygen Demand

		67 A	Analy	ses
		SE 3 (Feb 2009)		
Well ID	Well Type	SE 3 (Feb 2009) Analy Date Sampled Image: Comparison of the system Sector of the sys	VOCs	
MW-OB-1	Overburden	2/11/2009	•	
MW-OB-2	Overburden	2/11/2009	•	
MW-OB-3	Overburden	2/10/2009	•	
MW-OB-4	Overburden	2/10/2009	•	
MW-OB-5	Overburden	2/10/2009	•	
MW-OB-6	Overburden	2/10/2009	•	
MW-OB-7	Overburden	2/11/2009	•	
MW-OB-8	Overburden	2/11/2009	•	
MW-OB-9	Overburden	2/11/2009	•	
MW-OB-10	Overburden	2/11/2009	•	
MW-OB-11	Overburden	2/11/2009	•	
MW-OB-12	Overburden	2/11/2009	•	
MW-OB-13	Overburden	2/11/2009	•	
B18W29SR	Overburden	2/10/2009	•	
URS-MW-2D	Bedrock	2/12/2009		٠
URS-MW-22D	Bedrock	2/12/2009		٠
URS-MW-24D	Bedrock	2/12/2009		٠

Notes:

• = Requested for the indicated analyses.

ID = Identification

VOCs = Volatile Organic Compounds

		SE 4								Analys	ses						
		SE 4 (Dec 2009)				sb		Sulfate									
Well ID	Well Type	Date Sampled	Total Uranium	VOCs	Total Iron	Volatile Fatty Acids	Hydrogen	Nitrate, Nitrite, St	Sulfide	Chloride	Alkalinity	Carbon Dioxide	BOD	COD	TOC	Methane, Ethane, Ethene	Ferrous Iron
MW-OB-1	Overburden	12/15/2009	٠		٠	٠	•	•	•	٠	•	٠	•	٠	•		
MW-OB-2	Overburden	12/16/2009	•		•	•	•	•	•	•	•	•	•	•	•		
MW-OB-3	Overburden	12/15/2009	•		•	•	•	•	٠	•	٠	٠	•	٠	•		
MW-OB-4	Overburden	12/15/2009	•		٠	•	•	٠	•	•	•	٠	•	٠	•		
MW-OB-5	Overburden	12/16/2009	٠		٠	٠	٠	•	•	٠	•	٠	•	•	•		
MW-OB-6	Overburden	12/16/2009	•		٠	•	•	•	•	•	•	٠	•	•	•		
MW-OB-7	Overburden	12/16/2009	•		•	•	•	•	•	•	•	•	•	•	•		
MW-OB-8	Overburden	12/16/2009	•		•	٠	•	•	•	•	•	•	•	•	•		
MW-OB-9	Overburden	12/16/2009	•		٠	•	•	•	•	•	•	٠	•	•	•		
MW-OB-10	Overburden	12/17/2009	•														
MW-OB-11	Overburden	12/16/2009	•		•	•	•	•	•	•	•	٠	٠	•	•		
MW-OB-12	Overburden	12/17/2009	٠		•	•	•	•	٠	٠	٠	٠	٠	٠	٠		
MW-OB-13	Overburden	12/17/2009	٠		•	•	•	•	٠	٠	٠	٠	٠	٠	٠		
B18W29SR	Overburden	12/16/2009	٠		٠	٠	•	٠	٠	٠	٠	٠	٠	٠	٠	1	
URS-MW-2D	Bedrock	12/15/2009		•	٠		٠	٠	٠		٠	٠			٠	•	٠
URS-MW-22D	Bedrock	12/15/2009		٠	•		•	•	•		•	•			•	•	٠
URS-MW-24D	Bedrock	12/15/2009		•	٠		•	•	•		•	•			•	٠	•

Notes:

• = Requested for the indicated analyses.

ID = Identification

VOCs = Volatile Organic Compounds

TOC = Total Organic Carbon

COD = Chemical Oxygen Demand

BOD = Biological Oxygen Demand

		SE 5				Ana	lyses								
		(April 2010)					lfate				st				
Well ID	Well Type	Date Sampled	Total Uranium	VOCs	Total Iron	Hydrogen	Nitrate, Nitrite, Sulfate	Sulfide	Carbon Dioxide	TOC	Volatile Fatty Acids	Chloride	BOD	x x x x x x x x x x x x x x x x x x x	Methane, Ethane, Ethene
MW-OB-1	Overburden	4/14/2010	•		•	Х	•	•	•	Х	Х	Х	Х	Х	
MW-OB-2	Overburden	4/14/2010	•		•	Х	٠	•	٠	Х	Х	Х	Х	Х	
MW-OB-3	Overburden	4/14/2010	•		•	Х	٠	٠	•	Х	Х	Х	Х	Х	
MW-OB-4	Overburden	4/15/2010	•		•	Х	٠	٠	•	Х	Х	Х	Х	Х	
MW-OB-5	Overburden	4/15/2010	•		•	Х	٠	٠	•	Х	Х	Х	Х	Х	
MW-OB-6	Overburden	4/16/2010	•		•	Х	٠	٠	•	Х	Х	Х	Х	Х	
MW-OB-7	Overburden	4/15/2010	•		•	Х	٠	•	•	Х	Х	Х	Х	Х	
MW-OB-8	Overburden	4/15/2010	•		•	Х	٠	•	•	Х	Х	Х	Х	Х	
MW-OB-9	Overburden	4/15/2010	•		•	Х	٠	٠	•	Х	Х	Х	Х	Х	
MW-OB-10	Overburden							Not S	ampled						
MW-OB-11	Overburden	4/15/2010	•		•	Х	•	٠	•	Х	Х	Х	Х	Х	
MW-OB-12	Overburden	4/15/2010	•		•	Х	•	٠	•	Х	Х	Х	Х	Х	
MW-OB-13	Overburden	4/16/2010	•		•	Х	•	٠	•	Х	Х	Х	Х	Х	
B18W29SR	Overburden	4/15/2010	•		•	Х	•	•	•	Х	Х	Х	Х	Х	
URS-MW-2D	Bedrock	4/14/2010		•	•	•	•	•	•	•					•
URS-MW-22D	Bedrock	4/14/2010		•	•	٠	٠	•	•	•					•
URS-MW-24D	Bedrock	4/14/2010		•	•	•	•	•	•	٠				1	•
	Residential Spigot	4/16/2010	•	•	•	•	•	•	•	•	1	1		1	•

Notes:

• = Requested for the indicated analyses.

ID = Identification

X = Out of scope analysis, sampled in error. Out of scope analyses were not evaluated.

VOCs = Volatile Organic Compounds TOC = Total Organic Carbon COD = Chemical Oxygen Demand

BOD = Biological Oxygen Demand

		ST (Ana	lyses				
		SE 6 (Nov 2010)					ulfate				
Well ID	Well Type	Date Sampled	Total Uranium	VOCs	Total Iron	Hydrogen	Nitrate, Nitrite, Sulfate	Sulfide	Carbon Dioxide	TOC	Methane, Ethane, Ethene
MW-OB-1	Overburden	11/16/2010	•		•		•	•	•		
MW-OB-2	Overburden	11/17/2010	•		•		•	•	•		
MW-OB-3	Overburden	11/17/2010	•		٠		٠	٠	٠		
MW-OB-4	Overburden	11/17/2010	•		•		•	•	•		
MW-OB-5	Overburden	11/18/2010	•		•		٠	٠	٠		
MW-OB-6	Overburden	11/18/2010	•		•		٠	•	•		
MW-OB-7	Overburden	11/17/2010	•		•		•	•	•		
MW-OB-8	Overburden	11/16/2010	•		•		•	•	•		
MW-OB-9	Overburden	11/17/2010	•		•		•	•	•		
MW-OB-10	Overburden	11/17/2010	•								
MW-OB-11	Overburden	11/18/2010	•		•		•	•	•		
MW-OB-12	Overburden	11/17/2010	•		•		•	•	•		
MW-OB-13	Overburden	11/17/2010	•		•		•	•	•		
B18W29SR	Overburden	11/17/2010	•		•		٠	•	•		
URS-MW-2D	Bedrock	11/16/2010		•	٠	٠	٠	٠	٠	٠	•
URS-MW-22D	Bedrock	11/18/2010		•	•	•	•	٠	•	٠	•
URS-MW-24D	Bedrock	11/15/2010		•	٠	٠	٠	٠	٠	٠	•
ECC-MW-25C	Bedrock	11/15/2010		•	•	•	•	٠	٠	٠	•
ECC-MW-25D	Bedrock	11/15/2010		•	•	•	٠	٠	•	٠	•
ECC-MW-26C	Bedrock	11/16/2010		•	•	•	٠	٠	•	٠	•
ECC-MW-26D	Bedrock	11/16/2010		•	•	•	•	٠	•	٠	٠
ECC-MW-27C	Bedrock	11/16/2010		•	•	•	•	٠	•	٠	٠
ECC-MW-27D	Bedrock	11/16/2010		•	٠	٠	٠	٠	٠	٠	•

Notes:

• = Requested for the indicated analyses.

ID = Identification

VOCs = Volatile Organic Compounds TOC = Total Organic Carbon

					A	Analys	es				
		SE 7 (May 2011)				Ĺ					
Well ID	Well Type	Date Sampled	Total Uranium	Total Iron	Hydrogen	Nitrate, Nitrite, Sulfate	Sulfide	Carbon Dioxide	TOC	Methane, Ethane, Ethene	VOCs
MW-OB-1	Overburden	5/24/2011	•	•		•	٠	•			
MW-OB-2	Overburden	5/27/2011	•	•		•	•	•			
MW-OB-3	Overburden	5/24/2011	•	•		٠	٠	٠			
MW-OB-4	Overburden	5/24/2011	•	•		•	٠	•			
MW-OB-5	Overburden	5/25/2011	•	•		•	•	•			
MW-OB-6	Overburden	5/25/2011	٠	•		•	٠	٠			
MW-OB-7	Overburden	5/25/2011	•	٠		٠	٠	٠			
MW-OB-8	Overburden	5/24/2011	•	•		•	•	•			
MW-OB-9	Overburden	5/26/2011	•	•		٠	٠	٠			
MW-OB-10	Overburden	5/26/2011	•	•		•	٠	•			
MW-OB-11	Overburden	5/25/2011	•	٠		٠	٠	٠			
MW-OB-12	Overburden	5/26/2011	•	٠		٠	٠	٠			
MW-OB-13	Overburden	5/26/2011	•	٠		٠	٠	٠			
B18W29SR	Overburden	5/25/2011	٠	•		•	٠	٠			
URS-MW2D	Bedrock	5/26/2011		٠	٠	٠	٠	٠	٠	٠	٠
URS-MW22D	Bedrock	5/27/2011		•	•	•	•	•	٠	•	٠
URS-MW24D	Bedrock	5/24/2011		•	•	•	٠	٠	٠	•	•
ECC-MW-25C	Bedrock	5/24/2011		•	•	•	•	•	•	•	•
ECC-MW-25D	Bedrock	5/25/2011		•	•	•	•	•	•	•	•
ECC-MW-26B	Bedrock	5/26/2011									•
ECC-MW-26C	Bedrock	5/25/2011		•	•	•	•	•	٠	•	٠
ECC-MW-26D	Bedrock	5/25/2011		•	•	•	•	•	٠	•	٠
ECC-MW-27C	Bedrock	5/26/2011		•	٠	•	٠	•	٠	٠	٠
ECC-MW-27D	Bedrock	5/26/2011		•	•	•	•	•	•	•	•
ECC-MW-28B	Bedrock	5/27/2011		•	•	•	•	•	•	•	•
ECC-MW-29B	Bedrock	5/26/2011		•	•	•	•	•	•	•	•

Notes:

• = Requested for the indicated analyses.

ID = Identification

VOCs = Volatile Organic Compounds TOC = Total Organic Carbon

					4	Analys	es				
		SE 8 (Aug 2011)				Γ					
Well ID	Well Type	Date Sampled	Total Uranium	Total Iron	Hydrogen	Nitrate, Nitrite, Sulfate	Sulfide	Carbon Dioxide	TOC	Methane, Ethane, Ethene	VOCs
MW-OB-1	Overburden	8/22/2011	٠	•		•	•	•			
MW-OB-2	Overburden	8/25/2011	•	٠		•	•	٠			
MW-OB-3	Overburden	8/22/2011	•	٠		٠	٠	٠			
MW-OB-4	Overburden	8/22/2011	•	٠		٠	٠	٠			
MW-OB-5	Overburden	8/23/2011	•	•		٠	•	•			
MW-OB-6	Overburden	8/23/2011	•	•		•	•	•			
MW-OB-7	Overburden	8/24/2011	•	•		٠	•	•			
MW-OB-8	Overburden	8/22/2011	•	•		٠	•	•			
MW-OB-9	Overburden	8/23/2011	•	•		•	•	•			
MW-OB-10	Overburden	8/24/2011	•	٠		٠	٠	٠			
MW-OB-11	Overburden	8/23/2011	•	•		•	•	•			
MW-OB-12	Overburden	8/24/2011	•	•		٠	٠	٠			
MW-OB-13	Overburden	8/24/2011	•	•		٠	٠	٠			
B18W29SR	Overburden	8/23/2011	•	٠		٠	٠	٠			
URS-MW2D	Bedrock	8/24/2011		٠	٠	٠	٠	٠	٠	٠	•
URS-MW22D	Bedrock	8/25/2011		٠	٠	٠	٠	٠	٠	٠	٠
URS-MW24D	Bedrock	8/22/2011		•	•	•	•	•	•	•	•
ECC-MW-25C	Bedrock	8/22/2011		٠	٠	•	٠	٠	٠	٠	٠
ECC-MW-25D	Bedrock	8/22/2011		•	•	•	•	•	•	•	•
ECC-MW-26B	Bedrock	8/23/2011	1	٠	٠	•	•	•	•	٠	•
ECC-MW-26C	Bedrock	8/23/2011		•	٠	٠	•	•	٠	٠	٠
ECC-MW-26D	Bedrock	8/23/2011		•	٠	٠	•	•	٠	٠	٠
ECC-MW-27C	Bedrock	8/24/2011		•	٠	٠	•	•	٠	٠	٠
ECC-MW-27D	Bedrock	8/24/2011	1	٠	٠	•	•	•	•	٠	•
ECC-MW-28B	Bedrock	8/25/2011		٠	٠	٠	٠	٠	•	٠	٠
ECC-MW-29B	Bedrock	8/23/2011		•	•	•	•	•	•	•	٠

Notes:

• = Requested for the indicated analyses.

ID = Identification

VOCs = Volatile Organic Compounds TOC = Total Organic Carbon

		SE 0				A	nalys	es			
		SE 9 (Nov 2011)				ulfate					
Well ID	Well Type	Date Sampled	Total Uranium	Total Iron	Hydrogen	Nitrate, Nitrite, Sulfate	Sulfide	Carbon Dioxide	TOC	Methane, Ethane, Ethene	vocs
MW-OB-1	Overburden	11/9/2011	٠	•		٠	٠	٠			
MW-OB-2	Overburden	11/9/2011	•	•		•	•	•			
MW-OB-3	Overburden	11/8/2011	•	•		•	•	•			
MW-OB-4	Overburden	11/8/2011	•	•		•	٠	٠			
MW-OB-5	Overburden	11/7/2011	٠	٠		٠	٠	٠			
MW-OB-6	Overburden	11/7/2011	•	٠		٠	٠	٠			
MW-OB-7	Overburden	11/7/2011	•	٠		٠	٠	٠			
MW-OB-8	Overburden	11/7/2011	•	•		•	٠	٠			
MW-OB-9	Overburden	11/7/2011	•	•		•	•	•			
MW-OB-10	Overburden	11/9/2011	•	•							
MW-OB-11	Overburden	11/8/2011	•	•		•	•	•			
MW-OB-12	Overburden	11/9/2011	•	•		•	•	•			
MW-OB-13	Overburden	11/9/2011	•	٠		٠	٠	٠			
B18W29SR	Overburden	11/8/2011	•	٠		٠	٠	٠			
URS-MW2D	Bedrock	11/10/2011									٠
URS-MW22D	Bedrock	11/9/2011		٠	٠	٠	٠	٠	٠	٠	٠
URS-MW24D	Bedrock	11/10/2011									٠
ECC-MW-22D	Bedrock	11/10/2011		•	•	•	•	•	•	•	•
ECC-MW-23D	Bedrock	11/10/2011	1						1		•
ECC-MW-24D	Bedrock	11/10/2011	1	•	•	•	٠	٠	•	٠	٠
ECC-MW-25C	Bedrock	11/7/2011		٠	•	•	•	•	•	•	٠
ECC-MW-25D	Bedrock	11/7/2011		٠	•	•	•	•	•	•	٠
ECC-MW-26B	Bedrock	11/8/2011		٠	•	•	•	•	•	•	٠
ECC-MW-26C	Bedrock	11/8/2011		٠	•	•	•	•	•	•	٠
ECC-MW-26D	Bedrock	11/8/2011		٠	٠	•	•	•	٠	•	٠
ECC-MW-27C	Bedrock	11/7/2011		٠	٠	•	•	•	٠	•	٠
ECC-MW-27D	Bedrock	11/7/2011		٠	•	•	•	•	•	٠	•
ECC-MW-28B	Bedrock	11/9/2011		٠	•	٠	٠	٠	•	٠	٠
ECC-MW-29B	Bedrock	11/9/2011		٠	•	•	•	•	•	•	٠

Notes:

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VOCs = Volatile Organic Compounds

TOC = Total Organic Carbon

				C	1		MALA	D			
		SE 10	<u> </u>	oC		1	MNA	Para	meters		-
Well ID	Well Type	(Feb 2012) Date Sampled	Total Uranium	S	Total Iron	Hydrogen	Nitrate, Nitrite, Sulfate	de	Carbon Dioxide		Methane, Ethane, Ethene
			Tota	VOCs	Tota	Hydi	Nitra	Sulfide	Cart	TOC	Methan Ethene
MW-OB-1	Overburden	2/9/2012	•		•		٠	٠	•		
MW-OB-2	Overburden	2/9/2012	•		•		•	•	•		
MW-OB-3	Overburden	2/6/2012	•		•		•	•	•		
MW-OB-4	Overburden	2/6/2012	•		•		٠	٠	٠		
MW-OB-5	Overburden	2/7/2012	•		•		٠	٠	٠		
MW-OB-6	Overburden	2/7/2012	•		•		•	•	•		
MW-OB-7	Overburden	2/7/2012	•		•		٠	٠	٠		
MW-OB-8	Overburden	2/6/2012	•		•		٠	٠	٠		
MW-OB-9	Overburden	2/8/2012	•		•		•	•	•		
MW-OB-10	Overburden	2/7/2012	•		•		•	•	•		
MW-OB-11	Overburden	2/8/2012	•		•		•	•	•		
MW-OB-12	Overburden	2/8/2012	•		•		•	•	•		
MW-OB-13	Overburden	2/8/2012	•		•		•	•	•		
B18W29SR	Overburden	2/6/2012	•		•		•	•	•		
URS-MW2D	Bedrock	2/9/2012		•	٠	٠	٠	•	•	٠	٠
URS-MW22D	Bedrock	2/9/2012		٠	•	٠	٠	٠	٠	٠	•
URS-MW24D	Bedrock	2/6/2012		•	•	٠	٠	٠	٠	•	٠
ECC-MW-25C	Bedrock	2/6/2012		•	•	•	•	•	•	٠	•
ECC-MW-25D	Bedrock	2/6/2012		٠	•	٠	٠	٠	٠	٠	•
ECC-MW-26B	Bedrock	2/7/2012		٠	•	•	٠	٠	٠	٠	•
ECC-MW-26C	Bedrock	2/7/2012		•	•	٠	٠	٠	٠	٠	٠
ECC-MW-26D	Bedrock	2/7/2012		•	•	٠	٠	٠	٠	٠	٠
ECC-MW-27C	Bedrock	2/8/2012		•	•	٠	•	٠	•	•	•
ECC-MW-27D	Bedrock	2/8/2012		•	•	•	٠	•	•	٠	•
ECC-MW-28B	Bedrock	2/9/2012		•	•	•	•	•	•	•	•
ECC-MW-29B	Bedrock	2/8/2012		•	•	•	•	•	•	•	•

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VOCs = Volatile Organic Compounds

TOC = Total Organic Carbon

				.C	1		MANIA	D			
		SE 11	<u> </u>	oC	<u> </u>	1	MINA	Para	neters	1	1
		(June 2012)					ulfate				
Well ID	Well Type	Date Sampled	Total Uranium	VOCs	Total Iron	Hydrogen	Nitrate, Nitrite, Sulfate	Sulfide	Carbon Dioxide	TOC	Methane, Ethane, Ethene
MW-OB-1	Overburden	6/20/2012	•		٠		•	•	•		
MW-OB-2	Overburden	6/20/2012	•		•		•	•	•		
MW-OB-3	Overburden	6/19/2012	•		٠		•	•	•		
MW-OB-4	Overburden	6/19/2012	٠		٠		٠	٠	•		
MW-OB-5	Overburden	6/19/2012	٠		٠		٠	٠	•		
MW-OB-6	Overburden	6/19/2012	•		•		•	•	•		
MW-OB-7	Overburden	6/22/2012	٠		٠		٠	٠	•		
MW-OB-8	Overburden	6/20/2012	•		٠		•	٠	•		
MW-OB-9	Overburden	6/21/2012	•		•		•	•	•		
MW-OB-10	Overburden	6/21/2012	٠		٠		٠	•	•		
MW-OB-11	Overburden	6/20/2012	•		٠		٠	٠	٠		
MW-OB-12	Overburden	6/21/2012	٠		٠		٠	•	•		
MW-OB-13	Overburden	6/21/2012	٠		٠		٠	•	•		
B18W29SR	Overburden	6/20/2012	•		٠		٠	٠	٠		
URS-MW2D	Bedrock	6/22/2012		٠							
URS-MW22D	Bedrock	6/20/2012		•							
ECC-MW-24B	Bedrock	6/22/2012		•	•	•	•	•	•	•	•
URS-MW-24D	Bedrock	6/22/2012		٠							
ECC-MW-25C	Bedrock	6/19/2012		•	•	•	•	•	•	•	•
ECC-MW-25D	Bedrock	6/19/2012		•	•	•	•	•	•	•	•
ECC-MW-26B	Bedrock	6/21/2012		•	•	•	•	•	•	•	•
ECC-MW-26C	Bedrock	6/21/2012		•	٠	•	•	•	٠	٠	•
ECC-MW-26D	Bedrock	6/21/2012		•	•	•	•	•	•	•	•
ECC-MW-27C	Bedrock	6/20/2012		٠	٠	٠	٠	•	•	٠	•
ECC-MW-27D	Bedrock	6/20/2012		٠	٠	•	٠	•	٠	•	•
ECC-MW-28B	Bedrock	6/19/2012		٠	٠	•	٠	•	٠	•	•
ECC-MW-29B	Bedrock	6/20/2012		•	•	•	•	•	•	•	•
ECC-MW-30B	Bedrock	6/22/2012		٠	٠	٠	٠	•	•	•	•
ECC-MW-30D	Bedrock	6/22/2012		٠	٠	•	٠	•	٠	•	•

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			C	оC			MNA	Para	neters		
		SE 12					1				
Well		(Aug 2012)	_				Sulfate				e,
ID	Well Type	Date Sampled	Total Uranium	VOCs	Total Iron	Hydrogen	Nitrate, Nitrite, Sulfate	Sulfide	Carbon Dioxide	TOC	Methane, Ethane, Ethene
MW-OB-1	Overburden	8/22/2012	•		٠		٠	٠	•		
MW-OB-2	Overburden	8/22/2012	•		•		•	•	•		
MW-OB-3	Overburden	8/20/2012	•		•		•	•	•		
MW-OB-4	Overburden	8/20/2012	•		٠		٠	٠	•		
MW-OB-5	Overburden	8/20/2012	•		•		•	•	•		
MW-OB-6	Overburden	8/20/2012	•		•		•	•	•		
MW-OB-7	Overburden	8/22/2012	•		•		•	•	•		
MW-OB-8	Overburden	8/22/2012	•		•		•	•	•		
MW-OB-9	Overburden	8/21/2012	•		•		•	•	•		
MW-OB-10	Overburden	8/21/2012	•		•		•	•	•		
MW-OB-11	Overburden	8/21/2012	•		•		•	•	•		
MW-OB-12	Overburden	8/21/2012	•		•		•	•	•		
MW-OB-13	Overburden	8/21/2012	•		•		•	•	•		
B18W29SR	Overburden	8/20/2012	•		٠		٠	٠	٠		
URS-MW-2D	Bedrock	8/23/2012		٠							
URS-MW-22D	Bedrock	8/22/2012		•							
ECC-MW-24B	Bedrock	8/23/2012		•	٠	•	٠	٠	٠	٠	٠
URS-MW-24D	Bedrock	8/23/2012		•							
ECC-EMW-25C	Bedrock	8/20/2012		•	•	•	•	•	•	•	•
ECC-MW-25D	Bedrock	8/20/2012		•	•	•	•	•	•	•	•
ECC-MW-26B	Bedrock	8/21/2012		•	٠	٠	٠	٠	٠	٠	٠
ECC-MW-26C	Bedrock	8/21/2012		•	•	•	•	•	٠	٠	•
ECC-MW-26D	Bedrock	8/21/2012		•	•	•	•	•	٠	٠	•
ECC-MW-27C	Bedrock	8/22/2012		•	•	•	•	•	•	•	٠
ECC-MW-27D	Bedrock	8/22/2012		•	•	•	٠	•	•	•	•
ECC-MW-28B	Bedrock	8/20/2012		•	•	•	٠	•	•	•	•
ECC-MW-29B	Bedrock	8/22/2012		•	•	•	•	•	•	•	•
ECC-MW-30B	Bedrock	8/23/2012		•	•	•	•	•	•	•	•
ECC-MW-30D	Bedrock	8/23/2012		•	•	•	•	•	•	•	•

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Table 1 Sample Collection Summaries - August 2008 to January 2016 Groundwater Sampling Events Groundwater Investigation Technical Memorandum **Middlesex Sampling Plant** Middlesex, New Jersey

			C	oC			MNA	Para	meters		
		SE 13 (Nov 2012)					1				
Well ID	Well Type	Date Sampled	Total Uranium	VOCs	Total Iron	Hydrogen	Nitrate, Nitrite, Sulfate	Sulfide	Carbon Dioxide	TOC	Methane, Ethane, Ethene
MW-OB-1	Overburden	11/27/2012	•		•		•	•	•		
MW-OB-2	Overburden	11/27/2012	•		•		•	•	•		
MW-OB-3	Overburden	11/26/2012	•		•		•	•	•		
MW-OB-4	Overburden	11/26/2012	•		•		•	•	•		
MW-OB-5	Overburden	11/26/2012	•		•		•	•	•		
MW-OB-6	Overburden	11/26/2012	•		•		•	•	•		
MW-OB-7	Overburden	11/27/2012	•		٠		•	•	٠		
MW-OB-8	Overburden	11/27/2012	•		•		•	•	•		
MW-OB-9	Overburden	11/28/2012	•		•		•	•	•		
MW-OB-10	Overburden	NS									
MW-OB-11	Overburden	11/28/2012	•		•		•	•	•		
MW-OB-12	Overburden	11/28/2012	•		•		•	•	•		
MW-OB-13	Overburden	11/28/2012	•		•		•	•	•		
B18W29SR	Overburden	11/26/2012	•		٠		•	•	•		
URS-MW-2D	Bedrock	11/30/2012		٠							
URS-MW-22D	Bedrock	11/28/2012		•							
ECC-MW-24B	Bedrock	11/28/2012		•	•	•	•	•	•	•	•
URS-MW-24D	Bedrock	11/28/2012		•							
ECC-MW-25C	Bedrock	11/26/2012		٠	٠	٠	٠	٠	٠	٠	•
ECC-MW-25D	Bedrock	11/26/2012		•	•	٠	•	•	•	•	•
ECC-MW-26B	Bedrock	11/29/2012		٠	٠	٠	٠	٠	٠	٠	•
ECC-MW-26C	Bedrock	11/29/2012		٠	٠	٠	•	٠	٠	٠	•
ECC-MW-26D	Bedrock	11/29/2012		٠	•	•	•	•	•	•	•
ECC-MW-27B	Bedrock	11/27/2012		٠							
ECC-MW-27C	Bedrock	11/27/2012		•	٠	•	•	•	•	•	•
ECC-MW-27D	Bedrock	11/27/2012		٠	٠	٠	٠	٠	٠	•	•
ECC-MW-28B	Bedrock	11/26/2012		•	•	•	•	•	•	•	•
ECC-MW-29B	Bedrock	11/28/2012		٠	٠	•	•	٠	٠	٠	•
ECC-MW-30B	Bedrock	11/28/2012		٠	٠	٠	٠	٠	٠	٠	٠
ECC-MW-30D	Bedrock	11/30/2012		٠	٠	•	٠	٠	٠	٠	•
ECC-MW-31B	Bedrock	11/29/2012		٠							
ECC-MW-32B	Bedrock	11/29/2012		٠							
ECC-MW-32C	Bedrock	11/29/2012		•							
ECC-MW-33B	Bedrock	11/29/2012		•							
ECC-MW-34B	Bedrock	11/29/2012		•							

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VOCs = Volatile Organic Compounds TOC = Total Organic Carbon

NS = A sample could not be collected at overburden well 10 (OB-10) because the well was dry.

		SE 14 (Feb 2013)	CoC
Well ID	Well Type	Date Sampled	vocs
ECC-MW-30B	Bedrock	2/19/2013	•
ECC-MW-35B	Bedrock	2/19/2013	•
ECC-MW-35C	Bedrock	2/19/2013	•

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- VOCs = Volatile Organic Compounds

			C	ъC
		SE 15 (Oct 2014)	0	
Well ID	Well Type	Date Sampled	Total Uranium	VOCs
MW-OB-1	Overburden	10/7/2014	•	•
MW-OB-2	Overburden	10/7/2014	•	•
MW-OB-3	Overburden	10/6/2014	•	•
MW-OB-4	Overburden	10/6/2014	•	•
MW-OB-5	Overburden	10/6/2014	•	•
MW-OB-6	Overburden	10/6/2014	•	•
MW-OB-7R	Overburden	10/7/2014	•	•
MW-OB-8	Overburden	10/7/2014	•	•
MW-OB-11	Overburden	10/7/2014	•	•
MW-OB-13	Overburden	10/7/2014	•	•
B18W29SR	Overburden	10/6/2014	•	•
URS-MW-2D	Bedrock	10/7/2014		•
URS-MW-22D	Bedrock	10/7/2014		•
ECC-MW-24B	Bedrock	10/9/2014		•
URS-MW-24D	Bedrock	10/7/2014		•
ECC-MW-25C	Bedrock	10/8/2014		•
ECC-MW-25D	Bedrock	10/8/2014		•
ECC-MW-26B	Bedrock	10/6/2014		•
ECC-MW-26C	Bedrock	10/6/2014		•
ECC-MW-26D	Bedrock	10/7/2014		•
ECC-MW-27B	Bedrock	10/7/2014		•
ECC-MW-27C	Bedrock	10/6/2014		•
ECC-MW-27D	Bedrock	10/7/2014		•
ECC-MW-28B	Bedrock	10/7/2014		•
ECC-MW-29B	Bedrock	10/7/2014		•
ECC-MW-30B	Bedrock	10/9/2014		•
ECC-MW-30D	Bedrock	10/9/2014		•
ECC-MW-31B	Bedrock	10/9/2014		•
ECC-MW-32B	Bedrock	10/8/2014		•
ECC-MW-32C	Bedrock	10/8/2014		•
ECC-MW-33B	Bedrock	10/8/2014		•
ECC-MW-34B	Bedrock	10/8/2014		•
ECC-MW-35B	Bedrock	10/8/2014		•
ECC-MW-35C	Bedrock	10/8/2014		•
EE-MW-36B	Bedrock	10/9/2014		•
EE-MW-37B	Bedrock	10/9/2014		•
EE-MW-38B	Bedrock	10/9/2014		•
EE-MW-39B	Bedrock	10/9/2014		•
EE-MW-40B	Bedrock	10/8/2014		•
EE-MW-41S	Bedrock	10/8/2014		•

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VOCs = Volatile Organic Compounds

			C	ъC
		SE 16 (Jan 2016)		
Well ID	Well Type	Date Sampled	Total Uranium	VOCs
MW-OB-1	Overburden	11/12/2015	•	•
MW-OB-2	Overburden	11/12/2015	•	•
MW-OB-3	Overburden	11/10/2015	•	•
MW-OB-4	Overburden	11/10/2015	•	•
MW-OB-5	Overburden	11/10/2015	•	•
MW-OB-6	Overburden	11/10/2015	•	•
MW-OB-7R	Overburden	11/10/2015	•	•
MW-OB-8	Overburden	11/10/2015	•	•
MW-OB-9	Overburden	11/11/2015	•	•
MW-OB-11	Overburden	11/13/2015	•	•
MW-OB-12	Overburden	11/11/2015	•	•
MW-OB-13	Overburden	11/11/2015	•	•
B18W29SR	Overburden	11/10/2015	•	•
URS-MW-2D	Bedrock	11/9/2015		•
URS-MW-22D	Bedrock	11/9/2015		•
ECC-MW-24B	Bedrock	11/11/2015		•
URS-MW-24D	Bedrock	11/11/2015		•
ECC-MW-25C	Bedrock	11/11/2015		•
ECC-MW-25D	Bedrock	11/11/2015		•
ECC-MW-26B	Bedrock	11/10/2015		•
ECC-MW-26C	Bedrock	11/10/2015		•
ECC-MW-26D	Bedrock	11/10/2015		•
ECC-MW-27B	Bedrock	11/10/2015		•
ECC-MW-27D	Bedrock	11/10/2015		•
ECC-MW-27D	Bedrock	11/10/2015		•
ECC-MW-28B	Bedrock	11/11/2015		•
ECC-MW-28B ECC-MW-29B	Bedrock	11/11/2015		
ECC-MW-29B ECC-MW-30B		11/11/2013		•
	Bedrock			-
ECC-MW-30D	Bedrock	11/13/2015		•
ECC-MW-31B	Bedrock	11/12/2015		•
ECC-MW-32B	Bedrock	11/12/2015		•
ECC-MW-32C	Bedrock	11/11/2015		•
ECC-MW-33B	Bedrock	11/12/2015		•
ECC-MW-34B	Bedrock	11/12/2015		•
ECC-MW-35B	Bedrock	12/2/2015		•
ECC-MW-35C	Bedrock	12/3/2015		•
EE-MW-36B	Bedrock	11/9/2015		•
EE-MW-37B	Bedrock	11/9/2015		•
EE-MW-38B	Bedrock	11/9/2015		•
EE-MW-39B	Bedrock	11/9/2015		•
EE-MW-40B	Bedrock	11/13/2015		•
EE-MW-41S	Bedrock	11/9/2015		•
EE-MW-42B	Bedrock	1/19/2016		•
EE-MW-43B	Bedrock	11/13/2015		•
EE-MW-44S	Bedrock	11/13/2015		•
EE-MW-45S	Bedrock	11/13/2015		•

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Table 2 Well C	onstruction I	Details																		
				Ground Elevation	ToC Elevation		Borehole Diameter	Surface Casing Diameter	Surface Casing Depth	Total Depth	Bottom of Screen or Open Hole	Top of Screen or Open Hole	Length of Screen or Open Hole			Filter Pack	Top of Sand	Top of Seal	Top of Grout	
Well ID	Date Installed	Northing	Easting	(feet amsl)	(feet amsl)	Permit Number	(inches)	(inches)	(feet)	(feet bgs)	(feet bgs)	(feet bgs)	(feet BGS)	Slot Size	Casing/Screen Material		(feet bqs)	(feet bgs)	(feet bgs)	Surface Completion
Overburden Mor		Northing	Easting	(leet allisi)	(leet allisi)	Number	(inches)	(inches)	(1661)	(ieer bgs)	(leer bys)	(leer bgs)	(1001)	SIOL SIZE	Wateria		(leer bgs)	(1661.093)	(leer bgs)	Completion
		622.950	404.460	F7.9F	50.02	NA	6 1/2	6	NA	14	14	4	10	10	2" schedule 40 PVC	#00 Sand	NA	NA	NA	Stick up
MW-OB-1	6/9/2008	632,859	494,469	57.85	59.92 55.12	NA	6 1/2	6	NA	14	14	4	10	10	2" schedule 40 PVC	#00 Sand	NA	NA	NA	Stick-up
MW-OB-2	6/16/2008	632,302	494,576	52.86			-	6	NA		14	4		10						Stick-up
MW-OB-3	6/12/2008	632,194	494,355	52.53	55.14	NA	61/2	6		14			10	10	2" schedule 40 PVC	#00 Sand	NA	NA	NA	Stick-up
MW-OB-4	6/11/2008	632,011	494,413	49.18	51.56	NA	6 1/2	-	NA	14	14	4	10	10	2" schedule 40 PVC	#00 Sand	NA	NA	NA	Stick-up
MW-OB-5	6/11/2008	632,030	494,170	50.06	52.32	NA	6 1/2	6	NA	15	15	5	10	10	2" schedule 40 PVC	#00 Sand	NA	NA	NA	Stick-up
MW-OB-6	6/11/2008	632,340	494,122	53.68	55.94	NA	6 1/2	6	NA	15	15	5	10	10	2" schedule 40 PVC	#00 Sand	NA	NA	NA	Stick-up
MW-OB-7R**	8/28/2014	632504.95	494197.74	NA	58.33	E201411526	6	6	NA	15	15	5	10	10	2" schedule 40 PVC	#1 sand	3	0.5	0	Stick-up
MW-OB-8	6/13/2008	632,686	494,356	57.75	60.21	NA	6 1/2	6	NA	14	14	4	10	10	2" schedule 40 PVC	#00 Sand	NA	NA	NA	Stick-up
MW-OB-9	6/12/2008	632,817	494,205	58.23	60.64	NA	6 1/2	6	NA	14	14	4	10	10	2" schedule 40 PVC	#00 Sand	NA	NA	NA	Stick-up
MW-OB-11	6/13/2008	631,985	494,563	51.24	53.46	NA	6 1/2	6	NA	16	16	6	10	10	2" schedule 40 PVC	#00 Sand	NA	NA	NA	Stick-up
MW-0B-12	6/10/2008	632,934	494,280	59.07	61.3	NA	6 1/2	6	NA	14.5	14.5	4.5	10	10	2" schedule 40 PVC	#00 Sand	NA	NA	NA	Stick-up
MW-0B-13	6/27/2008	633,001	494,227	60.01	59.73	NA	6 1/2	6	NA	30	30	20	10	10	2" schedule 40 PVC	#0 Sand	NA	NA	NA	flush mount
B18W29SR	8/29/2001	632,032	494,567	51.36	53.54	25-57647	8	6	NA	13.5	13.5	3.5	10	10	4" schedule 40 PVC	#1 Sand	2.5	1.5	0	Stick-up
Bedrock Monitor	ring Wells																			
URS-MW-2D	3/1/2001	632,700	494,355	57.09	59.91	25-57652	6	6	22	47	47	22	25	Open hole	n/a	n/a	n/a	n/a	n/a	Stick-up
URS-MW-22D	NA	632,751	494,565	58.1	57.75	2500064107	6	6	38	63	63	38	25	Open hole	n/a	n/a	n/a	n/a	n/a	Stick-up
URS-MW-24D	NA	633,025	494,498	59.2	58.84	2500064201	6	6	28	53	53	28	25	Open hole	n/a	n/a	n/a	n/a	n/a	Stick-up
ECC-MW-24B	5/18/2012	633,057	494,468	59.09	58.69	NA	6	6	20	115	84	74	10	20	2" schedule 40 PVC	#1 sand	71.5	69.5	0	flush mount
ECC-MW-25C	10/18/2010	633,060	494,610	60.5	60.04	E201013208	6	6	20	93	93	83	10	20	2" schedule 40 PVC	#1 sand	81	78	0	flush mount
ECC-MW-25D	10/13/2010	633,060	494,620	60.45	60.13	E201010122	6	6	20	150	150	135	15	10	2" schedule 40 PVC	#1 sand	133	130	0	flush mount
ECC-MW-26B	5/10/2011	632,830	494,190	58.04	57.64	E201104704	6	6	20	76	76	66	10	20	2" schedule 40 PVC	#1 sand	64	62	0	flush mount
ECC-MW-26C	10/15/2010	632,830	494,180	57.91	57.57	E201013209	6	6	20	98	98	88	10	20	2" schedule 40 PVC	#1 sand	86	83	0	flush mount
ECC-MW-26D	10/13/2010	632,820	494,180	57.83	57.55	E201010123	6	6	20	155	155	140	15	10	2" schedule 40 PVC	#1 sand	138	135	0	flush mount
ECC-MW-27B	11/8/2012	633,047	494,298	60.52	60.27	E201216652	6	6	20	95	95	85	10	10	2" schedule 40 PVC	#1 sand	82	n/a	0	flush mount
ECC-MW-27C	10/18/2010	633,050	494,310	60.53	60.03	E201013210	6	6	20	123	123	113	10	20	2" schedule 40 PVC	#1 sand	111	108	0	flush mount
ECC-MW-27D	10/13/2010	633,050	494,300	60.37	60.16	E201010124	6	6	20	178	178	163	15	10	2" schedule 40 PVC	#1 sand	161	158	0	flush mount
ECC-MW-28B	5/10/2011	632,960	494,520	59.44	59.04	E201104703	6	6	20	60	59	49	10	20	2" schedule 40 PVC	#1 sand	47	45	0	flush mount
ECC-MW-29B	5/12/2011	632,810	493,970	57.54	57.05	E201104705	6	6	40	90	90	80	10	20	2" schedule 40 PVC	#1 sand	78	76	0	flush mount
ECC-MW-30B	5/18/2012	632,797	494,361	58.22	59.45	NA	6	6	20	54	53	43	10	10	2" schedule 40 PVC	#1 sand	40.8	39	0	Stick-up
ECC-MW-30D	5/17/2012	632,803	494,301	57.45	59.06	NA	6	6	20	128	125	115	10	10	2" schedule 40 PVC	#1 sand	112	110	0	Stick-up
ECC-MW-31B	11/12/2012	632,654	494,250	56.19	58.14	E201216647	6	6	28	38	38	28	10	Open Hole	n/a	n/a	n/a	n/a	0	Stick-up
ECC-MW-31B	11/12/2012	632,693	494,230	56.19	58.14	E201216648	6	6	36	46	46	36	10	Open Hole					0	
ECC-MW-32D		•	· · · · ·				6	6	56	66	66	56	10		n/a	n/a	n/a	n/a		Stick-up
ECC-MW-33B	11/12/2012	632,697	494,245	56.55	58.78	E201216649	6	6		41		31	10	Open Hole Open Hole	n/a	n/a	n/a	n/a	0	Stick-up
ECC-MW-34B	11/12/2012	632,661	494,216	56.56	58.73	E201216650	6	6	31 28	38	41 38	28	10	Open Hole	n/a	n/a	n/a	n/a	0	Stick-up
	11/12/2012	632,683	494,278	57.02	59.19	E201216651	6	-							n/a	n/a	n/a	n/a	0	Stick-up
ECC-MW-35B	2/6/2013	632,759	493,528	55.15	54.90	E201300592	-	6	20	114	114	104	10	10	2" schedule 80 PVC	#1 sand	101	NA	0	flush mount
ECC-MW-35C	2/6/2013	632,763	493,538	54.86	54.63	E201300591	6	6	20	138	138	128	10	10	2" schedule 80 PVC	#1 sand	125	NA	0	flush mount
EE-MW-36B	9/8/2014	632967.25	492933.37	NA	50.78	E201411467	8	8	19	226	225	215	10	10	2.5" schedule 80 PVC	1	210	206	1	flush mount
EE-MW-37B	9/9/2014	633417.49	493468.98	NA	57.79	E201411468	8	8	21	246	245	235	10	10	2.5" schedule 80 PVC	#1 sand	230.5	226.5	1	flush mount
EE-MW-38B	9/10/2014	633740.45	493852.07	NA	57.31	E201411469	8	8	21	262	260	250	10	10	2.5" schedule 80 PVC	#1 sand	245	240	1	flush mount
EE-MW-39B	9/5/2014	633945.28	494089.6	NA	52.83	E201411470	8	8	21	276	260	250	10	10	2.5" schedule 80 PVC	#1 sand	246	242	1	flush mount
EE-MW-40B	8/25/2014	632652.64	494421.85	NA	59.21	E201411471	6	6	10	25	25	15	10	10	2" schedule 40 PVC	#1 sand	12	7	0	Stick-up
EE-MW-41S	8/25/2014	632786.06	494297.76	NA	59.87	E201414292	6	6	9	55	30	20	10	10	2" schedule 40 PVC	#1 sand	16	11.5	0	Stick-up
EE-MW-42B	10/15/2015	634903	492373	46.80	46.25	E201510382	8	12" casing to 30' depth/ 8" casing to 100' depth	100	616	615	590	25	10	2.5" schedule 80 PVC	#2 sand	587	581	0	flush mount
EE-MW-43B	10/9/2015	634949	495187	42.60	42.14	E201510383	8	8	25	340	335	325	10	10	2.5" schedule 80 PVC	#2 sand	322.2	318.5	0	flush mount
EE-MW-44S	9/18/2015	632873	494421	57.50	59.60	E201510322	8	8	15	30	30	20	10	10	2" schedule 40 PVC	#1 sand	18	15.5	0	Stick-up
EE-MW-45S	9/18/2015	632835	494327	57.90	60.40	E201510324	8	8	15	30	30	20	10	10	2" schedule 40 PVC	#1 sand	18	15.5	0	Stick-up
22-10100-433	5/10/2015	032033	454527	57.50	00.40	2201310324	0	0	15		30	20	10	10	2 Schedule 40 FVC	#1 Sallu	10	13.5	0	Juck-up

Notes:

ID = identification

ToC = top of casing

amsl = above mean sea level

bgs = below ground surface NA = information not available

n/a = not applicable

PVC = polyvinylchloride

Gray = Wells installed as part of the Additional Data Gathering Event - Phase 1

Blue = Wells installed as part of the Additional Data Gathering Event - Phase 2

**Replacement well for MW-OB-7 which was abandoned.

Table 3 Groundwater Level Measurements in Overburden and Bedrock Monitoring Wells Groundwater Investigation Technical Memorandum Middlesex Sampling Plant, Middlesex, New Jersey

													Over	burden W	ell Water I	evel Measu	urements								
									Depth	n of Water (f	eet below TO	DC)													
Well ID	TOC Elevation (feet AMSL)	Total Depth of Well from TOC (feet)		11/10/2008	2/10/2009	12/14/2009	4/14/2010	11/14/2010	5/24/2011	8/22/2011	11/7/2011	2/6/2012	6/19/2012	8/20/2012	11/26/2012	2/19/2013	10/6/2014	12/15/2015	8/1/2008	11/10/2008	2/10/2009	12/14/2009	4/14/2010	11/14/2010	5/24/2
MW-OB-1	59.92	16.4	5.24	4.69	4.57	2.23	5.79	8.53	2.94	2.60	4.82	4.76	6.25	7.81	6.45	4.15	9.43	8.75	54.68	55.23	55.35	57.69	54.13	51.39	56.9
MW-OB-2	55.12	16.59	6.33	5.95	5.74	3.35	6.36	7.15	6.98	3.42	6.01	6.35	6.60	7.01	7.09	5.42	8.40	7.14	48.79	49.17	49.38	51.77	48.76	47.97	48.1
MW-OB-3	55.14	16.63	6.43	6.14	6.71	4.48	6.31	6.68	4.94	3.19	5.67	5.79	5.95	6.52	6.32	5.03	8.50	6.29	48.71	49.00	48.43	50.66	48.83	48.46	50.2
MW-OB-4	51.56	16.45	5.37	4.03	4.67	2.61	4.83	4.67	3.40	2.53	4.50	3.74	5.10	5.79	4.56	3.40	7.70	3.48	46.19	47.53	46.89	48.95	46.73	46.89	48.1
MW-OB-5	52.32	17.05	5.49	4.38	5.93	2.79	5.63	5.65	2.93	2.57	4.70	4.51	5.40	6.08	5.95	4.28	8.11	3.22	46.83	47.94	46.39	49.53	46.69	46.67	49.3
MW-OB-6	55.94	16.31	3.84	4.17	4.10	3.40	4.06	4.41	3.68	3.26	6.12	4.20	4.11	4.22	4.54	3.99	5.24	4.13	52.10	51.77	51.84	52.54	51.88	51.53	52.2
MW-OB-7*	57.45	16.41	4.00	4.15	4.66	6.82	4.34	5.05	3.64	3.01	4.02	4.35	4.44	5.82	5.05	6.01			53.45	53.30	52.79	50.63	53.11	52.40	53.8
MW-OB-7R	58.33	15.0															8.06	6.09							
MW-OB-8	60.21	16.7	7.58	4.51	4.98	3.09	6.50	9.62	4.29	2.73	4.32	4.32	6.25	9.10	5.61	6.01	11.87	11.48	52.63	55.70	55.23	57.12	53.71	50.59	55.9
MW-OB-9	60.64	16.58	9.04	8.95	9.55	6.25	8.13	13.5	7.30	4.31	8.67	9.25	9.28	13.11	10.67	6.61	Dry	10.13	51.60	51.69	51.09	54.39	52.51	47.14	53.3
MW-OB-10*	59.17	18.52	13.44	15.38	14.43	13.25	13.19	16.15	11.85	7.25	16.30	15.31	15.45	16.21	Dry	14.74			45.73	43.79	44.74	45.92	45.98	43.02	47.3
MW-OB-11	53.46	18.41	9.10	9.33	8.95	8.68	8.77	10.04	8.70	4.65	4.90	5.05	4.85	4.90	9.05	8.31	9.65	3.71	44.36	44.13	44.51	44.78	44.69	43.42	44.1
MW-OB-12	61.3	16.39	11.07	9.33	10.88	8.09	10.88	12.85	10.20	8.18	10.90	10.85	11.15	12.06	13.23	9.95	Dry	13.02	50.23	51.97	50.42	53.21	50.42	48.45	51.1
MW-OB-13	59.73	29.2	17.51	11.06	18.30	14.39	15.65	20.99	14.81	15.08	16.93	15.64	17.12	20.37	18.41	14.63	23.59	21.52	42.22	48.67	41.43	45.34	44.08	38.74	44.9
B18W29SR	53.97	16.16	7.36	3.17	7.19	2.38	6.48	8.06	3.70	2.40	4.59	5.86	5.80	6.60	5.94	4.12	6.69	3.68	46.61	50.80	46.78	51.59	47.49	45.91	50.2

													Over	rburden W	ell Water I	Level Meas	urements																	
	TOG DI J			-	-		-		Deptl	h of Water (f	feet below TO	DC)			-	_	-				_		-	-	V	Vater Level (feet AMSL)	-		-	-	-		
Well ID	TOC Elevation (feet AMSL)	Total Depth of Well from TOC (feet)	8/1/2008	11/10/2008	2/10/2009	12/14/2009	4/14/2010	11/14/2010	5/24/2011	8/22/2011	11/7/2011	2/6/2012	6/19/2012	8/20/2012	11/26/2012	2/19/2013	10/6/2014	12/15/2015	8/1/2008	11/10/2008	2/10/2009	12/14/2009	4/14/2010	11/14/2010	0 5/24/2011	8/22/2011	11/7/2011	2/6/2012	6/19/2012	8/20/2012	11/26/2011	2/19/2013	10/6/2014	12/15/2015
MW-OB-1	59.92	16.4	5.24	4.69	4.57	2.23	5.79	8.53	2.94	2.60	4.82	4.76	6.25	7.81	6.45	4.15	9.43	8.75	54.68	55.23	55.35	57.69	54.13	51.39	56.98	57.32	55.10	55.16	53.67	52.11	53.47	55.77	50.49	51.17
MW-OB-2	55.12	16.59	6.33	5.95	5.74	3.35	6.36	7.15	6.98	3.42	6.01	6.35	6.60	7.01	7.09	5.42	8.40	7.14	48.79	49.17	49.38	51.77	48.76	47.97	48.14	51.70	49.11	48.77	48.52	48.11	48.03	49.70	46.72	47.98
MW-OB-3	55.14	16.63	6.43	6.14	6.71	4.48	6.31	6.68	4.94	3.19	5.67	5.79	5.95	6.52	6.32	5.03	8.50	6.29	48.71	49.00	48.43	50.66	48.83	48.46	50.20	51.95	49.47	49.35	49.19	48.62	48.82	50.11	46.64	48.85
MW-OB-4 MW-OB-5	51.56 52.32	16.45	5.37	4.03	4.67	2.61	4.83	4.67	3.40	2.53	4.50	3.74	5.10	5.79	4.56	3.40	7.70	3.48	46.19	47.53	46.89	48.95	46.73	46.89	48.16	49.03 49.75	47.06	47.82	46.46	45.77	47.00	48.16	43.86	48.08
MW-OB-5 MW-OB-6	52.32	17.05	5.49 3.84	4.38	5.93	2.79	5.63 4.06	5.65	2.93 3.68	2.57 3.26	4.70 6.12	4.51 4.20	5.40	6.08 4.22	5.95 4.54	4.28	8.11 5.24	3.22 4.13	46.83 52.10	47.94	46.39	49.53 52.54	46.69 51.88	46.67	49.39 52.26	49.75	47.62 49.82	47.81	46.92 51.83	46.24	46.37	48.04 51.95	44.21 50.70	49.10 51.81
MW-OB-7*	57.45	16.41	4.00	4.17	4.66	6.82	4.34	5.05	3.64	3.01	4.02	4.35	4.44	5.82	5.05	6.01	5.24	4.15	53.45	53.30	52.79	50.63	53.11	52.40	53.81	54.44	53.43	53.10	53.01	51.63	52.40	51.44	50.70	51.01
MW-OB-7R	58.33	15.0															8.06	6.09															51.27	52.24
MW-OB-8	60.21	16.7	7.58	4.51	4.98	3.09	6.50	9.62	4.29	2.73	4.32	4.32	6.25	9.10	5.61	6.01	11.87	11.48	52.63	55.70	55.23	57.12	53.71	50.59	55.92	57.48	55.89	55.89	53.96	51.11	54.60	54.20	48.34	48.73
MW-OB-9	60.64	16.58	9.04	8.95	9.55	6.25	8.13	13.5	7.30	4.31	8.67	9.25	9.28	13.11	10.67	6.61	Dry	10.13	51.60	51.69	51.09	54.39	52.51	47.14	53.34	56.33	51.97	51.39	51.36	47.53	49.97	54.03	└─── ′	50.51
MW-OB-10* MW-OB-11	59.17 53.46	18.52 18.41	13.44 9.10	15.38 9.33	14.43	13.25 8.68	13.19	16.15	11.85 8.70	7.25	16.30 4.90	15.31 5.05	15.45 4.85	16.21 4.90	Dry 9.05	14.74 8.31	9.65	3.71	45.73 44.36	43.79	44.74	45.92 44.78	45.98 44.69	43.02 43.42	47.32	51.92 48.81	42.87 48.56	43.86 48.41	43.72 48.61	42.96 48.56	44 41	44.43	43.81	49.75
MW-OB-12	61.3	16.39	11.07	9.33	10.88	8.09	10.88	12.85	10.20	8.18	10.90	10.85	11.15	12.06	13.23	9.95	Dry	13.02	50.23	51.97	50.42	53.21	50.42	48.45	51 10	53.12	50.40	50.45	50.15	49.24	48.07	51.35	45.61	48.28
MW-OB-13	59.73	29.2	17.51	11.06	18.30	14.39	15.65	20.99	14.81	15.08	16.93	15.64	17.12	20.37	18.41	14.63	23.59	21.52	42.22	48.67	41.43	45.34	44.08	38.74	44.92	44.65	42.80	44.09	42.61	39.36	41.32	45.10	36.14	38.21
B18W29SR	53.97	16.16	7.36	3.17	7.19	2.38	6.48	8.06	3.70	2.40	4.59	5.86	5.80	6.60	5.94	4.12	6.69	3.68	46.61	50.80	46.78	51.59	47.49	45.91	50.27	51.57	49.38	48.11	48.17	47.37	48.03	49.85	46.85	49.86
									Dent	h of Water (f	eet below T()C)	Be	drock Wel	l Water Le	vel Measu	rements								v	Vater Level (feet AMSL)							
Well ID	ToC Elevation	Total Depth of Well				1		1				,,							l 1			1			<u> </u>				1	1	1	T		
wen ib	(feet AMSL)	from ToC ¹ (feet)	8/1/2008	11/10/2008	2/10/2009	12/14/2009	4/14/2010	11/14/2010	5/24/2011	8/22/2011	11/7/2011	2/6/2012	6/19/2012	8/20/2012	11/26/2012	2/19/2013	10/6/2014	12/15/2015	8/1/2008	11/10/2008	2/10/2009	12/14/2009	4/14/2010	11/14/2010	0 5/24/2011	8/22/2011	11/7/2011	2/6/2012	6/19/2012	8/20/2012	11/26/2012	2/19/2013	10/6/2014	12/15/2015
URS-MW-1D	59.93		21.66	21.59	21.75	20.95	20.70	24.54	22.17	20.75	20.59	20.76	21.45	21.90	21.89	20.69	23.73	23.15	38.27	38.34	38.18	38.98	39.23	35.39	37.76	39.18	39.34	39.17	38.48	38.03	38.04	39.24	,	
URS-MW-2D	57.83	50.78	18.08	17.63	17.63	16.97	16.69	18.79	16.90	16.93	17.28	17.53	18.35	18.85	18.64	17.87	20.98	19.89	39.75	40.20	40.20	40.86	41.14	39.04	40.93	40.90	40.55	40.30	39.48	38.98	39.19	39.96	38.93	40.02
URS-MW-3D	55.02		16.08	15.95	15.91	14.96	14.83	16.50	15.21	15.22	15.31	15.58	15.63	16.39	16.34	15.70	10.07	17.35	38.94	39.07	39.11	40.06	40.19	38.52	39.81	39.80	39.71	39.44	39.39	38.63	38.68	39.32	└─── ′	L
URS-MW-5D URS-MW-9D	55.07 50.46		18.21 11.68	17.93 11.45	17.52 11.42	16.81 10.63	16.67	18.36	16.88 11.16	16.70 11.02	16.95 10.99	17.41	17.76 11.96	18.23 12.19	18.11 12.07	17.25	18.86 13.31	18.61 12.69	36.86 38.78	37.14 39.01	37.55 39.04	38.26 39.83	38.40 39.39	36.71 38.19	38.19 39.30	38.37 39.44	38.12 39.47	37.66 38.91	37.31 38.50	36.84 38.27	36.96 38.39	37.82 39.00	┝───┘	L
URS-MW-11D	52.42		16.95	16.24	11.42	15.20	15.22	12.27	15.42	15.25	15.45	15.38	16.16	12.19	12.07	11.40	17.13	12.69	35.78	36.18	39.04	39.83	39.39	35.61	39.30	39.44	36.97	37.04	36.26	35.82	35.97	39.00	┝───┦	<u> </u>
URS-MW-21D	57.36		20.97	20.97	20.73	20.10	19.89	22.18	20.59	20.69	20.62	20.86	21.43	21.82	21.77	20.97	22.85	22.58	36.39	36.39	36.63	37.26	37.47	35.18	36.77	36.67	36.74	36.50	35.93	35.54	35.59	36.39	<u>├</u> ──┤	
URS-MW-22D	57.75	65.3	22.09	21.56	21.28	20.56	20.51	22.12	20.13	20.20	22.00	20.41	21.00	20.41	21.28	20.47	22.10	21.66	35.66	36.19	36.47	37.19	37.24	35.63	37.62	37.55	35.75	37.34	36.75	37.34	36.47	37.28	35.65	36.09
URS-MW-23D	59.06		23.67	23.58	23.45	22.79	22.41	24.67	22.93	23.05	22.91	23.19	23.85	24.20	24.20	23.42	25.14	24.90	35.39	35.48	35.61	36.27	36.65	34.39	36.13	36.01	36.15	35.87	35.21	34.86	34.86	35.64	<u> </u>	
URS-MW-24D ECC-MW-24B	58.84 58.69	70.1	21.47	21.42	21.18	20.59	20.41	22.27	20.52	20.70	20.64	20.80	21.46	21.71 20.81	21.72	20.93	22.95	22.51	37.37	37.42	37.66	38.25	38.43	36.57	38.32	38.14	38.20	38.04	37.38	37.13	37.12	37.91	35.89 36.94	36.33 38.88
ECC-MW-24B ECC-MW-25C	60.04	93						22.13	20.49	20.51	20.46	20.58	20.30	20.81	21.25	20.67	22.27	21.98						37.91	39.55	39.53	39.58	39.46	38.80	37.88	37.44	39.37	30.94	38.06
ECC-MW-25D	60.13	150						22.21	20.73	20.69	20.61	20.69	21.45	21.88	21.65	20.89	22.58	22.32						37.92	39.40	39.44	39.52	39.44	38.68	38.25	38.48	39.24	37.55	37.81
ECC-MW-26B	57.64	76							19.24	18.95	19.00	19.27	19.91	20.28	20.23	19.45	21.14	21.12							38.40	38.69	38.64	38.37	37.73	37.36	37.41	38.19	36.50	36.52
ECC-MW-26C	57.57	98				-		20.48	18.81	18.89	18.20	18.92	19.61	19.89	19.51	19.12	29.10	21.50						37.09	38.76	38.68	39.37	38.65	37.96	37.68	38.06	38.45	28.47	36.07
ECC-MW-26D ECC-MW-27B	57.55	155				1		20.46	18.34	19.17	17.20	18.82	19.42	20.08	19.38 22.61	19.06 21.69	27.50 23.50	19.36 23.39						37.09	39.21	38.38	40.35	38.73	38.13	37.47	38.17 37.66	38.49 38.58	30.05 36.77	38.19 36.88
ECC-MW-27D	60.03	123						22.84	21.54	21.27	21.13	21.38	22.14	22.41	22.01	21.69	23.23	23.10						37.19	38.49	38.76	38.90	38.65	37.89	37.62	37.60	38.39	36.80	36.93
ECC-MW-27D	60.16	178						27.91	20.62	21.39	21.24	21.48	21.12	22.51	22.30	21.67	23.55	23.28						32.25	39.54	38.77	38.92	38.68	39.04	37.65	37.86	38.49	36.61	36.88
ECC-MW-28B	59.04	61							19.68	20.25	19.84	21.00	20.81	21.15	21.00	20.24	22.05	22.00							39.36	38.79	39.20	38.04	38.23	37.89	38.04	38.80	36.99	37.04
ECC-MW-29B	57.05 59.58	90							19.49	19.25	19.07	19.41	20.16	20.48	20.41	19.70	20.91	21.39							37.56	37.80	37.98	37.64	36.89	36.57	36.64	37.35	36.14	35.66
ECC-MW-30B ECC-MW-30D	59.58	54.6 128.97											20.68 20.70	20.95 21.04	20.79 20.91	19.90 20.10	21.94 21.78	21.10 21.50											38.90 38.36	38.63 38.02	38.79	39.68 38.96	37.51 37.28	38.35 37.56
ECC-MW-30D ECC-MW-31B	58.14	38											20.70	21.04	17.05	16.31	18.42	17.79											56.50	58.14	41.09	41.83	39.72	40.35
ECC-MW-32B	58.14	48													19.49	18.80	20.53	20.23												58.14	38.65	39.34	37.61	37.91
ECC-MW-32C	58.78	66													20.74	19.95	21.55	21.31												58.78	38.04	38.83	37.23	37.47
ECC-MW-33B	58.73	41													16.84	16.11	18.21	17.98												58.73	41.89	42.62	40.52	40.75
ECC-MW-34B ECC-MW-35B	59.19 54.90	42 114													18.70	18.10 18.76	20.02 20.00	19.63 19.98												59.19	40.49	41.09 36.14	39.17 34.90	39.56 34.92
ECC-MW-35B ECCMW-35C	54.63	138														18.76	19.89	20.04														36.00	34.90	34.92
EE-MW-36B	50.78	226															17.30	18.15											1				33.48	32.63
EE-MW-37B	57.79	246															23.08	23.54															34.71	34.25
EE-MW-38B	57.31	262															22.25	22.67															35.06	34.64
EE-MW-39B EE-MW-40B	52.83 59.21	276															17.60 9.43	18.06 6.82														-	35.23 49.78	34.77 52.39
EE-MW-40B EE-MW-41S	59.21	25															9.43	6.82														-	49.78	52.39 37.86
EE-MW-41S EE-MW-42B ²	46.25	616															22.33	22.01															57.20	57.00
EE-MW-43B	40.23	340																3.62														-	+	38.52
EE-MW-44S	59.60	30																20.30					İ											39.30
EE-MW-45S	60.40	30																21.30																39.10
	* Wolle MW OP	7 and MW OP 10 way			Wall MW OP																													

* Wells MW-OB-7 and MW-OB-10 were abandoned on 10/7/14. Well MW-OB-7R was installed near the prevous well location of MW-OB-7.

Notes: ¹ Well depth in italics is measured from ground surface. Shaded cell indicates that well was not installed at the time water levels were measured.

² Well depth to water did not stabilize, could not be collected. ----- data not available ID - identification AMSL - above mean sea level ToC - top of casing

Table 4a Results for Domestic Well Samples Collected From Property Adjacent to MSP Site Middlesex Sampling Plant Middlesex, New Jersey

		:	Sample ID*:	MSP-233M-GW-081610	MSP-233M-INF-090710 (influent)	MSP-233M-MID-090710 (mid-point)	MSP-233M-EFF-090710 (effluent)
			Sample Date:	8/16/2010	9/7/2010	9/7/2010	9/7/2010
			SDG:	680-60531-1	680-61043-1	680-61043-1	680-61043-1
	NJDEP Drinking Water						
Volatile Organic Compounds	Standards	MCL					
Benzene		5	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Bromobenzene		,	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
	See	See					
Bromoform	Trihalomethanes	Trihalomethanes	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Bromomethane			ug/L	2.0 U	1.0 U	1.0 U	1.0 U
Carbon Tetrachloride	2	5	ug/L	19	19	0.50 U	0.50 U
Chlorobenzene	50	100	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
	See		/	101	0.50.11	0.50 U	0.50 U
Chlorodibromomethane	Trihalomethanes	60	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Chloroethane			ug/L	2.0 U	1.0 U	1.0 U	1.0 U
Chloroform	See Trihalomethanes	70	ug/L	1.4	1.4	0.50 U	0.50 U
Chloromethane			ug/L	1.0 U	0.50 U	0.50 U	0.50 U
2-Chlorotoluene			ug/L	1.0 U	0.50 U	0.50 U	0.50 U
4-Chlorotoluene			ug/L	1.0 U	0.50 U	0.50 U	0.50 U
cis-1,2-Dichloroethene	70	70	ug/L	1.1	0.92	0.50 U	0.50 U
cis-1,3-Dichloropropene			ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Dibromomethane			ug/L	1.0 U	0.50 U	0.50 U	0.50 U
1,2-Dichlorobenzene	600	600	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
1,3-Dichlorobenzene	600		ug/L	1.0 U	0.50 U	0.50 U	0.50 U
1,4-Dichlorobenzene	75	75	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Dichlorobromomethane	See Trihalomethanes	See Trihalomethanes	ug/L	2.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	50		ug/L	4.3	4.2	0.50 U	0.50 U
1,2-Dichloroethane	2	5	ug/L	1.0 U	0.29 J	0.50 U	0.50 U
1,1-Dichloroethene	2	7	ug/L	62	54	0.50 U	0.50 U
1,2-Dichloropropane	5	5	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
1,3-Dichloropropane			ug/L	1.0 U	0.50 U	0.50 U	0.50 U
1,1-Dichloropropene			ug/L	1.0 U	0.50 U	0.50 U	0.50 U
2,2-Dichloropropane			ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Ethylbenzene	700	700	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Methylene Chloride	3	5	ug/L	1.0 U	0.50 U	0.71	1.1
Methyl tert-butyl Ether (MTBE)	70		ug/L	1.0 U	0.50 U	0.50 U	0.50 U
m-Xylene & p-Xylene	See Total	See Total	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
o-Xylene	See Total	See Total	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Styrene	100	100	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
1,1,1,2-Tetrachloroethane			ug/L	1.0 U	0.50 U	0.50 U	0.50 U
1,1,2,2-Tetrachloroethane	1		ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Tetrachloroethene	1	5	ug/L	13	13	0.50 U	0.50 U
Toluene	1,000	1,000	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
trans-1,2-Dichloroethene	100	100	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
trans-1,3-Dichloropropene			ug/L	1.0 U	0.50 U	0.50 U	0.50 U
1,2,4-Trichlorobenzene	9	70	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
1,1,1-Trichloroethane	30	200	ug/L	0.86 J	0.80	0.50 U	0.50 U
1,1,2-Trichloroethane	3	5	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Trichloroethene	1	5	ug/L	8.3	8.6	0.50 U	0.50 U
1,2,3-Trichloropropane			ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Vinyl Chloride	2	2	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Total Xylenes	1,000	10,000	ug/L	1.0 U	0.50 U	0.50 U	0.50 U
Trihalomethanes (total of 4 individual THMs)	80	80	ug/L	1.4	1.4	1.0 U	1.0 U

Notes:

Detections exceeding the MCL and/or the NJDEP DW Standards are highlighted in blue. Detections are in BOLD font.

Only analytes with bold numbers to the right were detected (present at a level that modern technology can detect). Concentrations between the RL and MDL are considered to be less than the RL and estimated (J).

*Samples on this table were collected from Well No. 2 on Figure 5. ID = Identification

ug/L = Micrograms per Liter

ug/L = Micrograms per Liter MCL = Federal Maximum Contaminant Level Standard MDL = Method Detection Limit (the lowest level that can be detected) NJDEP = New Jersey Department of Environmental Protection Standard RL = Reporting Limit (the lowest level that can be quantified accurately) THMs = Trihalomethanes U = Not Detected. Analyte is not present at a level greater than the method MDL.

UJ = Not Detected, Estimated Reporting Limit

Table 4a Results for Domestic Well Samples Collected From Property Adjacent to MSP Site Middlesex Sampling Plant Middlesex, New Jersey

				MSP-233M-2EFF-090710	MSP-233M-INF-101210	MSP-233M-MID-101210	MSP-233M-EFF-101210
			Sample ID*:	(effluent)	(influent)	(mid-point)	(effluent)
			Sample Date:	9/7/2010	10/12/2010	10/12/2010	10/12/2010
			SDG:	680-61043-1	680-62130-1	680-62130-1	680-62130-1
	NJDEP Drinking Water						
Volatile Organic Compounds	Standards	MCL					
Benzene		5	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Bromobenzene			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Bromoform	See	See	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
	Trihalomethanes	Trihalomethanes	÷				
Bromomethane			ug/L	1.0 U	1.0 U	1.0 U	1.0 U
Carbon Tetrachloride	2	5	ug/L	0.50 U	14	0.50 U	0.50 U
Chlorobenzene	50	100	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Chlorodibromomethane	See Trihalomethanes	60	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Chloroethane	Tinatomethanes	00	ug/L	1.0 U	1.0 U	1.0 U	1.0 U
Chloroform	See	70	ug/L	0.50 U	1.2	0.50 U	0.50 U
	Trihalomethanes		-				
Chloromethane			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
2-Chlorotoluene			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
4-Chlorotoluene	= 0		ug/L	0.50 U	0.50 U	0.50 U	0.50 U
cis-1,2-Dichloroethene	70	70	ug/L	0.50 U	0.84	0.50 U	0.50 U
cis-1,3-Dichloropropene			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Dibromomethane			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dichlorobenzene	600	600	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,3-Dichlorobenzene	600		ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,4-Dichlorobenzene	75	75	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Dichlorobromomethane	See Trihalomethanes	See Trihalomethanes	ug/L	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	50		ug/L	0.50 U	4.7	0.50 U	0.50 U
1,2-Dichloroethane	2	5	ug/L	0.50 U	0.27 J	0.50 U	0.50 U
1,1-Dichloroethene	2	7	ug/L	0.50 U	65	0.50 U	0.50 U
1,2-Dichloropropane	5	5	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,3-Dichloropropane			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1-Dichloropropene			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
2,2-Dichloropropane			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Ethylbenzene	700	700	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Methylene Chloride	3	5	ug/L	0.72	1.5 UJ	1.2 UJ	0.88 UJ
Methyl tert-butyl Ether (MTBE)	70		ug/L	0.50 U	0.50 U	0.50 U	0.50 U
m-Xylene & p-Xylene	See Total	See Total	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
o-Xylene	See Total	See Total	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Styrene	100	100	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,1,2-Tetrachloroethane			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,2,2-Tetrachloroethane	1		ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Tetrachloroethene	1	5	ug/L	0.50 U	13	0.50 U	0.50 U
Toluene	1,000	1,000	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
trans-1,2-Dichloroethene	100	100	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
trans-1,3-Dichloropropene			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2,4-Trichlorobenzene	9	70	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,1-Trichloroethane	30	200	ug/L	0.50 U	0.93	0.50 U	0.50 U
1,1,2-Trichloroethane	3	5	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Trichloroethene	1	5	ug/L ug/L	0.50 U	8.3	0.50 U	0.50 U
1,2,3-Trichloropropane	· · ·	2	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Vinyl Chloride	2	2	ug/L ug/L	0.50 U	0.50 U	0.50 U	0.35 J
Total Xylenes	1,000	10,000	ug/L ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Trihalomethanes			, i i i i i i i i i i i i i i i i i i i				
(total of 4 individual THMs)	80	80	ug/L	1.0 U	1.2	1.0 U	1.0 U

Notes:

Detections exceeding the MCL and/or the NJDEP DW Standards are highlighted in blue.

Detections are in BOLD font.

Only analytes with bold numbers to the right were detected (present at a level that modern technology can detect). Concentrations between the RL and MDL are considered to be less than the RL and estimated (J).

ID = Identification

ug/L = Micrograms per Liter

ugL = Micrograms per Liter MCL = Micrograms per Liter MCL = Maximum Contaminant Level MDL = Method Detection Limit (the lowest level that can be detected) NJDEP = New Jersey Department of Environmental Protection RL = Reporting Limit (the lowest level that can be quantified accurately) THMs = Trihalomethanes

UJ = Not Detected. Analyte is not present at a level greater than the method MDL. UJ = Not Detected, Estimated Reporting Limit

Table 4b Analytical Results for Residential Well and Private Water Supply Well Samples November 2010 and January 2011 Middlesex Sampling Plant Middlesex, New Jersey

		1		MSP-202F-DW-111810	MSP-160 FARRAGUT	MSP-110 BLACKFORD	MSP-107 BLACKFORD
			Sample ID:	(Well No. 4 on Figure 5)	(Well No. 3 on Figure 5)	(Well No. 6 on Figure 5)	(Well No. 5 on Figure 5)
			Sample Date:	11/18/2010	11/19/2010	11/23/2010	11/29/2010
			SDG:	680-63319-1	680-63373-1	680-63488-1	680-63555-1
Volatile Organic Compounds	NJDEP Drinking Water Standards	MCL	units				
Benzene		5	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Bromobenzene			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Bromoform	See Trihalomethanes	See Trihalomethanes	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Bromomethane			ug/L	1.0 U	1.0 U	1.0 U	1.0 U
Carbon Tetrachloride	2	5	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Chlorobenzene	50	100	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Chlorodibromomethane	See Trihalomethanes	60	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Chloroethane			ug/L	1.0 U	1.0 U	1.0 U	1.0 U
Chloroform	See Trihalomethanes	70	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Chloromethane			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
2-Chlorotoluene			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
4-Chlorotoluene			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
cis-1,2-Dichloroethene	70	70	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
cis-1,3-Dichloropropene			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Dibromomethane			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dichlorobenzene	600	600	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,3-Dichlorobenzene	600		ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,4-Dichlorobenzene	75	75	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Dichlorobromomethane	See Trihalomethanes	See Trihalomethanes	ug/L	1.0 U	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	50		ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dichloroethane	2	5	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1-Dichloroethene	2	7	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2-Dichloropropane	5	5	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,3-Dichloropropane			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1-Dichloropropene			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
2,2-Dichloropropane			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Ethylbenzene	700	700	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Methylene Chloride	3	5	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Methyl tert-butyl Ether (MTBE)	70		ug/L	0.50 U	0.50 U	0.50 U	0.50 U
m-Xylene & p-Xylene	See Total	See Total	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
o-Xylene	See Total	See Total	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Styrene	100	100	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,1,2-Tetrachloroethane			ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,2,2-Tetrachloroethane	1		ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Tetrachloroethene	1	5	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
Toluene	1,000	1,000	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
trans-1,2-Dichloroethene	100	100	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
trans-1,3-Dichloropropene	0	70	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,2,4-Trichlorobenzene	9	70	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,1-Trichloroethane	30 3	200	ug/L	0.50 U	0.50 U	0.50 U	0.50 U
1,1,2-Trichloroethane	3	5	ug/L	0.50 U 0.50 U	0.50 U 0.50 U	0.50 U 0.50 U	0.50 U 0.50 U
Trichloroethene	1	3	ug/L				
1,2,3-Trichloropropane	2	2	ug/L	0.50 U	0.50 U	0.50 U 0.50 U	0.50 U 0.50 U
Vinyl Chloride Total Xylenes	2 1,000	2 10,000	ug/L ug/L	0.50 U 0.50 U	0.50 U 0.50 U	0.50 U 0.50 U	0.50 U 0.50 U
Trihalomethanes (total of 4 individual THMs)	80	80	ug/L	1.0 U	1.0 U	1.0 U	1.0 U

Notes:

Detections exceeding the MCL and/or the NJDEP DW Standards are highlighted in blue.

Detections are in BOLD font.

Only analytes with bold numbers to the right were detected (present at a level that modern technology can detect). Concentrations between the RL and MDL are considered to be less than the RL and estimated (J).

ID = identification

ID = identification ug/L = micrograms per liter MCL = Federal Maximum Contaminant Level Standard MDL = Method Detection Limit (the lowest level that can be detected) NJDEP = New Jersey Department of Environmental Protection Standard RL = Reporting Limit (the lowest level that can be quantified accurately) THMs = Trihalomethanes U = Not Detected. Analyte is not present at a level greater than the method MDL. UJ = Not Detected, Estimated Reporting Limit

Table 4b Analytical Results for Residential Well and Private Water Supply Well Samples November 2010 and January 2011 Middlesex Sampling Plant Middlesex, New Jersey

				MSP-90WOOD-11711	MSP-430VOOR-11711	MSP-796WIL-11711
			Sample ID:	(Well No. 9 on Figure 5)	(Well No. 7 on Figure 5)	(Well No. 8 on Figure 5)
			Sample Date:	1/17/2011	1/17/2011	1/17/2011
			SDG:	680-64857-1	680-64857-1	680-64857-1
Volatile Organic Compounds	NJDEP Drinking Water	MCL	units			
-	Standards		-			
Benzene		5	ug/L	0.50 U	0.50 U	0.50 U
Bromobenzene			ug/L	0.50 U	0.50 U	0.50 U
Bromoform	See Trihalomethanes	See Trihalomethanes	ug/L	0.50 U	0.50 U	0.50 U
Bromomethane			ug/L	1.0 U	1.0 U	1.0 U
Carbon Tetrachloride	2	5	ug/L	0.50 U	0.50 U	0.50 U
Chlorobenzene	50	100	ug/L	0.50 U	0.50 U	0.50 U
	See		ug/L	0.50 U	0.50 U	0.50 U
Chlorodibromomethane	Trihalomethanes	60	-			
Chloroethane			ug/L	1.0 U	1.0 U	1.0 U
Chloroform	See Trihalomethanes	70	ug/L	0.50 U	0.50 U	0.50 U
Chloromethane			ug/L	0.50 U	0.50 U	0.50 U
2-Chlorotoluene		1	ug/L	0.50 U	0.50 U	0.50 U
l-Chlorotoluene			ug/L	0.50 U	0.50 U	0.50 U
cis-1,2-Dichloroethene	70	70	ug/L	0.50 U	0.50 U	0.50 U
is-1,3-Dichloropropene			ug/L	0.50 U	0.50 U	0.50 U
Dibromomethane			ug/L	0.50 U	0.50 U	0.50 U
,2-Dichlorobenzene	600	600	ug/L	0.50 U	0.50 U	0.50 U
.3-Dichlorobenzene	600		ug/L	0.50 U	0.50 U	0.50 U
,4-Dichlorobenzene	75	75	ug/L	0.50 U	0.50 U	0.50 U
Dichlorobromomethane	See Trihalomethanes	See Trihalomethanes	ug/L	1.0 U	1.0 U	1.0 U
1,1-Dichloroethane	50	Timatomethanes	ug/L	0.50 U	0.50 U	0.50 U
1,2-Dichloroethane	2	5	ug/L	0.50 U	0.50 U	0.50 U
1,1-Dichloroethene	2	7	ug/L	0.50 U	0.50 U	0.50 U
1,2-Dichloropropane	5	5	ug/L	0.50 U	0.50 U	0.50 U
1,3-Dichloropropane	5	5	ug/L ug/L	0.50 U	0.50 U	0.50 U
I,1-Dichloropropene			ug/L ug/L	0.50 U	0.50 U	0.50 U
2,2-Dichloropropane			ug/L ug/L	0.50 U	0.50 U	0.50 U
Ethylbenzene	700	700	ug/L	0.50 U	0.50 U	0.50 U
Methylene Chloride	3	5	ug/L	0.83 UJ	0.50 U	0.73 UJ
Methyl tert-butyl Ether (MTBE)	70	5	ug/L	1.9	0.29 J	0.50 U
n-Xylene & p-Xylene	See Total	See Total	ug/L ug/L	0.50 U	0.50 U	0.50 U
-Xylene	See Total	See Total	ug/L ug/L	0.50 U	0.50 U	0.50 U
Styrene	100	100	ug/L ug/L	0.50 U	0.50 U	0.50 U
,1,1,2-Tetrachloroethane	100	100	ug/L ug/L	0.50 U	0.50 U	0.50 U
,1,2,2-Tetrachloroethane	1		ug/L ug/L	0.50 U	0.50 U	0.50 U
Tetrachloroethene	1	5	ug/L ug/L	0.50 U	0.50 U	0.50 U
Foluene	1.000	1,000	ug/L ug/L	0.36 J	0.50 U	0.50 U
rans-1,2-Dichloroethene	100	1,000	ug/L ug/L	0.50 U	0.50 U	0.50 U
rans-1,3-Dichloropropene	100	100	ug/L ug/L	0.50 U	0.50 U	0.50 U
.2,4-Trichlorobenzene	9	70	ug/L	0.50 U	0.50 U	0.50 U
.1.1-Trichloroethane	30	200	ug/L ug/L	0.50 U	0.50 U	0.50 U
.1.2-Trichloroethane	3	5	ug/L	0.50 U	0.50 U	0.50 U
Trichloroethene	1	5	ug/L ug/L	0.50 U	0.30 U	0.50 U
,2,3-Trichloropropane	1	5	ug/L ug/L	0.50 U	0.50 U	0.50 U
Vinyl Chloride	2	2	ug/L ug/L	0.50 U	0.50 U	0.50 U
Fotal Xylenes	1.000	10,000	ug/L ug/L	0.50 U	0.50 U	0.50 U
Trihalomethanes	1,000	10,000	ug/L			
total of 4 individual THMs)	80	80	ug/L	1.0 U	1.0 U	1.0 U

Notes:

Detections exceeding the MCL and/or the NJDEP DW Standards are highlighted in blue.

Detections are in BOLD font.

Only analytes with bold numbers to the right were detected (present at a level that modern technolo Concentrations between the RL and MDL are considered to be less than the RL and estimated (J).

ID = identification

ID = identification ug/L = micrograms per liter MCL = Federal Maximum Contaminant Level Standard MDL = Method Detection Limit (the lowest level that can be detected) NJDEP = New Jersey Department of Environmental Protection Standard RL = Reporting Limit (the lowest level that can be quantified accurately) THMs = Trihalomethanes U = Not Detected. Analyte is not present at a level greater than the method MDL. UJ = Not Detected, Estimated Reporting Limit

TABLE 5 SUMMARY OF PACKER TESTING RESULTS FOR TEST HOLES Middlesex Sampling Plant Middlesex, New Jersey

TTH-25

Test Interval ID (feet below TOC)	Pretest Depth to Water (feet)	TZ Head* (feet)	TZ Head** (feet amsl)	Pumping Rate Q (gpm)	TZ Drawdown s (feet)	Transmissivity*** T (gpd/ft)	EC (uS/cm)	CT (ppb)	CF (ppb)	TCE (ppb)	PCE (ppb)	1,1DCE (ppb)	Comments
ZONE V 38-48	24.31	5.0	43.2										Pumping not sustainable at available low drawdown.
ZONE IV 63-73	24.40	2.7	40.8	0.2	28.4	6	410	3.7	0.52 J	10	6.7	34	UNIT B
ZONE III 84-94	24.44	0.9	39.0	1.36	27.8	41	299	10	1.0J	18	30	140	UNIT C
ZONE II 117-127	24.40	2.0	40.1										Tight zone not pumped.
ZONE I 135-145	24.47	0.1	38.2	2.5	21.5	97	402	3.5J	ND(4)	85	7.2	34	UNIT D High leakage from below

TTH-26

Test Interval ID	Pretest Depth	TZ Head*	TZ Head**	Pumping Rate	TZ Drawdown	Transmissivity***	EC	СТ	CF	TCE	PCE	1,1DCE	a
(feet below TOC)	to Water (feet)	(feet)	(feet amsl)	Q (gpm)	s (feet)	T (gpd/ft)	(uS/cm)	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)	Comments
ZONE IV 41-51	22.84	1.2	37.8	0.45	24.0	16	380	13	0.99 J	1.1	ND(1)	ND(1)	
ZONE III 67-77	22.89	0.3	36.8	3.0	31.0	81	327	64	5.2	5.0	ND(4)	ND(4)	UNIT B Some leakage from below.
ZONE II 90-100	22.89	2.1	38.6	0.45	37.5	10	363	84	7.1	8.1	1.9 J	2.6 J	UNIT C
ZONE I 123-133	22.55	3.3	40.1										Tight zone not pumped.
ZONE IA 123-152 (bottom)													Tight zone not pumped.

TTH-27

Test Interval ID	Pretest Depth	TZ Head*	TZ Head**	Pumping Rate	TZ Drawdown	Transmissivity***	EC	СТ	CF	TCE	PCE	1,1DCE	
(feet below TOC)	to Water (feet)	(feet)	(feet amsl)	Q (gpm)	s (feet)	T (gpd/ft)	(uS/cm)	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)	Comments
ZONE IV 57-67	26.31	0.7	36.7	2.1	24.0	73	347	25	2.3	3.4	0.38 J	0.35 J	Leakage from above
ZONE III 90-100	26.30	0.8	36.8	5.0	31.0	135	306	63	5.9	8.9	1.2 J	1.3 J	UNIT B
ZONE II 115-125	26.25	0.9	37.0	0.75	37.5	17	290	19	2	17	1.9	1.4	UNIT C Leakage from above
ZONE I 153-163	26.24	1.1	37.2	0.48	50.5	8	259	6	0.69 J	8.2	0.49J	ND(1)	UNIT D
ZONE IA 153-173 (bottom)	26.24												

Notes: * Relative to composite pre-test water level prior to inflating of the packers. Positive number indicates higher water level in the test zone relative to the ambient pre-test level. ** Relative to mean sea level. Elevation of 62.54 feet amsl was used for the top of casing in TTH-25.

*** Transmissivity values shown in italics were overestimated due to leakage into the test zone.

uS/cm - microSeimens per centimeter

gpd/ft - gallons per day per foot gpm - gallons per minute ID - identification

Groundwater quality samples were collected during the packer tests, but only from the fracture zones that produced inflows into the open hole.

1,1DCE - 1,1-Dichloroethene

CF - Chloroform CT - Carbon Tetrachloride

EC - Specific Electrical Conductance

ND - not detected

PCE - Tetrachloroethene TCE - Trichloroethene

- ppb parts per billion TOC top of casing TZ test zone

TABLE 6 Summary of Bedrock Monitoring Well Volatile Organic Compound Detections Sampling Events 1 Through 16 Middlesex Sampling Plant Middlesex, New Jersey

	USEPA	NJDEP									UR	S-MW-2D								ECC-MW-21D
Volatile Organic Compound	MCL	Criteria	Units	SE 1 8/2008	SE 2 11/2008	SE 3 2/2009	SE 4 12/2009	SE 5 4/2010	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 9 11/2011
Chloroform (CF)	80	70	ug/L	6.6	5U	1.9	1.3	3.1	0.93	2.5	ND	1.1	1.1	2.6	1.2	0.79	NS	1.78	0.69J	1U
1,1-Dichloroethene (1,1-DCE)	7	1	ug/L	5U	5U	1U	1U	0.7	0.6	1U	0.27	1U	0.29	0.36	0.32	0.31	NS	0.30U	0.57UJ	1U
Carbon Tetrachloride (CT)	5	0.4	ug/L	12	18	19	15	8.3	14	8	7.7	20.0	14	11	10	15	NS	6.28	7.4J	1U
Tetrachloroethene (PCE)	5	0.4	ug/L	5U	5U	1U	1U	1U	0.15	0.15	0.20	1U	0.23	0.23	0.29	0.21	NS	0.30U	0.30UJ	1U
Trichloroethene (TCE)	5	1	ug/L	25	29	26	27	24	23	23	28	32	26	31	37	27	NS	22.8	24J	1U

	USEPA	NJDEP									UR	S-MW-22D								ECC-MW-23D
Volatile Organic Compound	MCL	Criteria	Units	SE 1 8/2008	SE 2 11/2008	SE 3 2/2009	SE 4 12/2009	SE 5 4/2010	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 9 11/2011
Chloroform (CF)	80	70	ug/L	5U	5U	1UJ	1U	1U	1U	1U	1.8UJ	1.1	0.099	1U	1U	1U	NS	0.30U	0.25UJ	1U
1,1-Dichloroethene (1,1-DCE)	7	1	ug/L	5U	1	1.6	1.6	2.4	2.6	5	4.3	7.5	5.9	9.5	7.6	9.1	NS	5.14	10J	1U
Carbon Tetrachloride (CT)	5	0.4	ug/L	5U	5U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	1U	NS	0.30U	0.45UJ	1.4
Tetrachloroethene (PCE)	5	0.4	ug/L	5U	5U	1U	1U	1UJ	0.37	0.63	0.43	0.78	0.64	0.85	0.72	0.81	NS	0.42J	0.64J	1U
Trichloroethene (TCE)	5	1	ug/L	5U	5U	1U	0.8	1.1	0.99	1.6	1.4	1.7	1.6	2.2	1.9	1.8	NS	1.04	1.7J	1U

	USEPA	NJDEP				ECC-N	1W-24B											URS-MW	-24D						
Volatile Organic Compound	MCL	Criteria	Units	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 1 8/2008	SE 2 11/2008	SE 3 2/2009	SE 4 12/2009	SE 5 4/2010	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	ug/L	6.2	4.9	5	NS	4.64	4.3J	47	48	37	32	37	29	26	25	46	19	26	27	19	NS	21.8	19
1,1-Dichloroethene (1,1-DCE)	7	1	ug/L	9.5	2.7	4.7	NS	10.4	13	5U	5U	1U	1.1	1.4	3U	0.4	0.95	1.6	0.72	1.6	13U	13U	NS	0.82J	0.91J
Carbon Tetrachloride (CT)	5	0.4	ug/L	67	30	38	NS	6.29	7.6	280	270	270	120	220	210	300	220	310	87	230	220	240	NS	206	150
Tetrachloroethene (PCE)	5	0.4	ug/L	2.2	1.1	1.6	NS	1.14	0.92J	5U	5U	1U	1U	1U	1.5U	0.25	0.29	0.37	10	0.34	13U	13U	NS	0.30U	0.30U
Trichloroethene (TCE)	5	1	ug/L	11	6.6	7.3	NS	6.37	5.2	19	23	20	24	18	17	22	19	23	11	19	19	17	NS	17.5	13

	LICEDA	NUDED							ECC-MW-2	5C										ECC-MW-25D)				
Volatile Organic Compound		NJDEP Criteria	Units	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	ug/L	5U	1.1	1.1	1.5	1.1	1.2	1.3	0.86	NS	0.98J	0.97J	10U	0.28	0.24	0.48	0.35	0.46	10U	2U	NS	0.60U	0.39J
1,1-Dichloroethene (1,1-DCE)	7	1	ug/L	81	150	110	200	140	180	120	110	NS	95.5	110J	8	16	14	32	26	44	31	8.1	NS	39.2	50J
Carbon Tetrachloride (CT)	5	0.4	ug/L	7.4	11	8.8	15	9.1	12	11	8.1	NS	9.73	6.7	1.4U	0.65	0.43	0.82	0.58	0.92	10U	0.34	NS	0.60U	0.66J
Tetrachloroethene (PCE)	5	0.4	ug/L	15	26	20	31	28	32	22	22	NS	16.9	15	1.5U	1.4	1.1	1.9	1.8	2	2.3	0.49	NS	1.66J	1.7J
Trichloroethene (TCE)	5	1	ug/L	12	17	16	21	19	21	19	14	NS	16.5	15	150	160	120	220	170	190	160	50	NS	108	82

								ECC-N	/W-26B										ECC-M\	N-26C				
Volatile Organic Compound	USEPA MCL	NJDEP Criteria	Units	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	ug/L	2.9	2.7	3.4	2.6	1.1	1.8	0.83	NS	0.74J	0.41J	9.6	6.6	5.7	6	5.2	5.1	4.8	4.8	NS	3.63	3.5J
1,1-Dichloroethene (1,1-DCE)	7	1	ug/L	1U	10	1U	1U	1U	1U	1U	NS	0.30U	0.57U	4.3	8.6	11	13	18	26	23	29	NS	48.8	63
Carbon Tetrachloride (CT)	5	0.4	ug/L	41	18	27	10	11	21	6	NS	5.93	3.2J	110	88	78	87	69	80	79	43	NS	48.7	31
Tetrachloroethene (PCE)	5	0.4	ug/L	1U	10	1U	1U	1U	1U	1U	NS	0.30U	0.30U	2.7	3.1	3.4	4.5	4.9	6	5.8	6.8	NS	8.34	8.4
Trichloroethene (TCE)	5	1	ug/L	2.9	2.3	3	2.2	1.4	2.1	0.85	NS	0.50J	0.32J	9.6	8.4	8.5	10	8.8	9.2	8.8	8.4	NS	7.41	7.2

	USEPA	NJDEP							ECC-MW-26	5D						ECC-N	IW-27B	
Volatile Organic Compound	MCL	Criteria	Units	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	ug/L	0.46	0.42	1U	1U	0.3	0.4	0.25	0.24	NS	0.30U	0.25U	3.7	NS	3.29	2.9J
1,1-Dichloroethene (1,1-DCE)	7	1	ug/L	1U	1U	1U	1U	0.17	0.29	1U	1U	NS	0.30U	0.57U	9.7	NS	23.4	27J
Carbon Tetrachloride (CT)	5	0.4	ug/L	3.1	1.7	1.4	1.8	1.3	1.9	2.1	0.71	NS	0.68J	0.48J	45	NS	31.2	22J
Tetrachloroethene (PCE)	5	0.4	ug/L	1.3	0.91	0.67	1.1	0.85	1.2	1.2	0.38	NS	0.38J	0.51J	2.4	NS	2.68	3.5J
Trichloroethene (TCE)	5	1	ug/L	14	8.7	7.8	11	9.4	11	13	4.5	NS	6.37	6.4	12	NS	16.7	17J

	USEPA	NJDEP							ECC-MW-2	7C				
Volatile Organic Compound	MCL	Criteria	Units	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	ug/L	1.6	1.5	1.4UJ	1.9	1.5	1.3	1.3	1.1	NS	1.1	1.2J
1,1-Dichloroethene (1,1-DCE)	7	1	ug/L	2.1	3.4	3.2	5.6	5	7	6.8	7.8	NS	13.2	14J
Carbon Tetrachloride (CT)	5	0.4	ug/L	16	14	12	18	13	13	16	12	NS	10.1	6.7J
Tetrachloroethene (PCE)	5	0.4	ug/L	1.6	2	1.8	2.3	2	2.1	2.2	2.1	NS	2.21	1.7J
Trichloroethene (TCE)	5	1	ug/L	21	28	26	32	30	31	36	32	NS	36.4	30J

									ECC-MW-27	D'D									E	CC-MW-28B				
Volatile Organic Compound		NJDEP Criteria	Units	SE 6 11/2010	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015	SE 7 5/2011	SE 8 8/2011	SE 9 11/2011	SE 10 2/2012	SE 11 6/2012	SE 12 8/2012	SE 13 11/2012	SE 14 2/2013	SE 15 10/2014	SE 16 11/2015
Chloroform (CF)	80	70	ug/L	1.3	0.65	1U	0.71	0.41	0.53	0.51	0.41	NS	0.34J	0.40J	1.1	2.2	2	1.2	1.2	1.4	1.2	NS	1.29	1.1J
1,1-Dichloroethene (1,1-DCE)	7	1	ug/L	1U	1U	10	1U	1U	1U	1U	1U	NS	0.30U	0.57UJ	1.3	2.3	1.9	1.5	1.5	0.9	0.75	NS	0.47J	0.60J
Carbon Tetrachloride (CT)	5	0.4	ug/L	4.5	2.5	1.8	3.2	1.7	2.4	2.9	2.8	NS	2.44	2.0J	4	8.9	10	6.4	8	12	9.8	NS	8.57	4.5J
Tetrachloroethene (PCE)	5	0.4	ug/L	0.32	1U	10	0.28	1U	0.23	0.41	0.33	NS	0.41J	0.57J	0.37	0.46	0.57	0.42	0.32	0.25	1U	NS	0.30U	0.30U
Trichloroethene (TCE)	5	1	ug/L	5.3	4.6	4	6.1	4.4	5.7	7.5	6.9	NS	10.2	14J	0.54	1.3	1.4	0.86	0.79	0.9	0.63	NS	0.67J	0.68J

	USEPA	NJDEP						ECC-N	/W-29B							ECC-	-MW-30B					ECC-MW-30D			
Volatile Organic Compound	MCL	Criteria	Units	SE 7	SE 8	SE 9	SE 10	SE 11	SE 12	SE 13	SE 14	SE 15	SE 16	SE 11	SE 12	SE 13	SE 14	SE 15	SE 16	SE 11	SE 12	SE 13	SE 14	SE 15	SE 16
				5/2011	8/2011	11/2011	2/2012	6/2012	8/2012	11/2012	2/2013	10/2014	11/2015	6/2012	8/2012	11/2012	2/2013	10/2014	11/2015	6/2012	8/2012	11/2012	2/2013	10/2014	11/2015
Chloroform (CF)	80	70	ug/L	3	2.8	2.8	2.9	3.1	2.6	2.7	NS	2.48	2.8J	600	380	270	190	161J	75	2.1	1.7	0.57	NS	0.30U	0.31J
1,1-Dichloroethene (1,1-DCE)	7	1	ug/L	1.1	1.2	1.3	1.9	3	2.7	3	NS	6.66	11J	100U	750U	500U	100U	0.30U	0.57U	8.7	7.3	9.9	NS	12.8	18
Carbon Tetrachloride (CT)	5	0.4	ug/L	40	35	42	32	42	36	39	NS	31	23	13,000	8,000	6,100	3,600	2,360	1,200	5.6	3.1	0.7	NS	0.30U	0.45U
Tetrachloroethene (PCE)	5	0.4	ug/L	2.1	2	2.5	2.1	2.5	2.1	2	NS	2.01	2.4J	100U	750U	500U	100U	0.82J	0.52J	0.98	0.76	1.1	NS	0.88J	1.3J
Trichloroethene (TCE)	5	1	ug/L	12	12	13	14	15	16	14	NS	15.9	14	430	230	180	130	121J	50	51	37	49	NS	53	52

		NUDED			ECC-N	IW-31B			ECC-M	W-32B			ECC-M	IW-32C			ECC	-MW-33B			ECC-MW	-34B		E	ECC-MW-35	В
Volatile Organic Compound	USEPA	NJDEP Criteria	Units	SE 13	SE 14	SE 15	SE 16	SE 13	SE 14	SE 15	SE 16	SE 13	SE 14	SE 15	SE 16	SE 13	SE 14	SE 15	SE 16	SE 13	SE 14	SE 15	SE 16	SE 14	SE 15	SE 16
	IVICL	Criteria		11/2012	2/2013	10/2014	11/2015	11/2012	2/2013	10/2014	11/2015	11/2012	2/2013	10/2014	11/2015	11/2012	2/2013	10/2014	11/2015	11/2012	2/2013	10/2014	11/2015	2/2013	10/2014	11/2015
Chloroform (CF)	80	70	ug/L	1U	NS	0.30U	0.25U	0.22	NS	0.30U	0.25U	23	NS	8.47	14J	1U	NS	0.30U	0.25U	1U	NS	0.30U	2.8J	1.7	0.53J	0.51J
1,1-Dichloroethene (1,1-DCE)	7	1	ug/L	1U	NS	0.30U	0.57U	1U	NS	0.30U	0.57U	2.2	NS	1.05	1.5J	1U	NS	0.30U	0.57U	1U	NS	0.30U	11J	1.4	2.56	2.7J
Carbon Tetrachloride (CT)	5	0.4	ug/L	1U	NS	0.30U	0.45U	1U	NS	0.30U	0.45U	12	NS	61.9	47J	1U	NS	0.30U	0.45U	1U	NS	0.30U	22	5.7	2.85	3.0J
Tetrachloroethene (PCE)	5	0.4	ug/L	1U	NS	0.30U	0.30U	1U	NS	0.30U	0.30U	0.46	NS	0.30U	0.30U	1U	NS	0.30U	0.30U	1U	NS	0.30U	2.2J	3	0.48J	0.70J
Trichloroethene (TCE)	5	1	ug/L	1U	NS	0.30U	0.22U	0.81	NS	0.30U	0.45J	6.5	NS	4.89	5.8	1U	NS	0.30U	0.22U	0.15	NS	0.30U	14	11	26.2	23

	USEPA	NJDEP		E	CC-MW-35	с	EE-M	N-36B	EE-M	W-37B	EE-M	N-38B	EE-M	N-39B	EE-M\	N-40B	EE-M	N-41S	EE-MW-42B	EE-MW-43B	EE-MW-44S	EE-MW-45S
Volatile Organic Compound	MCL	Criteria	Units	SE 14	SE 15	SE 16	SE 15	SE 16	SE 15	SE 16	SE 15	SE 16	SE 15	SE 16	SE 15	SE 16	SE 15	SE 16	SE 16	SE 16	SE 16	SE 16
	IVICE	citteria		2/2013	10/2014	12/2015	10/2014	12/2015	10/2014	12/2015	10/2014	12/2015	10/2014	12/2015	10/2014	12/2015	10/2014	12/2015	1/2016	11/2015	11/2015	11/2015
Chloroform (CF)	80	70	ug/L	0.8	15.0U	0.25U	0.30U	0.25UJ	0.62J	0.64J	3.02	3.4J	1.49	1.5J	0.30U	0.25U	222	4.1J	0.44J	0.25U	0.27J	5.6
1,1-Dichloroethene (1,1-DCE)	7	1	ug/L	1.2	15.0U	3.8J	0.90J	0.57UJ	0.30U	0.57UJ	0.30U	0.57UJ	0.90J	0.67J	0.30U	0.57U	15.0U	0.57UJ	0.57U	18	0.57U	0.57U
Carbon Tetrachloride (CT)	5	0.4	ug/L	0.24	15.0U	0.45U	0.30U	0.45UJ	5.57	3.9J	29.0	7.7J	14.6	6.9J	0.30U	0.45U	2,460	32J	0.45U	0.45U	0.95J	46
Tetrachloroethene (PCE)	5	0.4	ug/L	1.3	15.0U	0.36J	0.30U	0.30UJ	1.04	0.30UJ	1.28	0.54J	2.84	1.3J	0.30U	0.30U	0.30U	0.30UJ	0.30U	0.30U	0.30U	0.30U
Trichloroethene (TCE)	5	1	ug/L	8.3	33.0J	25	4.10	1.2J	2.47	0.78J	3.17	2.1J	2.92	1.8J	0.30U	0.22U	62.0	0.61J	0.22U	0.80J	0.22U	0.97J

: Bold Font - value meets or exceeds the USEPA Maximum Contaminant Level (MCL) Blue Cell - value meets or exceeds the New Jersey Department of Environmental Protection (NJDEP) criteria.

MCL = Maximum Contaminant Level NJDEP = New Jersey Department of Environmental Protection NS = not sampled ug/L = micrograms per liter U = Not detected. Analyte is not present at a level greater than the reporting limit. UJ = Not detected. The reporting limit is estimated. J = Estimated value.

			Sample ID: Date: Depth:	ECC-MW-24B 11/11/2015 74-84 feet	Val Qual	ECC-MW-25C* 11/11/2015 83-93 feet	Val Qual	ECC-MW-25D 11/11/2015 140-150 feet	Val Qual
Compound	MCL	NJDEP Criteria	Units						
1,1,1-Trichloroethane	200	30	ug/L			0.75	J	1.6	J
1,1-Dichloroethane	N/A	50	ug/L	1.2	J	6.2	J	2.9	J
1,1-Dichloroethene	7	1	ug/L	13		110	J	50	J
1,2-Dichloroethane	5	0.3	ug/L			0.4	J		
Acetone	N/A	6000	ug/L						
Carbon Disulfide	N/A	700	ug/L						
Carbon Tetrachloride	5	0.4	ug/L	7.6		6.7		0.66	J
Chlorobenzene	100	50	ug/L						
Chloroform	N/A	70	ug/L	4.3	J	0.97	J	0.39	J
Cis-1,2-Dichloroethylene	70	70	ug/L			1.4	J	1.2	J
Methyl Ethyl Ketone (2-Butanone)	N/A	300	ug/L						
Methyl Tert-Butyl Ether	N/A	70	ug/L						
Tetrachloroethylene (PCE)	5	0.4	ug/L	0.92	J	15		1.7	J
Toluene	1000	600	ug/L						
Trichloroethylene (TCE)	5	1	ug/L	5.2		15		82	
Trichlorofluoromethane (Freon 11)	N/A	2000	ug/L			2.0	J		
Trichlorotrifluoroethane (Freon 113)	N/A	N/A	ug/L					0.90	J

Compound	MCL	NJDEP Criteria	Sample ID: Date: Depth: Units	ECC-MW-26B 11/10/2015 66-76 feet	Val Qual	ECC-MW-26C 11/10/2015 88-98 feet	Val Qual	ECC-MW-26D 11/10/2015 140-160 feet	Val Qual
1,1,1-Trichloroethane	200	30	ug/L			0.44	J		
1,1-Dichloroethane	N/A	50	ug/L			4.5	J		
1,1-Dichloroethene	7	1	ug/L			63			
1,2-Dichloroethane	5	0.3	ug/L						
Acetone	N/A	6000	ug/L						
Carbon Disulfide	N/A	700	ug/L						
Carbon Tetrachloride	5	0.4	ug/L	3.2	J	31		0.48	J
Chlorobenzene	100	50	ug/L						
Chloroform	N/A	70	ug/L	0.41	J	3.5	J		
Cis-1,2-Dichloroethylene	70	70	ug/L			0.98	J		
Methyl Ethyl Ketone (2-Butanone)	N/A	300	ug/L						
Methyl Tert-Butyl Ether	N/A	70	ug/L			0.29	J		
Tetrachloroethylene (PCE)	5	0.4	ug/L			8.4		0.51	J
Toluene	1000	600	ug/L						
Trichloroethylene (TCE)	5	1	ug/L	0.32	J	7.2		6.4	
Trichlorofluoromethane (Freon 11)	N/A	2000	ug/L						
Trichlorotrifluoroethane (Freon 113)	N/A	N/A	ug/L						

			Sample ID: Date: Depth:	ECC-MW-27B 11/10/2015 85-95 feet	Val Qual	ECC-MW-27C* 11/10/2015 110-120 feet	Val Qual	ECC-MW-27D 11/10/2015 160-180 feet	Val Qual
Compound	MCL	NJDEP Criteria	Units						
1,1,1-Trichloroethane	200	30	ug/L						
1,1-Dichloroethane	N/A	50	ug/L	1.7	J	0.91	J		
1,1-Dichloroethene	7	1	ug/L	27	J	14	J		
1,2-Dichloroethane	5	0.3	ug/L						
Acetone	N/A	6000	ug/L						
Carbon Disulfide	N/A	700	ug/L						
Carbon Tetrachloride	5	0.4	ug/L	22	J	6.7	J	2.0	J
Chlorobenzene	100	50	ug/L						
Chloroform	N/A	70	ug/L	2.9	J	1.2	J	0.40	J
Cis-1,2-Dichloroethylene	70	70	ug/L	0.59	J	0.67	J		
Methyl Ethyl Ketone (2-Butanone)	N/A	300	ug/L						
Methyl Tert-Butyl Ether	N/A	70	ug/L						
Tetrachloroethylene (PCE)	5	0.4	ug/L	3.5	J	1.7	J	0.57	J
Toluene	1000	600	ug/L						
Trichloroethylene (TCE)	5	1	ug/L	17	J	30	J	14	J
Trichlorofluoromethane (Freon 11)	N/A	2000	ug/L	0.28	J				
Trichlorotrifluoroethane (Freon 113)	N/A	N/A	ug/L	0.42	J	0.37	J	0.50	J

		-0					1	
		Sample ID: Date:	ECC-MW-28B 11/11/2015	al Qual	ECC-MW-29B 11/11/2015	al Qual	ECC-MW-30B 11/13/2015	Val Qual
		Depth:	49-59 feet	V.	80-90 feet	V:	43-53 feet	Ċ,
MCL	NJDEP Criteria	Units						
200	30	ug/L						
N/A	50	ug/L	0.47	J	1.1	J		
7	1	ug/L	0.60	J	11	J		
5	0.3	ug/L					1.8	J
N/A	6000	ug/L						
N/A	700	ug/L						
5	0.4	ug/L	4.5	J	23		1200	
100	50	ug/L						
N/A	70	ug/L	1.1	J	2.8	J	75	
70	70	ug/L			0.35	J	2.2	J
N/A	300	ug/L						
N/A	70	ug/L					0.37	J
5	0.4	ug/L			2.4	J	0.52	J
1000	600	ug/L						
5	1	ug/L	0.68	J	14		50	
N/A	2000	ug/L						
N/A	N/A	ug/L			0.83	J		
	200 N/A 7 5 N/A N/A 5 100 N/A 70 N/A 5 1000 5 N/A	200 30 N/A 50 7 1 5 0.3 N/A 6000 N/A 700 5 0.4 100 50 N/A 70 70 70 N/A 300 N/A 70 5 0.4 1000 600 5 1 N/A 2000	Sample ID: Date: Date: Toph: MCL Criteria Units 200 30 ug/L N/A 50 ug/L 7 1 ug/L 5 0.3 ug/L N/A 6000 ug/L N/A 6000 ug/L N/A 700 ug/L 5 0.4 ug/L 100 50 ug/L N/A 700 ug/L N/A 700 ug/L N/A 700 ug/L N/A 70 ug/L 5 0.4 ug/L 1000 600 ug/L 5 1 ug/L N/A 2000 ug/L	Sample ID: ECC-MW-28B Date: 11/11/2015 Depth: 49-59 feet MCL Criteria Units MCL 0 $49-59$ feet NDEP Units 49-59 feet NOP Units 49-59 feet NA 50 ug/L 0.47 N/A 50 ug/L 0.47 N/A 6000 ug/L 0.60 N/A 6000 ug/L 4.5 N/A 6000 ug/L 4.5 N/A 700 ug/L 4.5 N/A 700 ug/L 1.1 70 70 ug/L 4.5 N/A 300 ug/L 4.5 N/A 70 ug/L 4.5 N/A 70 ug/L 4.5 1000 600 ug/L 4.5 1000 600 ug/L 5 1000 600 ug/L 5.68 1	Sample ID: ECC-MW-28B pg Date: 11/11/2015 pg Depth: 49-59 feet $49-59$ feet MCL Criteria Units 49-59 feet $49-59$ feet MCL Criteria Units $49-59$ feet $49-59$ feet $49-59$ feet MCL Criteria Units $49-59$ feet $49-59$ feet $49-59$ feet N/A 50 ug/L 0.47 $40-47$ $40-47$ $40-47$ N/A 6000 ug/L 0.600 $40-47$ $40-47$ $40-47$ $40-47$ N/A 6000 ug/L $40-47$ $40-47$ $40-47$ $40-47$ N/A 6000 ug/L $40-47$ $40-47$ $40-47$ $40-47$ N/A 700 ug/L $40-47$ $40-47$ $40-47$ $40-47$ N/A 70 ug/L $11-1$ $40-47$ $40-47$ $40-47$ $40-47$ N/A 70 ug/L $11-1$	Sample ID: ECC-MW-28B 11/11/2015 \overline{P} ECC-MW-29B 11/11/2015 Date: 11/11/2015 80-90 feet MCL VDEP Criteria Units I MCL 0.00 ug/L J N/A 50 ug/L J 1.1 N/A 50 ug/L 0.47 J 1.1 N/A 50 ug/L 0.47 J 1.1 N/A 50 ug/L 0.47 J 1 1.1 N/A 6000 ug/L J 1.11 J 1.1 N/A 700 ug/L J 2.3 J 1.1 N/A 700 ug/L J 2.3 J J N/A 700 ug/L J J J J N/A 70 ug/L J J J J J N/A 70 ug/L J J J J J <	Sample ID: ECC-MW-28B 11/11/2015 \overline{Pg} ECC-MW-29B 11/11/2015 \overline{Pg} NDE: Date: 11/11/2015 \overline{Pg} ECC-MW-29B 11/11/2015 \overline{Pg} MCL Criteria Units I <thi< td=""><td>Sample ID: ECC-MW-28B \overline{p} ECC-MW-29B \overline{p} ECC-MW-30B $\overline{11/11/2015}$ \overline{p} ECC-MW-30B $\overline{11/13/2015}$ $\overline{43-53}$ feet $\overline{11/11/2015}$ \overline{p} ECC-MW-30B $\overline{11/13/2015}$ $\overline{43-53}$ feet $\overline{11/13/2015}$ $\overline{43-53}$ feet $\overline{11/13/2015}$ $\overline{43-53}$ feet $\overline{11/13/2015}$ $\overline{43-53}$ feet 200 30 ug/L $\overline{43-53}$ feet $\overline{43-53}$ feet $\overline{43-53}$ feet $\overline{11/13/2015}$ $\overline{43-53}$ feet <td< td=""></td<></td></thi<>	Sample ID: ECC-MW-28B \overline{p} ECC-MW-29B \overline{p} ECC-MW-30B $\overline{11/11/2015}$ \overline{p} ECC-MW-30B $\overline{11/13/2015}$ $\overline{43-53}$ feet $\overline{11/11/2015}$ \overline{p} ECC-MW-30B $\overline{11/13/2015}$ $\overline{43-53}$ feet $\overline{11/13/2015}$ $\overline{43-53}$ feet $\overline{11/13/2015}$ $\overline{43-53}$ feet $\overline{11/13/2015}$ $\overline{43-53}$ feet 200 30 ug/L $\overline{43-53}$ feet $\overline{43-53}$ feet $\overline{43-53}$ feet $\overline{11/13/2015}$ $\overline{43-53}$ feet <td< td=""></td<>

			Sample ID:	ECC-MW-30D	Qual	ECC-MW-32B	Qual	ECC-MW-32C	Ial
			Date:	11/13/2015	īQ	11/12/2015	īŎ	11/11/2015	Val Qual
			Depth:	120-130 feet	Val	36-46 feet	Val	56-66 feet	Va
Compound	MCL	NJDEP Criteria	Units						
1,1,1-Trichloroethane	200	30	ug/L	0.39	J				
1,1-Dichloroethane	N/A	50	ug/L	1.3	J			0.72	J
1,1-Dichloroethene	7	1	ug/L	18				1.5	J
1,2-Dichloroethane	5	0.3	ug/L						
Acetone	N/A	6000	ug/L						
Carbon Disulfide	N/A	700	ug/L						
Carbon Tetrachloride	5	0.4	ug/L					47	J
Chlorobenzene	100	50	ug/L						
Chloroform	N/A	70	ug/L	0.31	J			14	J
Cis-1,2-Dichloroethylene	70	70	ug/L	0.86	J				
Methyl Ethyl Ketone (2-Butanone)	N/A	300	ug/L						
Methyl Tert-Butyl Ether	N/A	70	ug/L					2.3	J
Tetrachloroethylene (PCE)	5	0.4	ug/L	1.3	J				
Toluene	1000	600	ug/L						
Trichloroethylene (TCE)	5	1	ug/L	52		0.45	J	5.8	
Trichlorofluoromethane (Freon 11)	N/A	2000	ug/L						
Trichlorotrifluoroethane (Freon 113)	N/A	N/A	ug/L						

			Sample ID:	ECC-MW-34B*	Qual	ECC-MW-35B	Qual	ECC-MW-35C	Qual
			Date: Depth:	11/12/2015 28-38 feet	Val Ç	12/2/2015 100-110 feet	Val C	12/3/2015 130-140 feet	Val Ç
Compound	MCL	NJDEP Criteria	Units						
1,1,1-Trichloroethane	200	30	ug/L						
1,1-Dichloroethane	N/A	50	ug/L	1.2	J				
1,1-Dichloroethene	7	1	ug/L	11	J	2.7	J	3.8	J
1,2-Dichloroethane	5	0.3	ug/L						
Acetone	N/A	6000	ug/L					130	
Carbon Disulfide	N/A	700	ug/L					2.4	J
Carbon Tetrachloride	5	0.4	ug/L	22		3.0	J		
Chlorobenzene	100	50	ug/L						
Chloroform	N/A	70	ug/L	2.8	J	0.51	J		
Cis-1,2-Dichloroethylene	70	70	ug/L	0.40	J	0.81	J	0.37	J
Methyl Ethyl Ketone (2-Butanone)	N/A	300	ug/L						
Methyl Tert-Butyl Ether	N/A	70	ug/L	0.69	J				
Tetrachloroethylene (PCE)	5	0.4	ug/L	2.2	J	0.70	J	0.36	J
Toluene	1000	600	ug/L						
Trichloroethylene (TCE)	5	1	ug/L	14		23		25	
Trichlorofluoromethane (Freon 11)	N/A	2000	ug/L			0.51	J		
Trichlorotrifluoroethane (Freon 113)	N/A	N/A	ug/L	0.90	J	25		6.9	

			Sample ID:	EE-MW-36B	Val Qual	EE-MW-37B	Val Qual	EE-MW-38B	Val Qual
			Date:	11/9/2015	al C	11/9/2015	al (11/9/2015	al
		NJDEP	Depth:	220-230 feet	~	240-250 feet	~	250-260 feet	~
Compound	MCL	NJDEP Criteria	Units						
1,1,1-Trichloroethane	200	30	ug/L						
1,1-Dichloroethane	N/A	50	ug/L						
1,1-Dichloroethene	7	1	ug/L						
1,2-Dichloroethane	5	0.3	ug/L						
Acetone	N/A	6000	ug/L						
Carbon Disulfide	N/A	700	ug/L						
Carbon Tetrachloride	5	0.4	ug/L			3.9	J	7.7	J
Chlorobenzene	100	50	ug/L						
Chloroform	N/A	70	ug/L			0.64	J	3.4	J
Cis-1,2-Dichloroethylene	70	70	ug/L			1.0	J	4.8	J
Methyl Ethyl Ketone (2-Butanone)	N/A	300	ug/L						
Methyl Tert-Butyl Ether	N/A	70	ug/L						
Tetrachloroethylene (PCE)	5	0.4	ug/L					0.54	J
Toluene	1000	600	ug/L						
Trichloroethylene (TCE)	5	1	ug/L	1.2	J	0.78	J	2.1	J
Trichlorofluoromethane (Freon 11)	N/A	2000	ug/L		, in the second s				
Trichlorotrifluoroethane (Freon 113)	N/A	N/A	ug/L	6.0	J	0.84	J	1.0	J
			Ũ		1 1		1 1		I
			Sample ID:	EE-MW-39B	Val Qual	EE-MW-40B	ual	EE-MW-41S	ual
			Date:	11/9/2015	Õ	11/13/2015	Val Qual	11/9/2015	Val Qual
			Depth:	250-260 feet	Va	15-25 feet	Va	20-30 feet	Va
Compound	MCL	NJDEP	Units						
1,1,1-Trichloroethane	200	Criteria 30	ug/L						
1,1-Dichloroethane	200 N/A	50							
1,1-Dichloroethene	N/A 7	50 1	ug/L	0.67					
,	5	0.3	ug/L	0.07	J				
1,2-Dichloroethane			ug/L						
Acetone	N/A	6000	ug/L						
Carbon Disulfide	N/A	700	ug/L	<u>()</u>				20	
Carbon Tetrachloride	5	0.4	ug/L	6.9	J			32	J
Chlorobenzene	100	50	ug/L						_
Chloroform	N/A	70	ug/L	1.5	J			4.1	J
Cis-1,2-Dichloroethylene	70	70	ug/L	6.1	J				
Methyl Ethyl Ketone (2-Butanone)	N/A	300	ug/L						
Methyl Tert-Butyl Ether	N/A	70	ug/L			0.47	J	0.46	J
Tetrachloroethylene (PCE)	5	0.4	ug/L	1.3	J				
Toluene	1000	600	ug/L						
Trichloroethylene (TCE)	5	1	ug/L	1.8	J			0.61	J
Trichloroethylene (TCE) Trichlorofluoromethane (Freon 11)	5 N/A N/A	1 2000 N/A	ug/L ug/L ug/L	1.8 0.64	J			0.61	J

			Sample ID: Date: Depth:	EE-MW-42B* 1/19/2016 595-600 feet	Val Qual	EE-MW-42B 1/19/2016 600-605 feet	Val Qual	EE-MW-42B 1/19/2016 610-615 feet	Val Qual
Compound	MCL	NJDEP Criteria	Units						
1,1,1-Trichloroethane	200	30	ug/L						
1,1-Dichloroethane	N/A	50	ug/L						
1,1-Dichloroethene	7	1	ug/L						
1,2-Dichloroethane	5	0.3	ug/L						
Acetone	N/A	6000	ug/L						
Carbon Disulfide	N/A	700	ug/L						
Carbon Tetrachloride	5	0.4	ug/L						
Chlorobenzene	100	50	ug/L	3.0	J	3.2	J	2.4	J
Chloroform	N/A	70	ug/L	0.37	J	0.44	J	0.40	J
Cis-1,2-Dichloroethylene	70	70	ug/L						
Methyl Ethyl Ketone (2-Butanone)	N/A	300	ug/L	1.5	J	1.4	J	1.5	J
Methyl Tert-Butyl Ether	N/A	70	ug/L						
Tetrachloroethylene (PCE)	5	0.4	ug/L						
Toluene	1000	600	ug/L	33	J	35		26	
Trichloroethylene (TCE)	5	1	ug/L						
Trichlorofluoromethane (Freon 11)	N/A	2000	ug/L						
Trichlorotrifluoroethane (Freon 113)	N/A	N/A	ug/L						

()					1 1		I	1	I	1
			Sample ID:	EE-MW-43B	а	EE-MW-44S	al	EE-MW-45S	al	1
			Date:	11/13/2015	Val Qual	11/13/2015	Val Qual	11/13/2015	Val Qual	
			Depth:	330-340 feet	Val	20-30 feet	Val	20-30 feet	Val	
		NJDEP								1
Compound	MCL	Criteria	Units							
1,1,1-Trichloroethane	200	30	ug/L							Τ
1,1-Dichloroethane	N/A	50	ug/L	0.36	J					
1,1-Dichloroethene	7	1	ug/L	18						
1,2-Dichloroethane	5	0.3	ug/L							
Acetone	N/A	6000	ug/L							
Carbon Disulfide	N/A	700	ug/L							
Carbon Tetrachloride	5	0.4	ug/L			0.95	J	46		
Chlorobenzene	100	50	ug/L							
Chloroform	N/A	70	ug/L			0.27	J	5.6		
Cis-1,2-Dichloroethylene	70	70	ug/L							
Methyl Ethyl Ketone (2-Butanone)	N/A	300	ug/L							
Methyl Tert-Butyl Ether	N/A	70	ug/L			7.8		0.74	J	
Tetrachloroethylene (PCE)	5	0.4	ug/L							
Toluene	1000	600	ug/L							
Trichloroethylene (TCE)	5	1	ug/L	0.80	J			0.97	J	
Trichlorofluoromethane (Freon 11)	N/A	2000	ug/L							
Trichlorotrifluoroethane (Freon 113)	N/A	N/A	ug/L							
									•	

			Sample ID: Date: Depth:	URS-MW-22D 11/9/2015 38-63 feet	Val Qual	URS-MW-24D 11/11/2015 28-53 feet	Val Qual	URS-MW-2D 11/9/2015 22-47 feet	Val Qual
Compound	MCL	NJDEP Criteria	Units						
1,1,1-Trichloroethane	200	30	ug/L						
1,1-Dichloroethane	N/A	50	ug/L	2.4	J	0.44	J	0.24	J
1,1-Dichloroethene	7	1	ug/L	10	J	0.91	J		
1,2-Dichloroethane	5	0.3	ug/L					0.38	J
Acetone	N/A	6000	ug/L						
Carbon Disulfide	N/A	700	ug/L						
Carbon Tetrachloride	5	0.4	ug/L			150		7.4	J
Chlorobenzene	100	50	ug/L						
Chloroform	N/A	70	ug/L			19		0.69	J
Cis-1,2-Dichloroethylene	70	70	ug/L	0.49	J	0.77	J	0.76	J
Methyl Ethyl Ketone (2-Butanone)	N/A	300	ug/L						
Methyl Tert-Butyl Ether	N/A	70	ug/L	3.2	J			2.1	J
Tetrachloroethylene (PCE)	5	0.4	ug/L	0.64	J				
Toluene	1000	600	ug/L						
Trichloroethylene (TCE)	5	1	ug/L	1.7	J	13		24	J
Trichlorofluoromethane (Freon 11)	N/A	2000	ug/L						
Trichlorotrifluoroethane (Freon 113)	N/A	N/A	ug/L						

Notes: Detections exceeding the MCL and NJDEP are highlighted in blue Detections exceeding the NJDEP criteria, but below the MCL, are highlighted in orange. Reportable detections are in BOLD font. MCL = Federal Drinking Water Contaminant Maximum Contaminant Level Standard NJDEP Criteria = New Jersey Department of Environmental Protection, Specific Ground Water Quality Criteria - Class IIA Standard Detection = Analyte was determined to be present at the stated concentration using standard methodology. Concentrations between the RL (or method equivalent) and MDL (or method equivalent) are estimated. MW 22D is the site background well. No concentrations were detected in ECC-MW-31B and ECC-MW-33B, these wells are not listed on the table. *Duplicate sample collected from this well. Highest concentrations are shown on the table.

FD = Field Duplicate J = Estimated MDL = Method Detection Limit ug/L = Micrograms per Liter NA = Not Applicable RL = Reporting Limit VOC = Volatile Organic Compounds

TABLE 8 Summary of Overburden Monitoring Well Total Uranium Detections Sampling Events 1 Through 16 Middlesex Sampling Plant Middlesex, New Jersey

WELL ID	Units	SE 1	SE 2	SE 3	SE 4	SE 5	SE 6	SE 7	SE 8	SE 9	SE 10	SE 11	SE 12	SE 13	SE 15	SE 16
WELLID	Units	Aug-08	Nov-08	Feb-09	Dec-09	Apr-10	Nov-10	May-11	Aug-11	Nov-11	Feb-12	June-12	Aug-12	Nov-12	Oct-14	Nov-15
MW-OB-1	ug/L	3.63	1.83	1.89	1U	1U	1.60	1.20	1U	1U	0.67 J	0.96 J	0.74 J	1.2	0.317	0.321
MW-OB-2	ug/L	3.55	1U	2.98	1U	1U	1.40	1U	1U	1U	1U	1U	0.77 J	0.27 J	0.350	0.112J
MW-OB-3	ug/L	10.40	14.00	7.49	2.59	3.16	5.50	1.40	1.7	1.9	1.6	2.1	0.60 J	3.0	2.62	3.62
MW-OB-4	ug/L	1U	2.98	1.50	1U	1U	0.34	1.2	1U	1U	1U	1U	2.9	1U	0.975	2.04
MW-OB-5	ug/L	7.67	4.78	2.81	2.02	1.99	3.10	1.2	1.4UJ	1.9	2.9	0.79 J	1.8	3.4	0.418	1.94
MW-OB-6	ug/L	3.31	2.75	3.72	1U	1U	9.60	0.65	1U	0.49 J	0.93 J	0.24 J	1U	0.54 J	0.698	2.82
MW-OB-7*	ug/L	35.10	36.10	38.10	10.70	11.10	41.10	15	5.8	10.4	32.3	9.0	10	44		
MW-OB-7R	ug/L														8.64	9.14
MW-OB-8	ug/L	34.20	6.89	2.55	1.24	5.69	25.80	1.7	1U	4.4	1.6	4.4	18	11	3.39	2.78
MW-OB-9	ug/L	18.20	6.36	10.50	2.80	4.53	1U	0.72	1U	1.2	0.60 J	0.57 J	4.2	2.3	Dry	0.780
MW-0B-10*	ug/L	4.30	7.23	23.60	19.20	NS	3.60	5.5	1.2	13.2	5.9	51	40	NS		
MW-OB-11	ug/L	3.38	2.71	3.64	1.12	1.44	0.27	0.81	1U	0.39 J	0.45 J	1U	1U	0.31 J	0.479	0.447
MW-0B-12	ug/L	1U	2.98	4.03	3.03	4.54	8.50	43.5	9.3	17.7	5.5	8.4	5.9	7.8	Dry	3.08
MW-OB-13	ug/L	7.15	5.74	2.79	4.03	2.84	3.10	1.9	2.6	2.0	1.8	1.8	2.6	1.8	2.14	2.27
B18W29SR	ug/L	7.65	14.00	7.86	8.72	7.38	1.90	7.9	6.4	10.6	2.2	3.2	0.82 J	3.3	0.738	1.15

Notes: Bold Font/Blue Cell - value meets or exceeds the USEPA Maximum Contaminant Level (MCL) of 30 micrograms per liter (ug/L)

Samples were not collected for total uranium during SE 14, only VOCs.

*Wells MW-OB-7 and MW-OB-10 were abandoned in October 2014. MW-OB-7 was replaced with MW-OB-7R near the original location.

Key: ug/L - micorgrams per liter

J - estimated value

U - not detected. Analyte is not present at a level greater than the reporting limit.

UJ - not detected. The reporting limit is estimated.

NS - no sample was collected for analysis due to insuffient water

TABLE 9 Summary of Overburden Monitoring Well VOC Detections Sampling Events 1 Through 16 Middlesex Sampling Plant Middlesex, New Jersey

WELL ID	Units	SE 1	SE 2 Nov-08	SE 3 Feb-09	SE 4 Dec-09	SE 5 Apr-10	SE 6 Nov-10	SE 7 Mav-11	SE 8	SE 9 Nov-11	SE 10 Feb-12	SE 11 June-12	SE 12	SE 13 Nov-12	SE 15 Oct-14	SE 16 Nov-15
	4	Aug-08						- 1	Aug-11	-			Aug-12	-		NOV-15
MW-OB-1	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	MTBE 0.37 J	
MW-OB-2	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
MW-OB-3	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
MW-OB-4	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
MW-OB-5	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
MW-OB-6	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	MTBE 4.60	MTBE 2.6 J
MW-OB-7*	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
MW-OB-7R	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	MTBE 0.38 J	MTBE 0.48 J
MW-OB-8	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
MW-OB-9	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
MW-0B-10*	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
MW-OB-11	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
MW-OB-12	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		
MW-OB-13	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	PCE 1.44	PCE 1.7 J
B18W29SR	ug/L	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS		

Notes: Bold Font/Blue Cell - Value meets or exceeds the NJ GW Standards (PCE 0.4 µg/L)

Bold Font - Denotes a positive hit

*Wells MW-OB-7 and MW-OB-10 were abandoned in October 2014. MW-OB-7 was replaced with MW-OB-7R near the original location.

Key: ug/L - micorgrams per liter

J - estimated value

NS - no sample was collected for analysis

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Table 10a Summary of Monitoring Well Natural Attenuation Parameter Results Temperature Sampling Events 1 - 14 (August 2008 - February 2013) Middlesex Sampling Plant Middlesex, New Jersey

		1	1						1					
	SE-1	SE-2	SE-3	SE-4	SE-5	SE-6	SE-7	SE-8	SE-9	SE-10	SE-11	SE-12	SE-13	SE-14
	August 2008	November 2008	February 2009	December 2009	April 2010	November 2010	May 2011	August 2011	November 2011	February 2012	June 2012	August 2012	November 2012	February 2013
	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature	Temperature
Well ID	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)	(°C)
Overburden Wells														
MW-OB-1	19.84	16.49	9.18	12.11	12.90	16.35	16.4	19.2	17.0	10.5	16.8	19.4	13.7	
MW-OB-2	17.89	16.11	10.06	10.48	12.79	15.52	14.0	19.1	15.7	9.1	16.8	18.2	11.1	
MW-OB-3	21.92	16.05	10.71	13.27	11.88	15.22	15.0	21.1	18.9	10.0	16.5	19.9	15.1	
MW-OB-4	21.48	14.66	7.55	10.71	12.13	13.40	14.1	20.1	13.9	8.0	15.0	18.4	13.1	
MW-OB-5	19.43	14.69	9.21	9.89	11.60	13.89	14.8	19.2	14.2	9.9	15.3	19.1	12.6	
MW-OB-6	20.70	15.73	8.57	11.04	10.30	15.07	14.6	19.2	15.4	9.8	14.9	18.5	13.4	
MW-OB-7	21.47	16.50	10.43	12.51	11.19	15.35	15.0	19.7	16.1	10.9	16.6	20.2	13.1	
MW-OB-8	21.40	16.11	11.91	12.00	11.60	16.16	14.8	19.7	16.2	10.8	17.3	18.9	12.6	
MW-OB-9	24.92	16.91	11.51	12.81	12.80	15.46	14.2	20.5	16.7	10.9	17.8	18.4	12.9	
MW-OB-10	19.52	18.33	16.51	14.05	*	16.91	18.3	20.4	17.8	15.7	18.9	19.8	*	
MW-OB-11	18.53	15.05	11.88	11.86	11.27	14.74	12.5	18.6	15.6	10.1	17.5	18.2	12.2	
MW-OB-12	19.89	17.00	12.15	13.36	13.41	16.79	15.6	19.4	17.9	11.9	17.8	19.4	13.0	
MW-OB-13	17.43	15.59	16.48	13.25	14.37	15.68	16.3	16.5	16.6	14.3	18.8	16.7	11.7	
B18W29SR	18.18	14.59	9.78	10.31	11.01	14.89	16.2	19.5	16.2	11.0	17.0	20.5	13.1	
Bedrock Wells														<u></u>
URS-MW-2D	18.34	15.29	14.49	13.75	13.79	7.30	17.3	16.5	15.5	13.3	18.2	16.2	11.3	
URS-MW-22D	16.57	13.94	13.54	12.35	14.25	11.50	14.5	14.7	14.1	13.0	15.9	16.0	12.0	
URS-MW-24D	17.22	14.65	14.39	13.34	14.83	14.64	15.3	17.4	15.3	14.9	17.2	17.8	13.0	
ECC-MW-25C						14.98	16.0	17.9	14.6	13.9	16.8	17.0	14.7	
ECC-MW-25D						14.78	15.2	16.9	14.0	12.3	15.8	16.0	7.3	
ECC-MW-26B							15.2	16.5	16.0	14.6	17.3	17.3	13.9	
ECC-MW-26C						14.31	16.4	16.2	15.2	13.9	16.4	16.3	13.7	
ECC-MW-26D						14.09	16.2	15.7	16.1	14.3	17.4	16.2	13.5	
ECC-MW-27C						14.67	16.1	16.2	15.8	13.7	7.92	18.8	10.7	
ECC-MW-27D						14.90	16.0	16.0	16.0	13.9	17.7	17.0	14.0	
ECC-MW-28B (Ianiero Well)							16.5	16.9	14.5	12.8	16.0	15.8	14.0	
ECC-MW-29B							15.8	18.0	15.6	13.2	17.5	18.0	14.6	
ECC-MW-29C														
ECC-MW-1D									16.3					
ECC-MW-21D									15.2					
ECC-MW-23D									15.3					
ECC-MW-24B											18.3	17.3	13.6	
ECC-MW-30B											16.9	16.2	12.9	12.3
ECC-MW-30D											17.2	17.4	12.9	
ECC-MW-27B													13.4	
ECC-MW-31B													13.6	
ECC-MW-32B													13.3	
ECC-MW-32C													12.6	
ECC-MW-33B													13.7	
ECC-MW-34B													12.9	
ECC-MW-35B														14.2
ECC-MW-35C														13.6
														10.0

Notes:

ID = identification

SE = Sampling Event

°C = degrees Celcius

 \ast Well MW-OB-10 ran dry and was not sampled for the MNA parameters.

--- These well locations were not developed at the time the samples were taken or were not sampled for temperature measurements during the sampling event.

Table 10b Summary of Monitoring Well Natural Attenuation Parameter Results Alkalinity Sampling Events 1 - 14 (August 2008 - February 2013) Middlesex Sampling Plant Middlesex, New Jersey

	SE-1 August 2008	SE-2 November 2008	SE-3 February 2009	Decemb	E-4 per 2009 nalyses Performed)	SE-5 April 2010	SE-6 November 2010	SE-7 May 2011	SE-8 August 2011	SE-9 November 2011	SE-10 February 2012	SE-11 June 2012	SE-12 August 2012	SE-13 November 2012	SE-14 February 2013
Well ID	Alkalinity (mg/L)	Alkalinity (mg/L)	Alkalinity (mg/L)	Alkalinity (mg/L) Lab Results	Alkalinity (mg/L) Field Results	Alkalinity (mg/L) Field Results	Alkalinity (mg/L) Field Results	Alkalinity (mg/L)	Alkalinity (mg/L)	Alkalinity (mg/L)	Alkalinity (mg/L)	Alkalinity (mg/L)	Alkalinity (mg/L)	Alkalinity (mg/L)	Alkalinity (mg/L)
Overburden Wells															
MW-OB-1	200 J	140	NA	102	300	180	180	120	120	100	150	150	150	120	
MW-OB-2	230	120	NA	64.8	300	120	40	60	80	120	80	80	110	80	
MW-OB-3	270	310	NA	227	300	300	240	240	120	120	120	180	240	200	
MW-OB-4	65	210	NA	139	NA	120	40	180	120	150	100	150	100	150	
MW-OB-5	180	290	NA	274	NA	180	240	240	240	240	300	200	200	200	
MW-OB-6	240	280	NA	259	NA	180	180	240	240	240	180	180	180	180	
MW-OB-7	210	240	NA	186	300	120	240	240	150	180	200	180	180	150	
MW-OB-8	400	230	NA	135	300	180	240	240	120	240	240	180	200	100	
MW-OB-9	270	160	NA	122	180	300	40	120	120	100	150	110	180	100	
MW-OB-10	200	*	NA	*	300	*	*	240	80	*	70	180	180	*	
MW-OB-11	180	170	NA	148	NA	720	80	120	120	100	80	80	100	100	
MW-OB-12	100	130	NA	95.4	120	120	40	120	110	100	80	100	80	80	
MW-OB-13	270	420	NA	376	NA	300	240	240	240	200	200	200	240	180	
B18W29SR	150	200	NA	209	NA	300	80	180	150	200	110	150	80	80	
Bedrock Wells															
URS-MW-2D	NA	NA	NA	148	180	180	240	180	110	120	120	NA	110		
URS-MW-22D	NA	NA	NA	150	300	720	80	180	150	150	150	NA	120	100	
URS-MW-24D	NA	NA	NA	196	180	300	180	120	120	200	120	NA	150	180	
ECC-MW-25C							120	120	120	120	100	100	110	100	
ECC-MW-25D							80	120	80	100	100	150	100	120	
200-1111-200							00	120	>240	>240	>300	>240	>240	>240	
								NA	pH>12 alkalinity	pH>10 alkalinity	pH>9 alkalinity	pH>12 alkalinity	pH>12 alkalinity	pH>11 alkalinity	
ECC-MW-26B								101	results affected	results affected	results affected	results affected	results affected	results affected	
ECC-MW-26C							120	180	180	100	80	100	110	100	
ECC-MW-26D							80	180	120	80	80	100	100	90	
ECC-MW-27C							80	240	120	100	120	100	150	80	
ECC-MW-27D							40	40	80	100	80	110	100	100	
ECC-MW-28B (Ianiero Well)								>240	>240	>240	>300	100	150	100	
ECC-MW-29B								120	120	120	80	100	120	100	
ECC-MW-29C															
ECC-MW-1D															
ECC-MW-21D															
ECC-MW-23D															
ECC-MW-24B												40	60	60	
ECC-MW-30B												180	200	180	100
ECC-MW-30D												110	110	110	
ECC-MW-27B															
ECC-MW-31B														100	
ECC-MW-32B														110	
ECC-MW-32C														100	
ECC-MW-33B														120	
ECC-MW-34B														90	
ECC-MW-34B ECC-MW-35B															>240
ECC-MW-35B ECC-MW-35C															>240 >240
L00-WW-330															~240

Notes:

URS-MW-22D is the background bedrock monitoring well

Positive detections are in BOLD font. ID = Identification SE = Sampling Event

IDL = Instrument Detection Limit

J = Estimated

MDL = Method Detection Limit

* Well MW-OB-10 ran dry and was not sampled for the MNA parameters.

U = Not detected. Analyte is not present at a level greater than the method MDL or IDL.

mg/L = Milligrams per Liter

NA = Not Analyzed

--- These well locations were not developed at the time the samples were taken or were not sampled for alkalinity during the sampling event.

Table 10c Summary of Monitoring Well Natural Attenuation Parameters pH Sampling Events 1 - 14 (August 2008 - February 2013) Middlesex Sampling Plant Middlesex, New Jersey

	1	1												
	SE-1 August 2008	SE-2 November 2008	SE-3 February 2009	SE-4 December 2009	SE-5 April 2010	SE-6 November 2010	SE-7 May 2011	SE-8 August 2011	SE-9 November 2011	SE-10 February 2012	SE-11 June 2012	SE-12 August 2012	SE-13 November 2012	SE-14 February 2013
Well ID	pH (standard units)													
Overburden Wells														
MW-OB-1	7.12	7.53	7.23	7.08	6.69	6.98	7.26	7.00	7.09	7.14	6.88	6.84	6.92	
MW-OB-2	6.76	6.94	6.71	6.28	5.86	6.40	6.15	6.28	6.27	6.19	6.28	6.72	6.43	
MW-OB-3	6.50	6.56	7.08	7.18	6.98	6.89	7.23	7.13	7.20	7.14	6.95	6.88	7.25	
MW-OB-4	6.03	8.21	6.29	6.73	6.35	6.26	6.75	6.69	6.64	6.50	6.37	6.23	6.60	
MW-OB-5	7.46	6.67	7.10	7.28	6.88	6.94	7.26	7.25	6.70	7.02	6.89	6.95	7.22	
MW-OB-6	6.57	6.42	6.73	7.12	6.65	6.96	7.25	7.17	7.02	7.01	6.90	6.78	7.08	
MW-OB-7	6.80	6.67	6.72	7.29	7.06	7.16	7.05	7.09	6.98	7.20	6.81	6.70	7.32	
MW-OB-8	6.51	7.64	6.52	6.55	6.65	6.71	6.75	6.52	6.70	6.56	6.38	6.67	6.84	
MW-OB-9	6.65	8.03	9.31	6.92	6.81	6.20	6.85	6.34	6.95	7.00	6.49	6.90	6.91	
MW-OB-10	6.48	8.22	6.82	6.74	*	6.45	7.01	6.85	7.22	7.00	6.68	6.86	*	
MW-OB-11	6.96	6.63	7.03	7.14	7.13	6.77	7.46	6.66	6.73	6.67	6.46	6.48	6.71	
MW-OB-12	5.79	7.74	6.58	6.48	5.83	5.98	6.46	6.45	6.55	6.51	6.25	6.18	6.32	
MW-OB-13	7.24	8.20	6.97	6.88	6.87	6.84	7.21	7.14	7.16	7.03	7.02	6.91	6.93	
B18W29SR	6.60	6.37	6.59	6.98	6.70	6.46	6.82	6.96	6.86	6.62	6.36	6.00	6.09	
Bedrock Wells														
URS-MW-2D	7.40	6.98	6.73	7.22	7.22	7.30	7.64	7.16	7.29	7.29	7.40	7.30	7.51	
URS-MW-22D	7.61	7.36	7.03	8.01	7.27	7.92	7.71	7.48	7.54	7.51	7.69	7.61	7.55	
URS-MW-24D	7.40	7.07	7.05	7.52	7.30	7.22	7.51	7.39	7.64	7.73	7.57	7.71	7.64	
ECC-MW-25C						7.89	7.85	8.44	8.12	7.80	8.19	8.11	7.84	
ECC-MW-25D						7.55	7.78	8.82	7.80	7.49	7.80	8.11	8.73	
ECC-MW-26B							12.05	12.19	10.17	9.18	12.11	12.08	11.12	
ECC-MW-26C						7.44	8.51	8.00	8.27	7.95	8.00	7.97	7.93	
ECC-MW-26D						9.98	9.7	9.10	8.95	8.14	8.96	9.03	8.39	
ECC-MW-27C						9.45	8.43	8.26	7.79	7.47	7.92	8.19	8.04	
ECC-MW-27D						9.17	8.77	8.07	8.04	7.35	8.04	7.43	7.97	
ECC-MW-28B (laniero Well)							12.52	11.65	11.24	8.50	10.68	9.55	8.58	
ECC-MW-29B							7.92	7.85	8.17	7.46	8.13	7.97	7.68	
ECC-MW-29C														
ECC-MW-1D									7.37					
ECC-MW-21D									7.33					
ECC-MW-23D									7.76					
ECC-MW-24B											6.97	8.85	8.38	
ECC-MW-30B											6.36	7.39	7.31	7.34
ECC-MW-30D											7.46	7.46	7.76	
ECC-MW-27B													7.86	
ECC-MW-31B													7.92	
ECC-MW-32B													9.80	
ECC-MW-32C													7.93	
ECC-MW-33B													7.67	
ECC-MW-34B													7.81	
ECC-MW-35B														12.52
ECC-MW-35C														12.51

Notes:

Red font indicates pH values are outside the optimal range for the reductive pathway

Positive detections are in BOLD font.

ID = identification

SE = Sampling Event

* Well MW-OB-10 ran dry and was not sampled for the MNA parameters.

E = Sampling Event

--- These well locations were not developed at the time the samples were taken or were not sampled for pH during the sampling event.

Wen MW OB TO fundity and was not sampled

Table 10d Summary of Monitoring Well Natural Attenuation Parameters Total Organic Carbon Sampling Events 1 - 13 (August 2008 - November 2012) Middlesex Sampling Plant Middlesex, New Jersey

	SE-1	SE-2	SE-3	SE-4	SE-5	SE-6	SE-7	SE-8	SE-9	SE-10	SE-11	SE-12	SE-13
	August 2008	November 2008	February 2009	December 2009	April 2010	November 2010	May 2011	August 2011	November 2011	February 2012	June 2012	August 2012	November 2012
W-11 ID	TOC	TOC	тос	TOC	TOC	TOC	TOC	TOC	TOC	TOC	TOC	TOC	TOC
Well ID	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)
Overburden Wells													
MW-OB-1	20	10	NA	5.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-OB-2	11	5.87	NA	3.8	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-OB-3	17	9.63	NA	4.5	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-OB-4	16	21	NA	11.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-OB-5 MW-OB-6	19	41	NA	19.3	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-OB-7	14	22	NA	18.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-OB-8	24 19	17 18	NA NA	10.1 10.7	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA	NA NA
MW-OB-9	19 37	18	NA	9.9	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-OB-10	11	15	NA	9.9 *	NA *	NA *	NA	NA	NA	NA	NA	NA	NA
MW-OB-10 MW-OB-11	13	5.58	NA	4.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-OB-11 MW-OB-12	13	5.19	NA	4.7 5.1	NA	NA	NA	NA	NA	NA	NA	NA	NA
MW-OB-12 MW-OB-13	11	5.32	NA	2.7	NA	NA	NA	NA	NA	NA	NA	NA	NA
B18W29SR	7.85	8.26	NA	6.4	NA	NA	NA	NA	NA	NA	NA	NA	NA
Bedrock Wells	7.05	0.20	hA	0.4	hA	INA	hA	INA	INA	INA	ha	INA	INA
URS-MW-2D	NA	NA	NA	0.95	1.1	1.3	1.2	1.3	0.98 J	1.2	NA	NA	NA
URS-MW-22D	NA	NA	NA	0.93	0.8	1.5	1.2	1.5	0.98 J 0.92 J	0.74 J	NA	NA	NA
URS-MW-24D	NA	NA	NA	0.85	0.8	0.94 J	0.69 J	0.87 J	0.52 J 0.51 J	1.0 U	NA	NA	NA
ECC-MW-25C						2.9	0.93 J	1.5	0.56 J	1.0 U	0.99 J	0.68 J	0.69 J
ECC-MW-25D						0.89 J	0.76 J	2.7	0.30 J 0.87 J	1.0 U	0.97 J	0.03 J 0.41 J	0.63 J
ECC-MW-26B						0.07 0	NA	1.8	1.2	1.2 UJ	3.6	2.2	4.2
ECC-MW-26C						1.0	1.4	1.1	0.83 J	1.0 U	0.98 J	0.68 J	0.89 J
ECC-MW-26D						1.6	1.2	1.3	1.1	1.3 J	1.0	0.68 J	2.0
ECC-MW-27C						1.5	0.73 J	0.73 J	0.45 J	0.61 J	0.70 J	0.37 J	1.0 U
ECC-MW-27D						3.0 J	1.4	1.2	0.78 J	0.98 J	0.94 J	0.55 J	0.49 J
ECC-MW-28B (laniero Well)							2.60	1.8	0.77 J	0.76 J	0.74 J	0.43 J	0.40 J
ECC-MW-29B							0.77 J	0.71 J	0.53 J	0.66 J	0.76 J	0.47 J	0.64 J
ECC-MW-29C													
ECC-MW-1D													
ECC-MW-21D													
ECC-MW-23D													
ECC-MW-24B											2.5	2.6	2.8
ECC-MW-30B											2.0	1.8	1.7
ECC-MW-30D											2.5	1.9	1.6
ECC-MW-27B													NA
ECC-MW-31B													NA
ECC-MW-32B													NA
ECC-MW-32C													NA
ECC-MW-33B													NA
ECC-MW-34B													NA

Notes:

Positive detections are in BOLD font. ID = Identification

tion SE = Sampling Event ent Detection Limit TOC = Total Organic O

IDL = Instrument Detection Limit MDL = Method Detection Limit mg/L = Milligrams per Liter NA = Not Analyzed TOC = Total Organic Carbon U = Not detected. Analyte is not present at a level greater than the method MDL or IDL.

* Well MW-OB-10 ran dry and was not sampled for the MNA parameters.

--- These well locations were not developed at the time the samples were taken or were not sampled for TOC during the sampling event.

Table 10e Summary of Monitoring Well Natural Attenuation Parameters Dissolved Oxygen Sampling Events 1 - 14 (August 2008 - February 2013) Middlesex Sampling Plant Middlesex, New Jersey

	SE-1 August 2008	SE-2 November 2008	SE-3 February 2009	SE-4 December 2009	SE-5 April 2010	SE-6 November 2010	SE-7 May 2011	SE-8 August 2011	SE-9 November 2011	SE-10 February 2012	SE-11 June 2012	SE-12 August 2012	SE-13 November 2012	SE-14 February 2013
Well ID	Dissolved Oxygen (mg/L)													
Overburden Wells			1		1	1	1		I		I	I		
MW-OB-1	3.99	1.97	5.64	2.21	2.03	1.16	0.93	2.29	0.84	0.40	0.35	0.39	1.04	
MW-OB-2	2.96	4.50	6.69	9.89	6.97	4.78	2.67	0.59	1.40	3.79	1.42	0.58	1.18	
MW-OB-3	3.10	0.8	3.44	1.43	1.29	5.00	1.21	1.09	1.34	3.37	0.21	0.39	1.72	
MW-OB-4	2.61	0.7	U	U	U	2.27	0.19	1.39	2.79	0.14	0.35	0.34	0.37	
MW-OB-5	2.28	2.61	U	U	U	3.02	0.12	0.67	2.46	0.28	0.18	0.38	0.58	
MW-OB-6	3.96	3.15	U	U	U	0.48	0.11	0.62	2.70	0.24	0.21	0.36	0.36	
MW-OB-7	2.83	3.64	0.35	U	0.97	1.32	0.19	0.23	2.06	1.06	0.18	0.68	1.78	
MW-OB-8	3.39	1.80	6.56	U	0.91	1.34	1.67	1.97	0.62	0.67	3.08	1.12	0.41	
MW-OB-9	3.22	4.14	4.86	4.03	6.18	7.91	3.66	2.09	4.40	2.31	1.44	0.60	0.77	
MW-OB-10	2.97	0.31	5.35	4.87	*	4.79	1.56	4.09	1.25	2.41	2.47	4.89	*	
MW-OB-11	5.26	6.75	1.41	7.64	7.11	8.61	6.65	2.76	3.31	3.19	2.63	2.24	8.48	
MW-OB-12	4.14	U	3.92	4.20	7.89	5.35	4.75	4.14	5.35	5.28	4.63	5.45	5.81	
MW-OB-13	7.50	U	5.76	0.75	3.65	3.78	5.07	3.73	3.58	2.78	3.96	5.23	3.19	
B18W29SR	3.81	9.92	4.17	U	U	7.20	0.29	0.54	2.48	4.01	0.38	0.52	1.76	
Bedrock Wells														
URS-MW-2D	2.64	U	U	U	U	0.76	0.41	0.40	0.24	0.53	0.26	0.47	0.63	
URS-MW-22D	2.99	U	U	U	U	0.76	0.37	0.10	0.36	0.11	0.33	0.31	0.29	
URS-MW-24D	3.90	U	U	U	0.98	3.03	0	0.26	0.32	0.26	0.24	0.27	0.51	
ECC-MW-25C						1.08	0.76	0.51	0.65	0.58	0.74	0.61	0.39	
ECC-MW-25D						1.73	1.05	2.38	0.86	1.11	1.07	1.05	2.99	
ECC-MW-26B							2.69	0.88	0.55	1.30	2.01	0.88	3.07	
ECC-MW-26C						1.26	1.25	0.49	0.53	0.50	0.47	0.50	0.60	
ECC-MW-26D						1.81	2.06	0.76	1.09	1.21	1.13	1.26	0.71	
ECC-MW-27C						1.79	2.15	1.31	1.49	1.33	1.42	1.39	1.89	
ECC-MW-27D						0.85	2.03	0.67	0.69	0.42	0.77	1.29	1.10	
ECC-MW-28B (Ianiero Well)							2.76	1.91	1.18	0.89	0.49	0.50	0.31	
ECC-MW-29B							1.65	0.86	0.83	0.73	0.78	0.80	0.95	
ECC-MW-29C														
ECC-MW-1D									0.61					
ECC-MW-21D									0.64					
ECC-MW-23D									0.89					
ECC-MW-24B											1.98	0.80	0.93	
ECC-MW-30B											0.71	1.28	1.15	0.72
ECC-MW-30D											0.78	0.92	0.69	
ECC-MW-27B													2.17	
ECC-MW-31B													0.79	
ECC-MW-32B													0.48	
ECC-MW-32C													0.52	
ECC-MW-33B													0.54	
ECC-MW-34B													9.50	
ECC-MW-35B														4.91
ECC-MW-35C														0.77

Notes:

Positive detections are in BOLD font.

ID = identification

SE = Sampling Event mg/L = milligrams per liter U = Not detected. Analyte is not present at a level greater than the method MDL or IDL.

* Well MW-OB-10 ran dry and was not sampled for the MNA parameters.

Table 10f Summary of Monitoring Well Natural Attenuation Parameters Oxidation-Reduction Potential Sampling Events 1 - 14 (August 2008 - February 2013) Middlesex Sampling Plant Middlesex, New Jersey

	SE-1 August 2008	SE-2 November 2008	SE-3 February 2009	SE-4 December 2009	SE-5 April 2010	SE-6 November 2010	SE-7 May 2011	SE-8 August 2011	SE-9 November 2011	SE-10 February 2012	SE-11 June 2012	SE-12 August 2012	SE-13 November 2012	SE-14 February 2013
Well ID	Reduction Potential (mV)													
Overburden Wells									•	•	•			
MW-OB-1	67.3	128	164	135	38	161	293.5	55.8	17.9	-17.8	62.8	74.1	102.4	
MW-OB-2	132.0	142	97	201	98	-160	350.4	-6.8	-32.4	171.1	123.8	99.1	76.3	
MW-OB-3	75	71	83	127	116	137	303.1	80.1	70.6	149.3	-21.4	12.6	30.4	
MW-OB-4	99.9	-8	55	-14	-84	156	334.9	26.3	-36.4	-4.3	-143.0	-27.7	-100.9	
MW-OB-5	27.4	103	45	55	-56	-61	277.1	58.7	-42.6	50.1	-146.8	-121.8	-164.6	
MW-OB-6	-67	-51	-108	-56	-133	-50	267.3	32.7	-73.9	-37.5	-121.7	-96.2	-98.9	
MW-OB-7	134	149	56	112	-40	103	310.7	45.7	56.4	53.1	69.7	83.3	32.2	
MW-OB-8					-40	9								
MW-OB-9	101	128	150	135	· · ·	, ,	336.9	73.1	-19.4	110.2	138.5	102.1	-63.6	
	136	135	135	151 80	66 *	210	334.9	97.2	101.2	164.0	124.5	32.8	-72.1	
MW-OB-10	132	100	133	00	-	221	316.4	148.0	109.7	91.5	108.1	111.8		
MW-OB-11	49.1	152	86	138	163	146	338.4	80.2	128.1	169.8	125.2	103.3	104.9	
MW-OB-12	179	122	148	181	116	239	359.5	182.7	156.9	190.8	141.1	121.6	110.4	
MW-OB-13	148.9	107	132	138	74	202	359.5	151.0	114.2	143.1	102.9	91.8	73.0	
B18W29SR	160.4	150	94	124	142	126	337.7	70.4	70.4	141.7	131.1	106.0	96.0	
Bedrock Wells														
URS-MW-2D	-53.9	1.8	66	-20	26	-25	282.4	104.2	73.8	52.6	26.6	-46.8	46.2	
URS-MW-22D	-48.5	-114	61	-119	-44	-173	29	103.8	57.3	32.8	24.1	-16.3	7.5	
URS-MW-24D	-11.4	29	-10	18	-15	84	-21	0.3	89.5	1.050	-104.2	148.1	9.5	
ECC-MW-25C						168	5	63.7	62.0	68.3	-97.0	58.0	-32.7	
ECC-MW-25D						135	4.6	5.1	58.2	63.5	-52.7	75.6	26.2	
ECC-MW-26B							-26	-123.4	6.2	-115.4	-224.2	-77.8	-70.9	
ECC-MW-26C						153	73	45	72.7	40.3	-135.4	63.3	36.8	
ECC-MW-26D						71	21	37.0	3.7	3.1	-130.6	44.2	-1.2	
ECC-MW-27C						28	110	128	346	77.3	-77.5	150.3	106.8	
ECC-MW-27D						102	-13	112.0	28.7	72.1	-113.9	139.0	85.8	
ECC-MW-28B (Ianiero Well)							139	-14.3	-25.0	-47.2	-211.9	3.4	-45.7	
ECC-MW-29B							116	133	67	40.1	-148.3	69.4	-5.3	
ECC-MW-29C										40.1	-148.5	05.4	-3.5	
ECC-MW-1D									82.0					
ECC-MW-1D ECC-MW-21D									51.9					
ECC-MW-21D ECC-MW-23D									51.9 96.6					
ECC-MW-23D ECC-MW-24B											-72.2			
												120.1	31.7	
ECC-MW-30B											118.8	28.5	34.5	-16.3
ECC-MW-30D											-64.4	4.9	47.7	
ECC-MW-27B													164.2	
ECC-MW-31B													-6	
ECC-MW-32B													-101.1	
ECC-MW-32C													-127.3	
ECC-MW-33B													-92.3	
ECC-MW-34B													30.0	
ECC-MW-35B														-145.3
ECC-MW-35C														-262.6

Notes: Positive detections are in BOLD font. ID = identification SE = Sampling Event

* Well MW-OB-10 ran dry and was not sampled for the MNA parameters.

mV = millivolts

Table 10g Summary of Monitoring Well Natural Attenuation Parameters Nitrate Sampling Events 1 - 13 (August 2008 - November 2012) **Middlesex Sampling Plant** Middlesex, New Jersey

	SE-1 August 2008	SE-2 November 2008	SE-3 February 2009	SE-4 December 2009	SE-5 April 2010	SE-6 November 2010	SE-7 May 2011	SE-8 August 2011	SE-9 November 2011	SE-10 February 2012	SE-11 June 2012	SE-12 August 2012	SE-13 November 2012
Well ID	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)	Nitrate (mg/L)
Overburden Wells		•				•		•	•	•		•	·
MW-OB-1	7.14	1.68	NA	0.34	0.357	0.13	0.64	0.050 U	0.23	0.050 U	0.050 U	0.050 U	0.20 U
MW-OB-2	35	19 J	NA	0.54	1.12	0.081	0.050 U	0.058	0.11	0.10	0.050 U	0.050 U	0.20 U
MW-OB-3	2.45	0.322 J	NA	0.44	0.295	1.2	0.13	0.21	0.20	0.32	R	0.11	0.32
MW-OB-4	0.1 U	0.10 U	NA	0.95	0.1 U	1.8	0.041 J	0.1	0.050 U	0.050 U	R	0.84	0.14 J
MW-OB-5	0.243	0.10 U	NA	0.1 U	0.1 U	0.11	0.050 U	0.050 UJ	0.050 U	0.053	R	0.13	0.21
MW-OB-6	0.19	0.10 U	NA	0.1 U	0.1 U	0.036 J	0.61	0.16	0.050 U	0.050 U	0.27 J	0.085	0.047 J
MW-OB-7	16	0.138	NA	0.65 J	0.1 U	1.4	0.033 J	0.51 J	0.050 U	0.049 J	0.043 J	0.074	0.20 U
MW-OB-8	0.83	0.256 J	NA	0.1 U	0.1 U	0.029 J	0.16	0.050 U	0.050 U	0.050 U	0.055	0.26	0.20 U
MW-OB-9	4.92	0.745	NA	0.27	0.492	0.15	0.058	0.094 J	0.21	0.13	0.050 J	0.44	0.20 U
MW-OB-10	1.23	*	NA	*	*	*	0.74	2.4	*	1.6	0.56	3.2	*
MW-OB-11	3.38	2.39	NA	0.93	0.693	0.59	0.19	0.32	0.59	0.66	0.096	0.11	1.4
MW-OB-12	1.3	1.06 J	NA	0.41 J	0.407	2.7	0.46	0.71	0.78	0.53	0.58	3.3	1.7
MW-OB-13	1.95	2.11	NA	3.5 J	3.79	4.7	5.3	5.7 J	5.5	5.3	4.8	6.2	5.4
B18W29SR	0.836	0.273	NA	0.26	0.344	2.2	0.046 J	0.11	0.25	0.34	0.053	0.15	0.23
Bedrock Wells								•		•		•	
URS-MW-2D	NA	NA	NA	0.81	0.276	0.65	0.19	0.091	0.48	0.54	NA	NA	NA
URS-MW-22D	NA	NA	NA	0.28 J	0.548	0.050 U	0.56	0.66	0.77 J	0.94	NA	NA	NA
URS-MW-24D	NA	NA	NA	0.95 J	0.866	0.86	1.1	0.87	0.68 J	0.34	NA	NA	NA
ECC-MW-25C						1.1	1.5	1.4	1.7	1.6	1.6 J	1.6	1.6
ECC-MW-25D						1.0	0.98	0.84	1.2	1.2	1.2 J	1.3	1.2
ECC-MW-26B						NA	NA	1.0	0.99	0.73	7.9	4.1	16
ECC-MW-26C						2.0	1.5	1.8	1.9	2.0	1.8	2.1	1.9 J
ECC-MW-26D						0.86	0.61	0.73 J	1.1	0.80	0.82	0.97	1.3 J
ECC-MW-27C						1.2	1.4	1.4	1.4	1.5	1.3	1.4	1.1
ECC-MW-27D						0.45	0.74	2.1 J	0.84	0.78	0.78	1.1	1.4
ECC-MW-28B (Ianiero Well)							0.55	1.2	1.2	1.4	1.6	1.8	2.0
ECC-MW-29B							1.2	1.2	1.1	1.3	1.2	1.2	1.2
ECC-MW-29C													
ECC-MW-24B											1.5	1.0 J	0.96
ECC-MW-30B											0.70	0.56	1.30
ECC-MW-30D											0.51	0.52	0.58
ECC-MW-27B													NA
ECC-MW-31B													NA
ECC-MW-32B													NA
ECC-MW-32C													NA
ECC-MW-33B													NA
ECC-MW-34B													NA

Notes:

Positive detections are in BOLD font.

ID = Identification

IDL = Instrument Detection Limit

J = Estimated

MDL = Method Detection Limit

- mg/L = Milligrams per Liter
- MNA = Monitored Natural Attenuation

NA = Not Analyzed

SE = Sampling Event R = The result was rejected as unusable.

U = Not detected. Analyte is not present at a level greater than the method MDL or IDL.

UJ = Not detected. The reporting limit is estimated.

* Well MW-OB-10 ran dry and was not sampled for the MNA parameters.

--- These well locations were not developed at the time the samples were taken or were not sampled for nitrate during the sampling event.

Table 10h Summary of Monitoring Well Natural Attenuation Parameters **Ferrous** Iron Sampling Events 1 - 14 (August 2008 - February 2013) Middlesex Sampling Plant Middlesex, New Jersey

	SE-1	SE-2	SE-3	SE-4	SE-5	SE-6	SE-7	SE-8	SE-9	SE-10	SE-11	SE-12	SE-13	SE-14
	August 2008	November 2008	February 2009	December 2009	April 2010	November 2010	May 2011	August 2011	November 2011	February 2012	June 2012	August 2012	November 2012	February 2013
Well ID	Ferrous Iron (mg/L)	Ferrous Iron (mg/L)	Ferrous Iron (mg/L)	Ferrous Iron (mg/L) Lab Results	Ferrous Iron (mg/L) Field Results	Ferrous Iron (mg/L) Field Results	Ferrous Iron (mg/L)	Ferrous Iron (mg/L)	Ferrous Iron (mg/L)	Ferrous Iron (mg/L)	Ferrous Iron (mg/L)	Ferrous Iron (mg/L)	Ferrous Iron (mg/L)	Ferrous Iron (mg/L)
Overburden Wells	•	•				•		•	•	•	•			
MW-OB-1	NA	NA	NA	NA	0.10	0.27	0.24	0.08	0.09	0.35	0.04	0.16	0.57	
MW-OB-2	NA	NA	NA	NA	0.09	0.23	2.65	> 3 mg/L	1.74	0.00	0.12	1.37	0.08	
MW-OB-3	NA	NA	NA	NA	0.33	0.11	0.07	0.00	0.00	0.06	0.00	0.00	0.10	
MW-OB-4	NA	NA	NA	NA	0.71	0.18	0.28	1.85	1.03	1.32	0.65	0.37	0.95	
MW-OB-5	NA	NA	NA	NA	0.04	0.11	0.30	0.22	0.38	0.00	1.01	0.57	0.74	
MW-OB-6	NA	NA	NA	NA	1.22	0.77	NA	0.95	1.35	0.92	1.23	1.52	2.61	
MW-OB-7	NA	NA	NA	NA	0.08	0.10	0.11	0.83	0.47	0.01	0.13	0.14	0.00	
MW-OB-8	NA	NA	NA	NA	0.29	2.14	0.10	2.51	0.58	0.03	0.02	0.01	0.23	
MW-OB-9	NA	NA	NA	NA	0.01	0.26	0.10	0.04	0.03	0.00	0.02	0.03	0.74	
MW-OB-10	NA	NA	NA	NA	*	*	>3.0	0.02	*	0.03	0.05	0.10	*	
MW-OB-11	NA	NA	NA	NA	0.07	0.17	0.10	0.17	0.07	0.00	0.02	0.04	0.07	
MW-OB-12	NA	NA	NA	NA	2.07	0.76 **	2.2	0.00	0.00	0.08	0.04	0.09	0.00	
MW-OB-13	NA	NA	NA	NA	U	0.03	0.05	0.01	0.00	0.02	0.00	0.04	0.03	
B18W29SR	NA	NA	NA	NA	0.01	0.16	0.17	0.02	0.01	0.01	0.06	0.02	0.00	
Bedrock Wells														
URS-MW-2D	NA	NA	NA	0.1 U	0.17	0.28	0.08	0.06	0.11	0.00	NA	0.04	NM	
URS-MW-22D	NA	NA	NA	0.1 U	0.19	0.54	0.10	0.00	0.00	0.00	NA	0.05	0.15	
URS-MW-24D	NA	NA	NA	0.1 U	0.10	0.07	0.15	0.04	0.00	0.00	NA	0.02	0.21	
ECC-MW-25C						0.17	0.14	0.03	0.02	0.01	0.01	0.02	0.08	
ECC-MW-25D						0.06	0.02	0.02	0.00	0.00	0.02	0.02	0.00	
							NA	0.25	0.09	0.30	1.14	0.96		
ECC-MW-26B								(pH>12 affecting ferrous iron results)	(pH>10 affecting ferrous iron results)	(pH>9 affecting ferrous iron results)	(pH>12 affecting ferrous iron results)	(pH>12 affecting ferrous iron results)	0.04	
ECC-MW-26C						1.00 **	0.23	0.08	0.04	0.00	0.03	0.02	0.06	
ECC-MW-26D						0.12	0.17	0.01	0.00	0.00	0.01	0.03	0.00	
ECC-MW-27C						0.17	0.05	0.03	0.02	0.05	0.01	0.02	0.00	
ECC-MW-27D						0.57 **	0.21	0.00	0.06	0.02	0.00	0.00	0.00	
ECC-MW-28B (Ianiero Well)							NA***	NA***	0.09 (pH>11 affecting ferrous iron results)	0.16 (pH>8 affecting ferrous iron results)	0.02	0.05	0.00	
ECC-MW-29B							0.00	0.01	0.01	0.00	0.01	0.02	0.02	
ECC-MW-29C														
ECC-MW-24B											0.03	0.05	0.00	
ECC-MW-30B											0.09	0.02	0.01	0.00
ECC-MW-30D											0.00	0.02	0.01	
ECC-MW-27B													NM	
ECC-MW-31B													0.86	
ECC-MW-32B													0.58	
ECC-MW-32C													2.80	
ECC-MW-33B													7.96	
ECC-MW-34B													5.72	
ECC-MW-35B														0.15
ECC-MW-35C														0.16

Notes:

Positive detections are in BOLD font.

ID = Identification SE = Sampling Event

U = Not detected. Analyte is not present at a level greater than the method MDL or IDL.

IDL = Instrument Detection Limit J = Estimated MDL = Method Detection Limit mg/L = Milligrams per Liter NA = Not Analyzed NM = Not Measured

* Well MW-OB-10 ran dry and was not sampled for the MNA parameters.
 ** Turbidity of sample may have biased ferrous iron result per Field Measurement Data Table

MNA = Monitored Natural Attenuation *** Ferrous Iron could not be determined. An unusual white precipitate was present, and the pH was high.

Table 10i Summary of Monitoring Well Natural Attenuation Parameters Sulfate Sampling Events 1 - 13 (August 2008 - November 2012) Middlesex Sampling Plant Middlesex, New Jersey

	SE-1 August 2008	SE-2 November 2008	SE-3 February 2009	SE-4 December 2009	SE-5 April 2010	SE-6 November 2010	SE-7 May 2011	SE-8 August 2011	SE-9 November 2011	SE-10 February 2012	SE-11 June 2012	SE-12 August 2012	SE-13 November 2012
Well ID	Sulfate (mg/L)	Sulfate (mg/L)	Sulfate (mg/L)	Sulfate (mg/L)	Sulfate (mg/L)	Sulfate (mg/L)	Sulfate (mg/L)	Sulfate (mg/L)	Sulfate (mg/L)	Sulfate (mg/L)	Sulfate (mg/L)	Sulfate (mg/L)	Sulfate (mg/L)
Overburden Wells						·						-	
MW-OB-1	68	30	NA	22.0	29	38.4	13	11	29	50	17	41	74
MW-OB-2	31	27	NA	31	25	28.2	24	9.7	21	22	17	17	23
MW-OB-3	78	71	NA	34.0	22	90.3	32	30	34	32	20	52	62
MW-OB-4	50	95	NA	11.0	31	144	32	20	34	29	50	40	58
MW-OB-5	32	130	NA	59	47	136	43	15	52	55	62	53	68
MW-OB-6	20	74 J	NA	34	18	87.5	22	22	22	20	16	15	39
MW-OB-7	100	84	NA	2.2	46	56.0	29	9.9	25	35	23	31	43
MW-OB-8	96	62	NA	33 J	19	119	84	27	54	51	42	66	180
MW-OB-9	66	34	NA	35	23	65.3	19	20	22	16	8.8 J	16	31
MW-OB-10	27	*	NA	*	*	*	16	13	*	13	13 J	13	*
MW-OB-11	28	19	NA	12	9.32	10.8	6.6	6.0	13	12	5.3	5.2	14
MW-OB-12	62	24	NA	27	15	14.9	15	15	13	12	10 J	11	12
MW-OB-13	90	45	NA	39	36	41.0	36	36	37	37	30 J	36	38
B18W29SR	32	73	NA	47	35	72.6	26	12	37	35	21	26	44
Bedrock Wells													
URS-MW-2D	NA	NA	NA	20.0	33	38.8	33	34	37	38	NA	NA	NA
URS-MW-22D	NA	NA	NA	8.0	16	6.8	16	15	16	20	NA	NA	NA
URS-MW-24D	NA	NA	NA	11.0	11	10.9	12	11	9.4	7.4	NA	NA	NA
ECC-MW-25C						94.4	16	18	14	12	12	11	11
ECC-MW-25D						10.8	8.4	9.2	11	10	10	9.7	8.7
ECC-MW-26B							NA	15	14	11	28	17	26
ECC-MW-26C						20.8	13	14	15	14	13	13	13
ECC-MW-26D						14.7	13	16	13	15	12	13	14
ECC-MW-27C						23.1	11	12	12	12	11	13	6.8
ECC-MW-27D						35.5	14	12	10	9.1	7.0	8.2	11
ECC-MW-28B (Ianiero Well)							120	37	29	27	26	23	21
ECC-MW-29B							12	13	10	13	11	12	11
ECC-MW-29C													
ECC-MW-24B											110	93 J	90
ECC-MW-30B											20	19	17
ECC-MW-30D											31	22	10
ECC-MW-27B													NA
ECC-MW-31B													NA
ECC-MW-32B													NA
ECC-MW-32C													NA
ECC-MW-33B													NA
ECC-MW-34B													NA

Notes:

Positive detections are in BOLD font.

ID = Identification IDL = Instrument Detection Limit J = Estimated MDL = Method Detection Limit mg/L = Milligrams per Liter NA = Not Analyzed SE = Sampling Event

U = Not detected. Analyte is not present at a level greater than the method MDL or IDL.

* Well MW-OB-10 ran dry and was not sampled for the MNA parameters.

Table 10j Summary of Monitoring Well Natural Attenuation Parameters Methane Sampling Events 1 - 13 (August 2008 - November 2012) Middlesex Sampling Plant Middlesex, New Jersey

	SE-1	SE-2	SE-3	SE-4	SE-5	SE-6	SE-7	SE-8	SE-9	SE-10	SE-11	SE-12	SE-13
	August 2008	November 2008	February 2009	December 2009	April 2010	November 2010	May 2011	August 2011	November 2011	February 2012	June 2012	August 2012	November 2012
Well ID	Methane (ug/L)												
Overburden Wells													
MW-OB-1	NA												
MW-OB-2	NA												
MW-OB-3	NA												
MW-OB-4	NA												
MW-OB-5	NA												
MW-OB-6	NA												
MW-OB-7	NA												
MW-OB-8	NA												
MW-OB-9	NA												
MW-OB-10	NA	NA	NA	NA	*	*	NA						
MW-OB-11	NA												
MW-OB-12	NA												
MW-OB-13	NA												
B18W29SR	NA												
Bedrock Wells													
URS-MW-2D	NA	NA	NA	2.58	5 U	36	0.24 J	6.0	11	6.3	NA	NA	NA
URS-MW-22D	NA	NA	NA	1.7 U	5 U	7.9	2.3	1.7	7.8	5.8	NA	NA	NA
URS-MW-24D	NA	NA	NA	2.31	5 U	27	42	28	59	310	NA	NA	NA
ECC-MW-25C						0.16 J	0.11 J	0.18 J	0.50 U	0.50 U	0.58 U	5.0 U	2.0 U
ECC-MW-25D						0.50 U	5.0 U	2.0 U					
ECC-MW-26B							NA	0.50 U	0.31 J	0.50 U	3.9	5.0 U	2.0 UJ
ECC-MW-26C						0.50 U	0.11 J	0.50 U	0.13 J	0.50 U	0.41 J	5.0 U	2.0 UJ
ECC-MW-26D						0.50 U	0.18 J	0.50 U	0.13 J	0.50 U	0.58 U	5.0 U	2.0 UJ
ECC-MW-27C						0.50 U	5.0 U	2.0 U					
ECC-MW-27D						0.55 UJ	0.28 J	0.50 U	0.11 J	0.50 U	0.58 UJ	5.0 U	2.0 U
ECC-MW-28B (Ianiero Well)							0.12 J	0.29 J	0.50 U	0.50 U	0.58 U	5.0 U	2.0 U
ECC-MW-29B							U	0.50 U	0.50 U	0.50 U	0.58 U	5.0 U	2.0 U
ECC-MW-29C													
ECC-MW-24B											3.9	5.0 U	2.0 U
ECC-MW-30B											14	5.0 U	2.0 U
ECC-MW-30D											0.58	5.0 U	2.0 U
ECC-MW-27B													NA
ECC-MW-31B													NA
ECC-MW-32B													NA
ECC-MW-32C													NA
ECC-MW-33B													NA
ECC-MW-34B													NA

Notes:

Positive detections are in BOLD font.

ID = Identification SE = Sampling Event

IDL = Instrument Detection Limit U = Not detected. Analyte is not present at a level greater than the method MDL or IDL.

J = Estimated ug/L = Micrograms per Liter

MDL = Method Detection Limit

MNA = Monitored Natural Attenuation * Well MW-OB-10 ran dry and was not sampled for the MNA parameters.

NA = Not Analyzed

--- These well locations were not developed at the time the samples were taken or were not sampled for methane during the sampling event.

Table 10k Summary of Monitoring Well Natural Attenuation Parameters Ethene Semuling Except 1 Semuling Except 1

Sampling Events 1 - 13 (August 2008 - November 2012) Middlesex Sampling Plant Middlesex, New Jersey

	SE-1	SE-2	SE-3	SE-4	SE-5	SE-6	SE-7	SE-8	SE-9	SE-10	SE-11	SE-12	SE-13
	August 2008	November 2008	February 2009	December 2009	April 2010	November 2010	May 2011	August 2011	November 2011	February 2012	June 2012	August 2012	November 2012
Well ID	Ethene (ug/L)												
Overburden Wells													
ECC-MW-MW-OB-1	NA												
ECC-MW-MW-OB-2	NA												
ECC-MW-MW-OB-3	NA												
ECC-MW-MW-OB-4	NA												
ECC-MW-MW-OB-5	NA												
ECC-MW-MW-OB-6	NA												
ECC-MW-MW-OB-7	NA												
ECC-MW-MW-OB-8	NA												
ECC-MW-MW-OB-9	NA												
ECC-MW-MW-OB-10	NA	NA	NA	NA	*	*	NA						
ECC-MW-MW-OB-11	NA												
ECC-MW-MW-OB-12	NA												
ECC-MW-MW-OB-13	NA												
B18W29SR	NA												
Bedrock Wells						11							
URS-URS-MW-2D	NA	NA	NA			0.50 U	0.50 U	0.50 U	0.50 U	0.050 U	NA	NA	NA
URS-URS-MW-22D	NA	NA	NA			0.50 U	NA	NA	NA				
URS-URS-MW-24D	NA	NA	NA			0.50 U	NA	NA	NA				
ECC-ECC-MW-25C						0.44 J	0.59 UJ	1.0	0.50 U	0.50 U	1.0 U	5.0 U	3.0 U
ECC-ECC-MW-25D						0.50 U	5.0 U	3.0 U					
ECC-ECC-MW-26B							NA	0.49 J	0.32 J	1.3	0.75 J	5.0 U	3.0 UJ
ECC-ECC-MW-26C						0.50 U	0.48 J	0.38 J	0.50 U	0.50	1.0 U	5.0 U	3.0 UJ
ECC-ECC-MW-26D						0.44 J	1.2	1.9	1.8	3.2	0.88 J	5.0 U	3.0 UJ
ECC-ECC-MW-27C						0.38 J	0.50 U	5.0 U	3.0 U				
ECC-ECC-MW-27D						1.6	2.40	0.36 J	0.50 U	0.50 U	1.0 U	5.0 U	3.0 U
ECC-ECC-MW-28B (laniero W							0.50 U	0.37 J	0.37 J	0.50 U	1.0 U	5.0 U	3.0 U
ECC-ECC-MW-29B							0.50 U	0.50 UJ	0.50 U	0.50 U	1.0 U	5.0 U	3.0 U
ECC-ECC-MW-29C													
ECC-ECC-MW-24B											1.2	5.0 U	3.0 U
ECC-ECC-MW-30B											1.0 U	5.0 U	3.0 U
ECC-ECC-MW-30D											1.0 U	5.0 U	3.0 U
ECC-ECC-MW-27B													NA
ECC-ECC-MW-31B													NA
ECC-ECC-MW-32B													NA
ECC-ECC-MW-32C													NA
ECC-ECC-MW-33B													NA
ECC-ECC-MW-34B													NA

Notes:

ID = Identification

Positive detections are in BOLD font.

IDL = Instrument Detection Limit

SE = Sampling Event

U = Not detected. Analyte is not present at a level greater than the method MDL or IDL.

UJ = Not detected. The reporting limit is estimated.

it ug/L = Micrograms per Liter

J = Estimated MDL = Method Detection Limit MNA = Monitored Natural Attenuatio NA = Not Analyzed

MNA = Monitored Natural Attenuation * Well ECC-MW-MW-OB-10 ran dry and was not sampled for the MNA parameters.

Table 11 Reductive Dechlorination Scoring ResultsBedrock Wells - May 2011Middlesex Sampling Plant, Middlesex, New Jersey

Parameter	Parameter Evaluation Criteria (in most contaminated zone)	Parameter Scoring	URS-N	MW-2D	URS-M	W 22-D	URS-MW-24D		
	(Parameter Value May 2011	Parameter Score May 2011	Parameter Value May 2011	Parameter Score May 2011	Parameter Value May 2011	Parameter Score May 2011	
DO (mg/L)	<0.5; 0.5 to 5; >5	3; 0; -3	0.41	3	0.37	3	0	3	
Nitrate (mg/L)	<1;>1	2; 0	0.19	2	0.56	2	1.1	0	
Iron II (mg/L)	>1; <1	3; 0	0.08	0	0.1	0	0.15	0	
Sulfate (mg/L)	<20;>20	2;0	33	0	16	2	12	2	
Methane (mg/L)	>0.5; <0.5	3;0	0.24	0	2.3	3	42	3	
ORP (mV)	< -100; -100 to 50; >50	2; 1; 0	282.4	0	29	1	-21	1	
pH	5 to 9; <5 or >9	0; -2	7.64	0	7.71	0	7.51	0	
TOC (mg/L)	>20; <20	2;0	1.2	0	1.3	0	0.69	0	
Temperature (°C)	>20; <20	1; 0	17.3	0	14.5	0	15.3	0	
Carbon dioxide	>2X background; <2X background	1; 0	11.4	0	8.52	NA	11.2	0	
Alkalinity	>2X background; <2X background	1; 0	180	0	180	NA	120	0	
Chloride	>2X background; <2X background	2; 0	NA	NA	NA	NA	NA	NA	
**Hydrogen (nM)	>1;<1	3; 0	1.5	3	1.4	3	1.3	3	
Volatile Fatty Acids (mg/L)	>0.1; <0.1	2; 0	NA	NA	NA	NA	NA	NA	
BTEX (ug/L)	>100; <100	2; 0	U	0	U	0	U	0	
Tetrachloroethene (PCE)	Material released	0	U	0	0.63	0	0.25	0	
Trichloroethene (TCE)	Daughter product of PCE; Material released	2ª; 0	23	0	1.6	0	22	0	
Dichloroethene (DCE)	Daughter product of TCE ^b ; Material released	2ª; 0	0.58	2	5	0	2.2	2	
Vinyl chloride	Daughter product of TCE; Material released	2ª; 0	U	0	U	0	U	0	
1,1,1-Trichloroethane	Material released	0	U	0	U	0	U	0	
Dichloroethane (DCA)	Daughter product of TCA under reducing conditions; Absent	2; 0	U	0	1.6	2	0.4	2	
Carbon Tetrachloride	Material released	0	8	0	U	0	300	0	
Chloroethane	Daughter product of DCA or vinyl chloride under reducing conditions; Absent	2; 0	U	0	U	0	U	0	
Ethene/Ethane (ug/L)	>100; 10 to 100; <10	3; 2; 0	NA	0	U	0	U	0	
Chloroform	Daughter product of carbon tetrachloride; Material released	2; 0	2.5	2	26	2	U	0	
Dichloromethane	Daughter product of chloroform; Material released	2; 0	U	0	U	0	U	0	
Total score for monitoring	well			12		18		16	

Score Interpretation

0 to 5 Inadequate evidence for anaerobic degradation* of chlorinated organics

6 to 14 Limited evidence for anaerobic degradation* of chlorinated organics

15 to 20 Adequate evidence for anaerobic degradation* of chlorinated organics

Strong evidence for anaerobic degradation* of chlorinated organics

Notes:

>20

- Bold = Required analysis for application of scoring system.
- * = by reductive dechlorination
- ** = Hydrogen values are from laboratory analysis
- ^a = Points awarded only if compound is shown to be a daughter product (i.e., not released from source).
- ^b = If cis-1,2-DCE is > 80% of total DCE, cis-1,2-DCE is likely a daughter product.
- 1,1,-DCE can be a chemical reaction product of TCA.
- BTEX = benzene, toluene, ethybenzene, and xylenes
- °C = degrees Celsius
- DO = dissolved oxygen

- ug/L = micrograms per liter
- mg/L = milligrams per liter
- mV = millivolts
- NA = not available or not applicable
- nM = nanomoles
- ORP = oxidation-reduction potential
- TCA = trichloroethane
- TOC = total organic carbon
- U = not detected

Table 11 Reductive Dechlorination Scoring Results Bedrock Wells - May 2011 Middlesex Sampling Plant, Middlesex, New Jersey

Parameter	Parameter Evaluation Criteria (in most contaminated zone)	Parameter Scoring	ECC-M	1W-25C	ECC-M	1W-25D	ECC-MW-26B		
	(Parameter Value May 2011	Parameter Score May 2011	Parameter Value May 2011	Parameter Score May 2011	Parameter Value May 2011	Parameter Score May 2011	
DO (mg/L)	<0.5; 0.5 to 5; >5	3; 0; -3	0.76	0	1.05	0	2.69	0	
Nitrate (mg/L)	<1;>1	2;0	1.5	0	0.98	2	NA	NA	
Iron II (mg/L)	>1; <1	3; 0	0.14	0	0.02	0	NA	NA	
Sulfate (mg/L)	<20;>20	2;0	16	2	8.4	2	NA	NA	
Methane (mg/L)	>0.5; <0.5	3; 0	0.11	0	U	0	NA	NA	
ORP (mV)	< -100; -100 to 50; >50	2; 1; 0	5	1	4.6	1	-26	1	
pH	5 to 9; <5 or >9	0; -2	7.85	0	7.78	0	12.05	-2	
TOC (mg/L)	>20; <20	2;0	0.93	0	0.76	0	NA	0	
Temperature (°C)	>20; <20	1;0	16	0	15.2	0	15.2	0	
Carbon dioxide	>2X background; <2X background	1; 0	3.36	0	5.46	0	NA	0	
Alkalinity	>2X background; <2X background	1; 0	120	0	120	0	NA	0	
Chloride	>2X background; <2X background	2; 0	NA	NA	NA	NA	NA	NA	
**Hydrogen (nM)	>1;<1	3; 0	2.8	3	2.4	3	NA	3	
Volatile Fatty Acids (mg/L)	>0.1; <0.1	2;0	NA	NA	NA	NA	NA	NA	
BTEX (ug/L)	>100; <100	2;0	U	0	U	0	U	0	
Tetrachloroethene (PCE)	Material released	0	26	0	1.4	0	U	0	
Trichloroethene (TCE)	Daughter product of PCE: Material		17	0	160	0	2.9	0	
Dichloroethene (DCE)	Daughter product of TCE ^b ; Material released	2ª; 0	151.8	0	17.4	0	U	0	
Vinyl chloride Daughter product of TCE; Materia released		2ª; 0	U	0	U	0	U	0	
1,1,1-Trichloroethane	Material released	0	1.9	0	0.34	0	U	0	
Dichloroethane (DCA)	Daughter product of TCA under reducing conditions; Absent	2; 0	7.5	2	0.82	2	U	0	
Carbon Tetrachloride	Material released	0	11	0	0.65	0	41	0	
Chloroethane Daughter product of DCA or vinyl chloride under reducing conditions; Absent		2; 0	U	0	U	0	U	0	
Ethene/Ethane (ug/L)	>100; 10 to 100; <10	3; 2; 0	U	0	U	0	U	0	
Chloroform	Daughter product of carbon tetrachloride; Material released	2; 0	1.1	2	0.28	2	2.9	2	
Dichloromethane Daughter product of chloroform; Material released		2; 0	U	0	U	0	U	0	
Total score for monitoring	well			10		12		4	

Score Interpretation

0 to 5 Inadequate evidence for anaerobic degradation* of chlorinated organics

6 to 14 Limited evidence for anaerobic degradation* of chlorinated organics

15 to 20 Adequate evidence for anaerobic degradation* of chlorinated organics

Strong evidence for anaerobic degradation* of chlorinated organics

Notes:

>20

- Bold = Required analysis for application of scoring system.
- * = by reductive dechlorination
- ** = Hydrogen values are from laboratory analysis
- ^a = Points awarded only if compound is shown to be a daughter product (i.e., not released from source).
- ^b = If cis-1,2-DCE is > 80% of total DCE, cis-1,2-DCE is likely a daughter produc 1,1,-DCE can be a chemical reaction product of TCA.
- BTEX = benzene, toluene, ethybenzene, and xylenes
- °C = degrees Celsius
- DO = dissolved oxygen

- ug/L = micrograms per liter
- mg/L = milligrams per liter
- mV = millivolts
- NA = not available or not applicable
- nM = nanomoles
- ORP = oxidation-reduction potential TCA = trichloroethane
- TOC = total organic carbon
- U = not detected

Table 11 Reductive Dechlorination Scoring Results Bedrock Wells - May 2011 Middlesex Sampling Plant, Middlesex, New Jersey

Parameter	Parameter Evaluation Criteria (in most contaminated zone)	Parameter Scoring	ECC-M	1W-26C	ECC-N	1W-26D	ECC-MW-27C		
			Parameter Value May 2011	Parameter Score May 2011	Parameter Value May 2011	Parameter Score May 2011	Parameter Value May 2011	Parameter Score May 2011	
DO (mg/L)	<0.5; 0.5 to 5; >5	3; 0; -3	1.25	0	2.06	0	2.15	0	
Nitrate (mg/L)	<1;>1	2;0	1.5	0	0.61	2	1.4	0	
Iron II (mg/L)	>1; <1	3; 0	0.23	0	0.17	0	0.05	0	
Sulfate (mg/L)	<20; >20	2;0	13	2	13	2	11	2	
Methane (mg/L)	>0.5; <0.5	3; 0	0.11	0	0.18	0	U	0	
ORP (mV)	< -100; -100 to 50; >50	2; 1; 0	73	0	21	1	110	0	
pH	5 to 9; <5 or >9	0; -2	8.51	0	9.7	-2	8.43	0	
TOC (mg/L)	>20; <20	2;0	1.4	0	1.2	0	0.73	0	
Temperature (°C)	>20; <20	1; 0	16.4	0	16.2	0	16.1	0	
Carbon dioxide	>2X background; <2X background	1; 0	1.47	0	U	0	1.61	0	
Alkalinity	>2X background; <2X background	1; 0	180	0	180	0	240	0	
Chloride	>2X background; <2X background	2; 0	NA	NA	NA	NA	NA	NA	
**Hydrogen (nM)	>1;<1	3; 0	1.7	3	2	3	1.6	3	
Volatile Fatty Acids (mg/L)	>0.1; <0.1	2; 0	NA	NA	NA	NA	NA	NA	
BTEX (ug/L)	>100; <100	2; 0	U	0	U	0	U	0	
Tetrachloroethene (PCE)	Material released	0	3.1	0	0.91	0	2	0	
Trichloroethene (TCE)	Frichloroethene (TCE) Daughter product of PCE; Material released		8.4	0	8.7	0	28	0	
Dichloroethene (DCE)	Daughter product of TCE ^b ; Material released	2ª; 0	8.93	0	U	0	3.85	0	
Vinyl chloride Daughter product of TCE; Mater released		2ª; 0	U	0	U	0	U	0	
1,1,1-Trichloroethane	Material released	0	U	0	U	0	U	0	
Dichloroethane (DCA)	Daughter product of TCA under reducing conditions; Absent	2; 0	1.3	2	U	0	U	0	
Carbon Tetrachloride	Material released	0	88	0	1.7	0	14	0	
Chloroethane Daughter product of DCA or vinyl chloride under reducing conditions; Absent		2; 0	U	0	U	0	U	0	
Ethene/Ethane (ug/L)	>100; 10 to 100; <10	3; 2; 0	0.48	0	1.2	0	U	0	
Chloroform	Daughter product of carbon tetrachloride; Material released	2; 0	6.6	2	0.42	2	1.5	2	
Dichloromethane Daughter product of chloroform; Material released		2; 0	U	0	U	0	U	0	
Total score for monitoring	well			9		8		7	

Score Interpretation

0 to 5 Inadequate evidence for anaerobic degradation* of chlorinated organics

6 to 14 Limited evidence for anaerobic degradation* of chlorinated organics

15 to 20 Adequate evidence for anaerobic degradation* of chlorinated organics

Strong evidence for anaerobic degradation* of chlorinated organics

Notes:

>20

- Bold = Required analysis for application of scoring system.
- * = by reductive dechlorination
- ** = Hydrogen values are from laboratory analysis
- ^a = Points awarded only if compound is shown to be a daughter product (i.e., not released from source).
- ^b = If cis-1,2-DCE is > 80% of total DCE, cis-1,2-DCE is likely a daughter produc 1,1,-DCE can be a chemical reaction product of TCA.
- BTEX = benzene, toluene, ethybenzene, and xylenes °C = degrees Celsius
- DO = dissolved oxygen

- ug/L = micrograms per liter
- mg/L = milligrams per liter
- mV = millivolts
- NA = not available or not applicable
- nM = nanomoles
- ORP = oxidation-reduction potential
- TCA = trichloroethane
- TOC = total organic carbon
- U = not detected

Table 11 Reductive Dechlorination Scoring ResultsBedrock Wells - May 2011Middlesex Sampling Plant, Middlesex, New Jersey

Parameter	Parameter Evaluation Criteria (in most contaminated zone)	Parameter Scoring	ECC-N	1W-27D	ECC-M	1W-28B	ECC-MW-29B		
			Parameter Value May 2011	Parameter Score May 2011	Parameter Value May 2011	Parameter Score May 2011	Parameter Value May 2011	Parameter Score May 2011	
DO (mg/L)	<0.5; 0.5 to 5; >5	3; 0; -3	2.03	0	2.76	0	1.65	0	
Nitrate (mg/L)	<1;>1	2;0	0.74	2	0.55	2	1.2	0	
Iron II (mg/L)	>1; <1	3;0	0.21	0	NA	NA	0	0	
Sulfate (mg/L)	<20;>20	2;0	14	2	120	0	12	2	
Methane (mg/L)	>0.5; <0.5	3; 0	0.28	0	0.12	0	U	0	
ORP (mV)	< -100; -100 to 50; >50	2; 1; 0	-13	1	139	0	116	0	
pH	5 to 9; <5 or >9	0; -2	8.77	0	12.52	-2	7.92	0	
TOC (mg/L)	>20; <20	2;0	1.4	0	2.6	0	0.77	0	
Temperature (°C)	>20; <20	1;0	16	0	16.5	0	15.8	0	
Carbon dioxide	>2X background; <2X background	1; 0	0.775	0	U	0	3.85	0	
Alkalinity	>2X background; <2X background	1; 0	40	0	>240	0	120	0	
Chloride	>2X background; <2X background	2; 0	NA	NA	NA	NA	NA	NA	
**Hydrogen (nM)	>1; <1	3;0	1.4	3	8.6	3	1.8	3	
Volatile Fatty Acids (mg/L)	>0.1; <0.1	2;0	NA	NA	NA	NA	NA	NA	
BTEX (ug/L)	>100; <100	2;0	U	0	0.29	0	U	0	
Tetrachloroethene (PCE)			U	0	0.37	0	2.1	0	
Trichloroethene (TCE) Daughter product of PCE; Material released		2 ^a ; 0	4.6	0	0.54	0	12	0	
Dichloroethene (DCE) Daughter product of TCE ^b ; Material released		2 ^a ; 0	U	0	1.3	0	1.3	0	
Vinyl chloride	Daughter product of TCE; Material released	2 ^a ; 0	U	0	U	0	U	0	
1,1,1-Trichloroethane	Material released	0	U	0	U	0	U	0	
Dichloroethane (DCA)	Daughter product of TCA under reducing conditions; Absent	2; 0	U	0	U	0	U	0	
Carbon Tetrachloride	Material released	0	2.5	0	4	0	40	0	
Chloroethane Daughter product of DCA or vinyl chloride under reducing conditions; Absent		2; 0	U	0	U	0	U	0	
Ethene/Ethane (ug/L)	>100; 10 to 100; <10	3; 2; 0	2.4	0	U	0	U	0	
Chloroform Daughter product of carbon tetrachloride; Material released		2; 0	0.65	2	1.1	2	3	2	
Dichloromethane	Daughter product of chloroform; Material released	2; 0	U	0	U	0	U	0	
Total score for monitoring	well			10		5		7	

Score Interpretation

0 to 5 Inadequate evidence for anaerobic degradation* of chlorinated organics

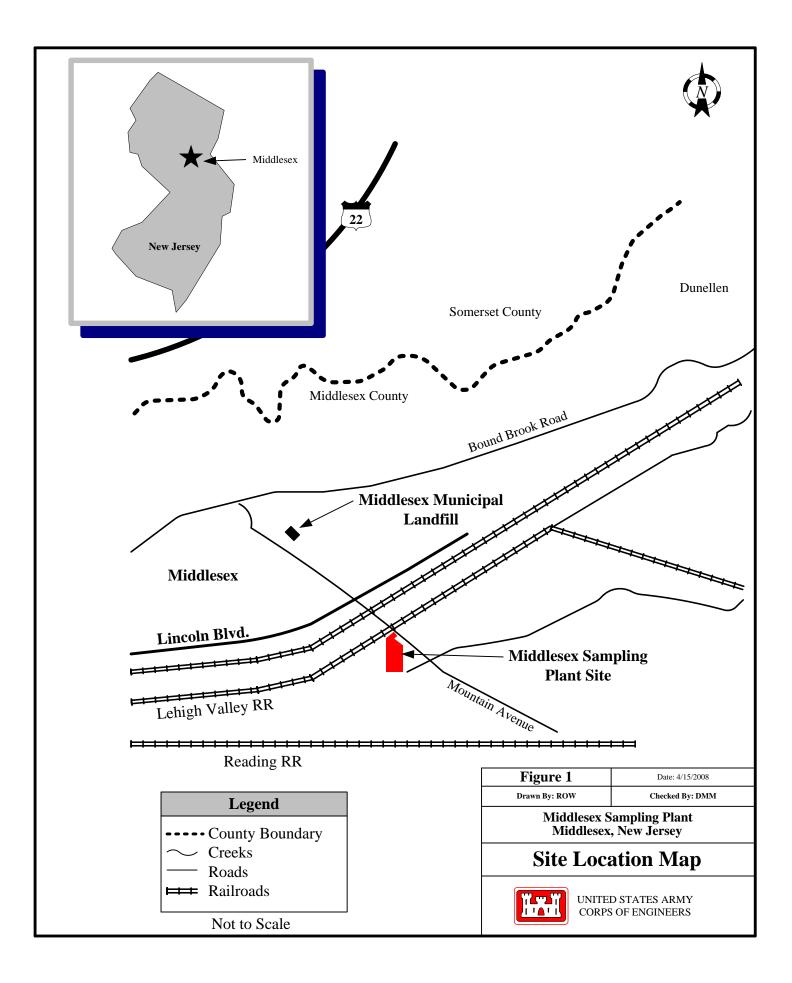
- 6 to 14 Limited evidence for anaerobic degradation* of chlorinated organics
- 15 to 20 Adequate evidence for anaerobic degradation* of chlorinated organics
- >20 Strong evidence for anaerobic degradation* of chlorinated organics

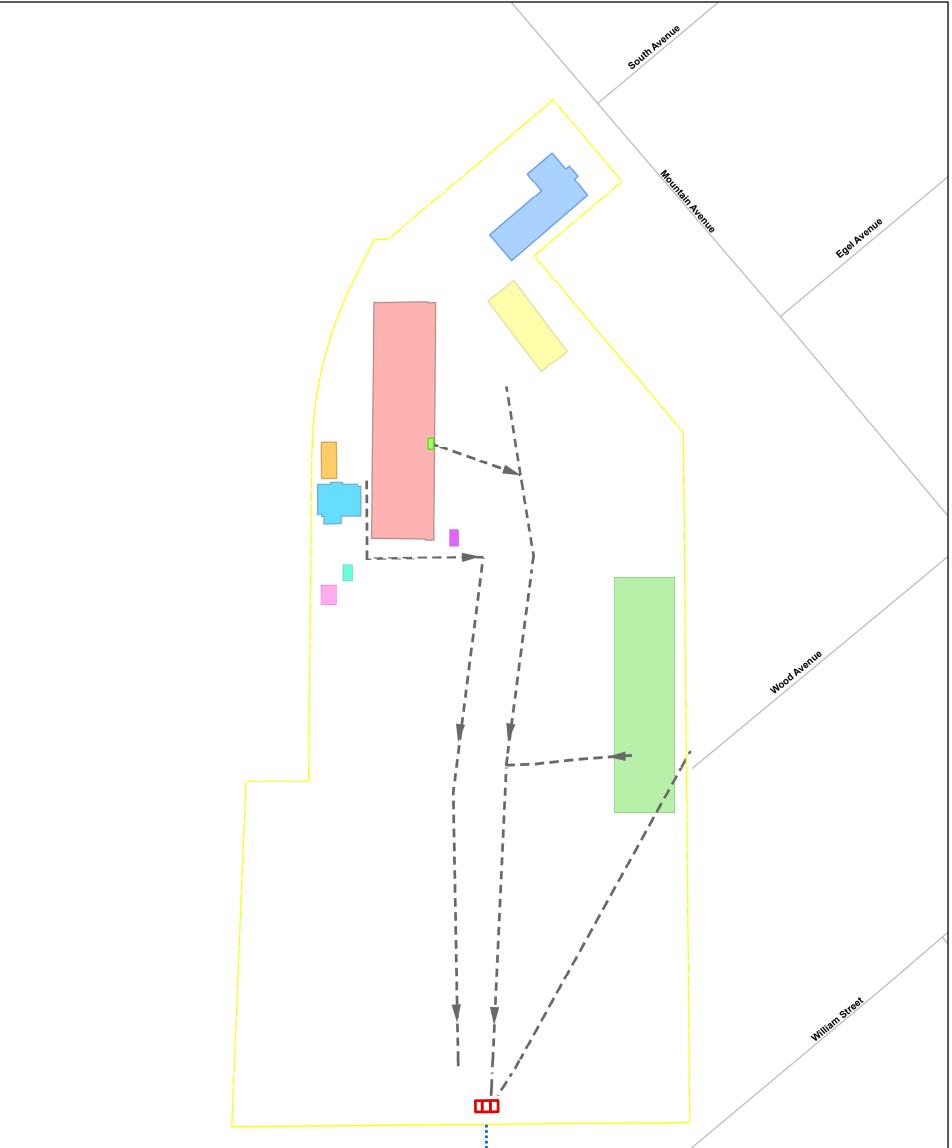
Notes:

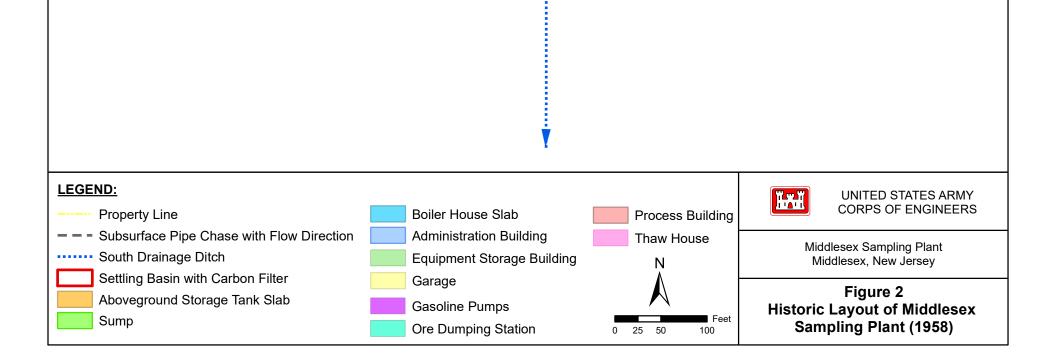
- Bold = Required analysis for application of scoring system.
- * = by reductive dechlorination
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- b = If cis-1,2-DCE is > 80% of total DCE, cis-1,2-DCE is likely a daughter produc 1,1,-DCE can be a chemical reaction product of TCA.
- BTEX = benzene, toluene, ethybenzene, and xylenes
- °C = degrees Celsius
- DO = dissolved oxygen

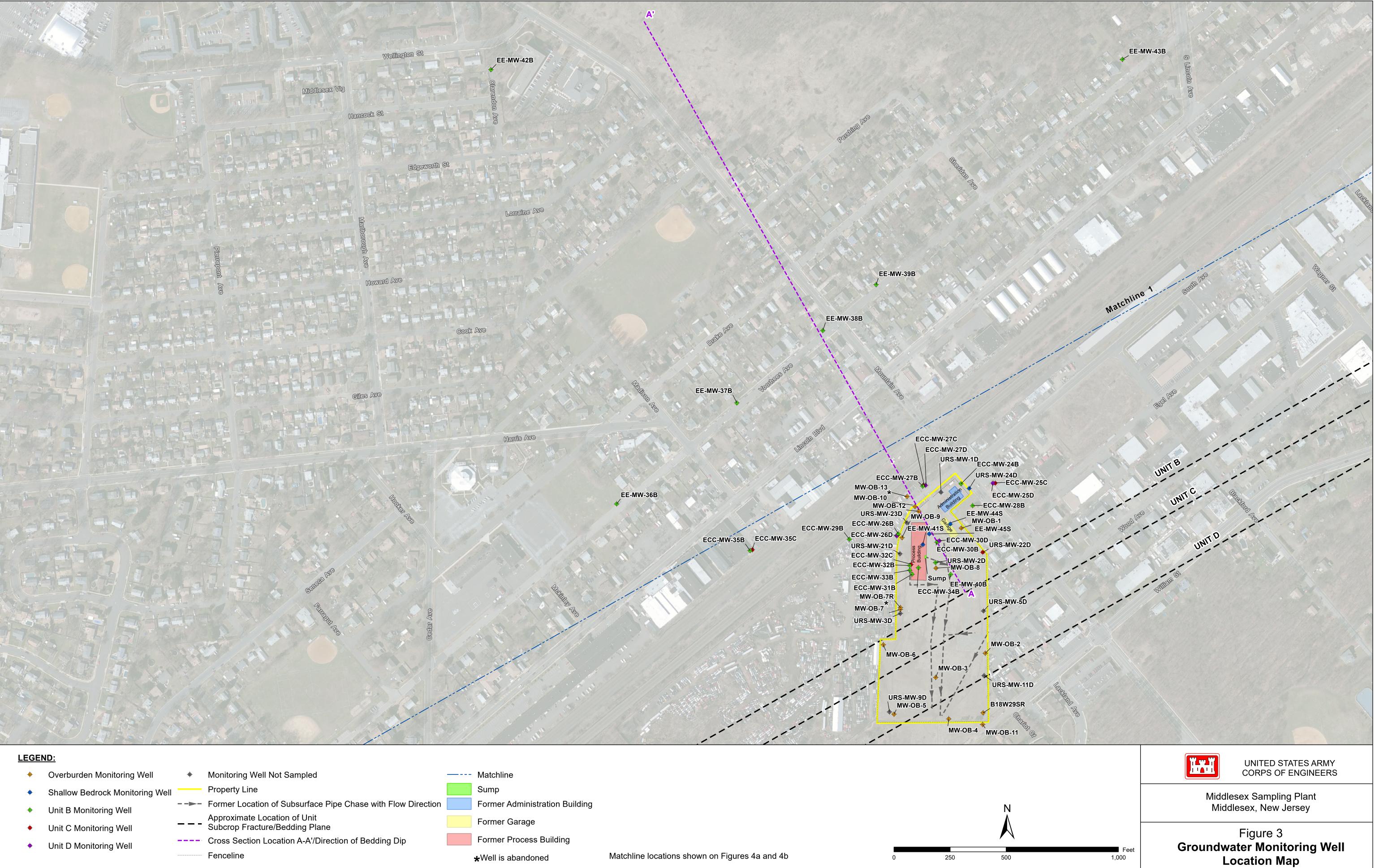
- ug/L = micrograms per liter
- mg/L = milligrams per liter
- mV = millivolts
- NA = not available or not applicable nM = nanomoles
- ORP = oxidation-reduction potential
- TCA = trichloroethane
- TOC = total organic carbon
- U = not detected

FIGURES

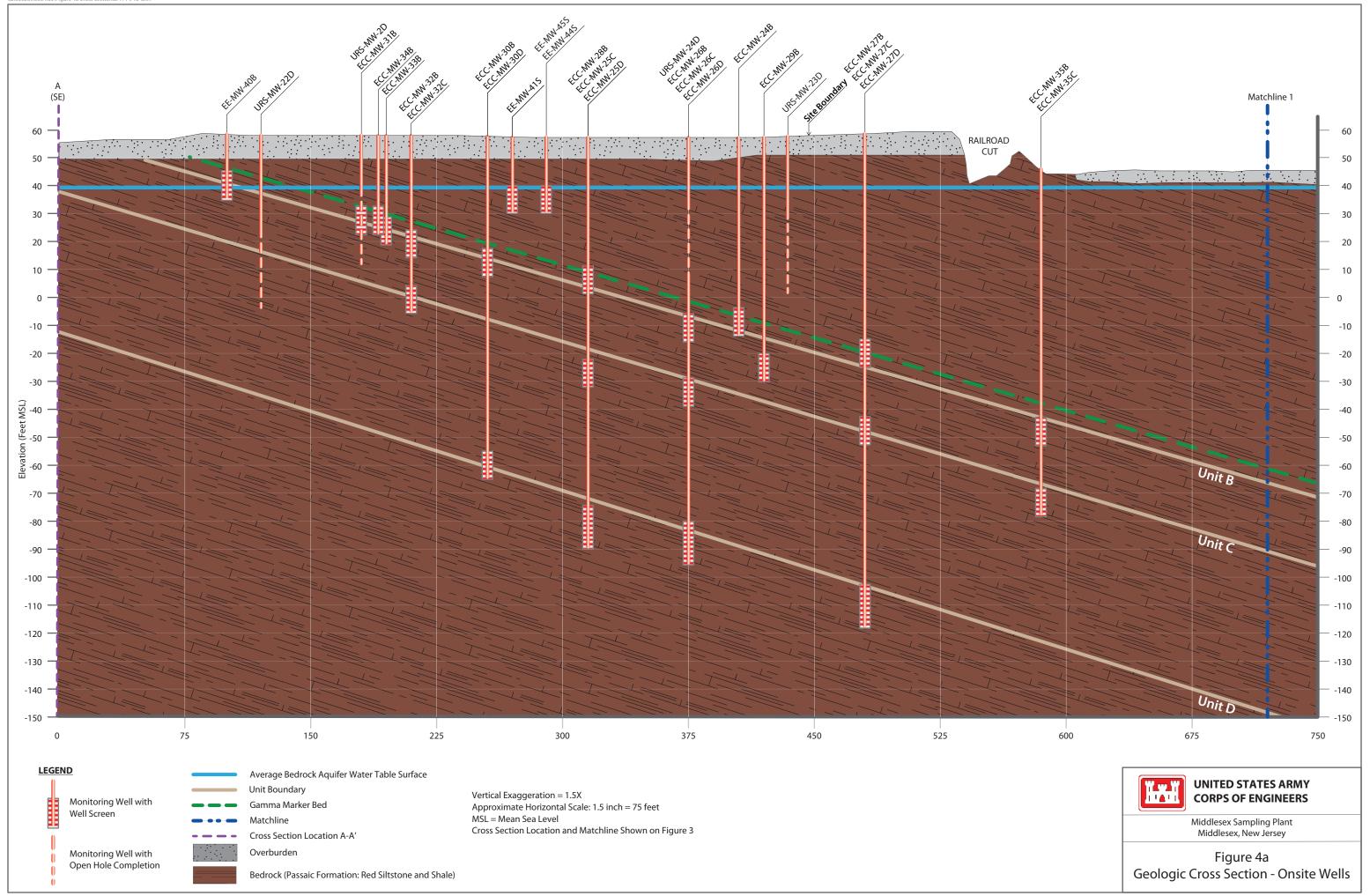


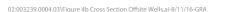


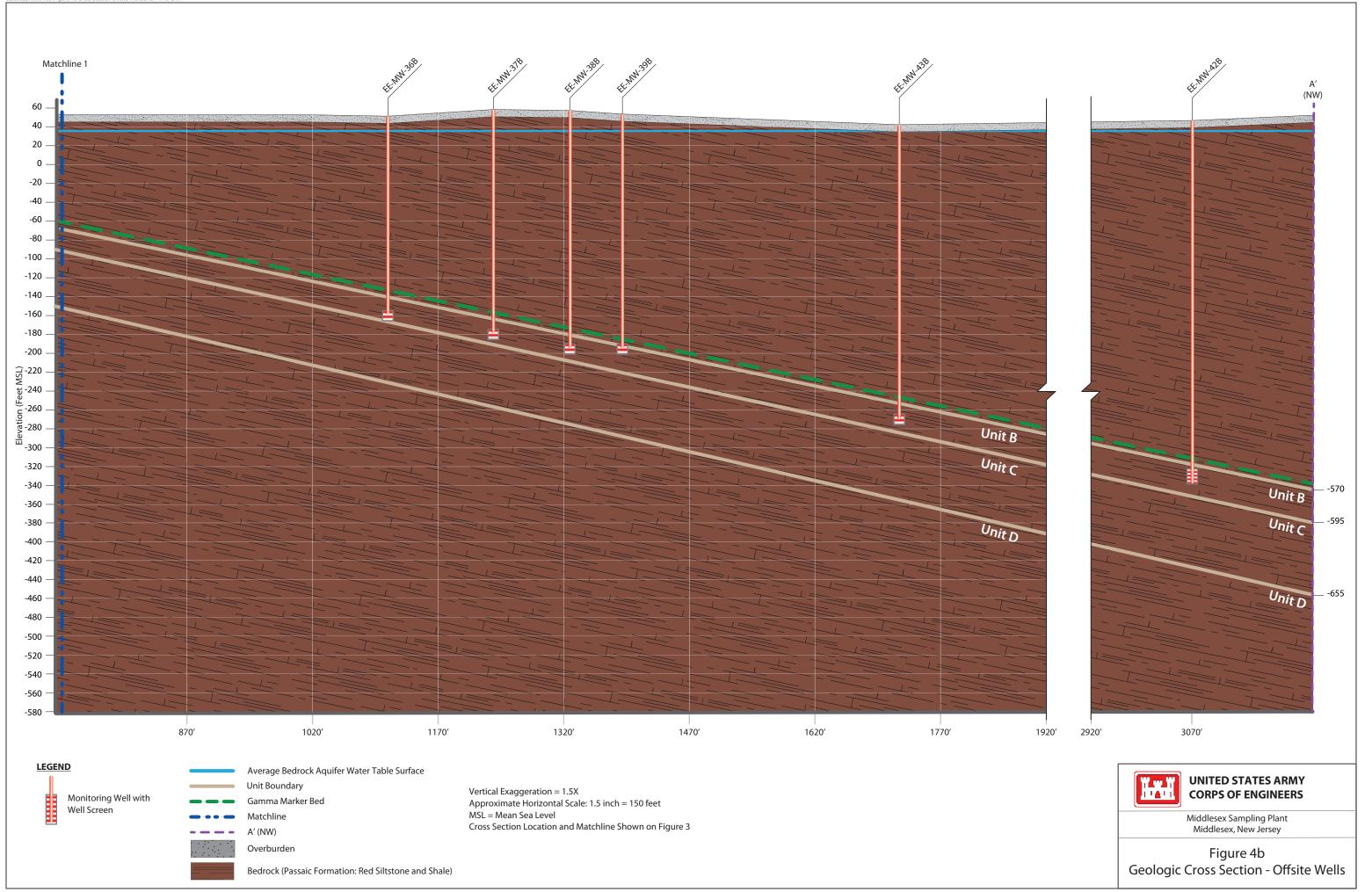


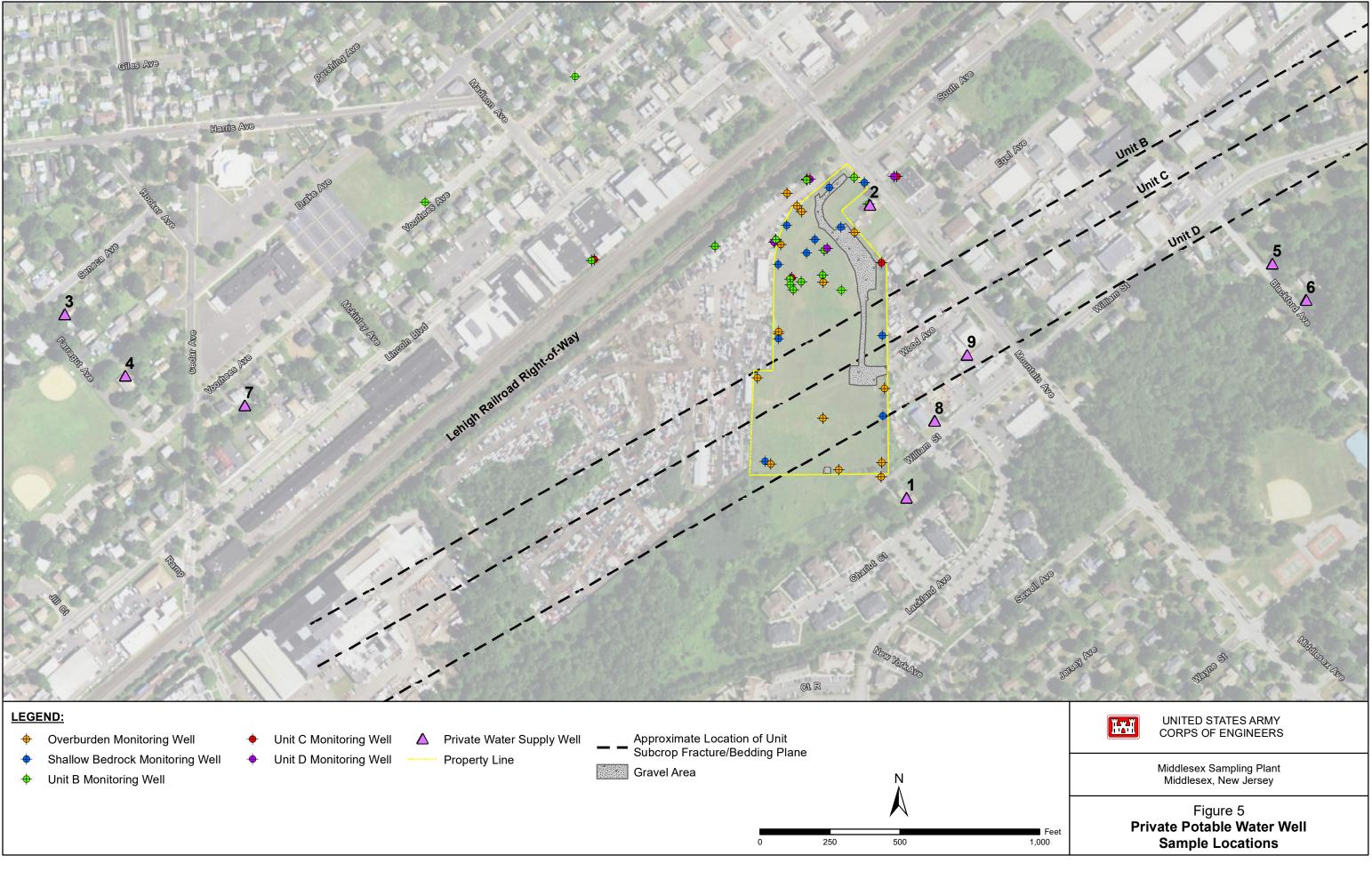


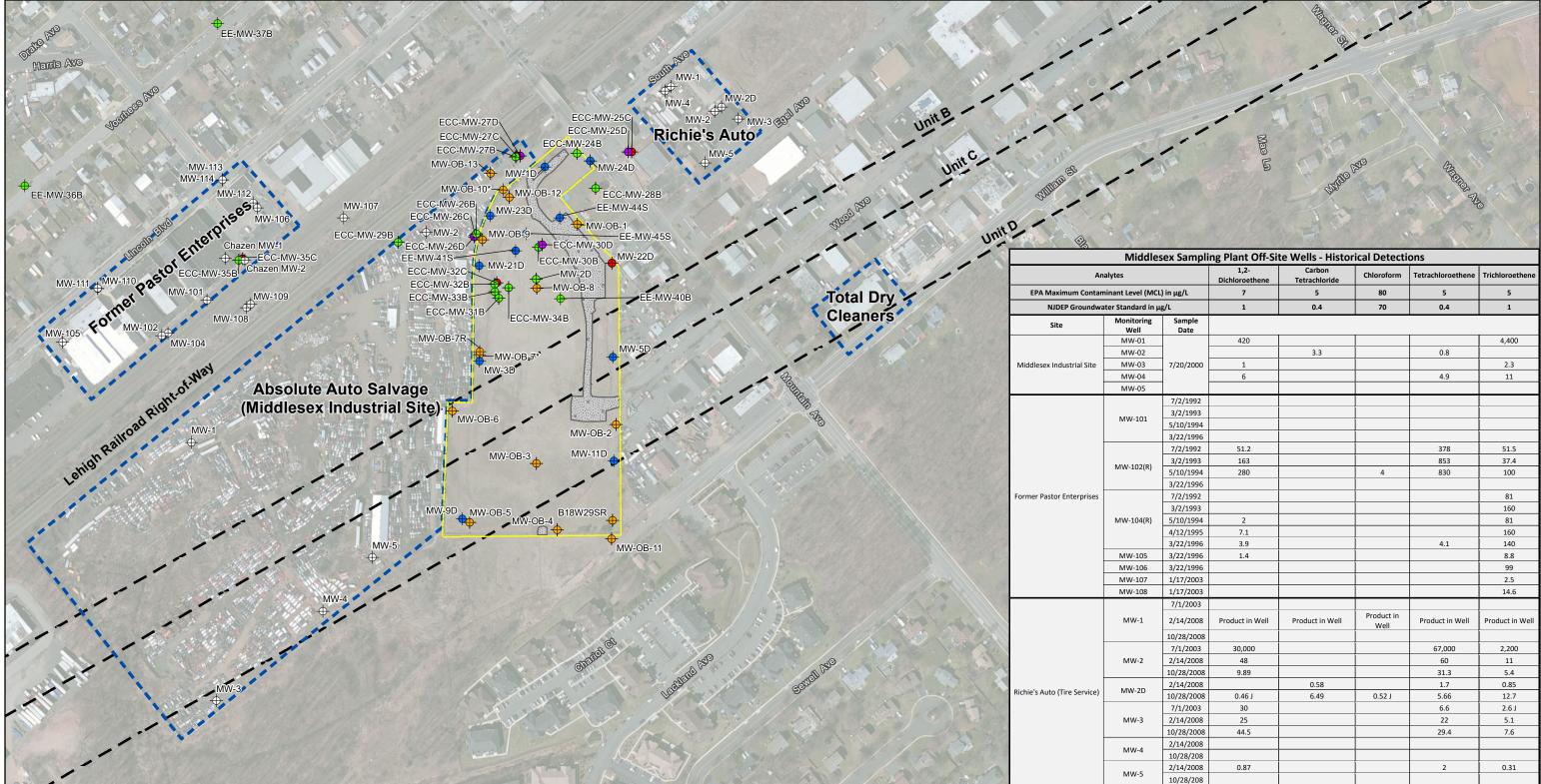
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ell is abandoned	Matchline locations shown on Figures 4a and 4b	0	250	500











LEGEND:

- Overburden Monitoring Well \oplus
- \bullet Shallow Bedrock Monitoring Well
- $\mathbf{\Phi}$ Unit B Monitoring Well
- Unit C Monitoring Well -
- **+** Unit D Monitoring Well
- ♦ Offsite Wells (Approximate Location)
- Property Line
- Approximate Location of Unit
- Subcrop Fracture/Bedding Plane
- Nearby Properties
- Gravel Area
- *Well is abandoned.

Ν 250 500

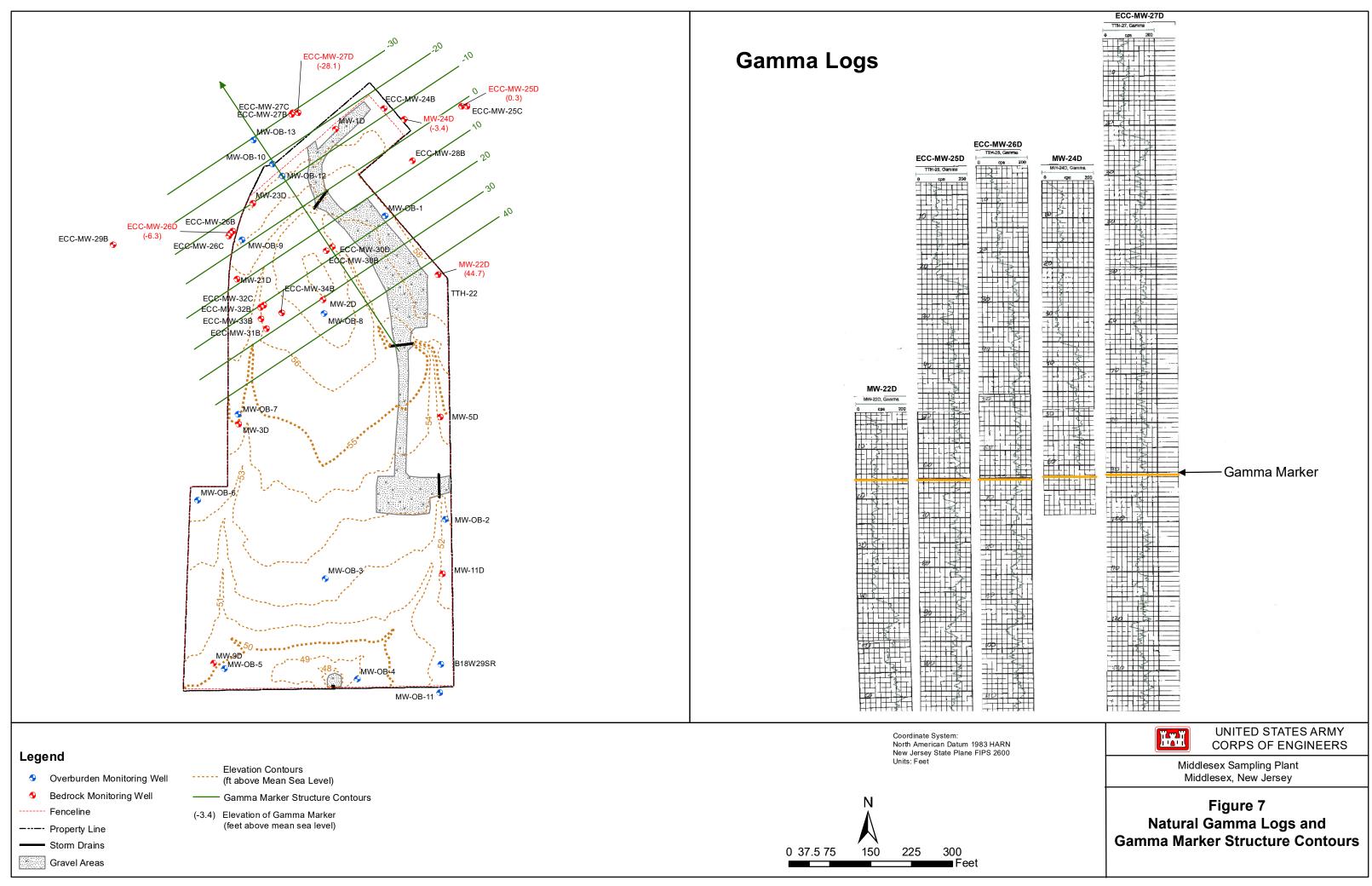
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10/28/2008 0.46 J 6.49 0.52 J 5.66 12.7 7/1/2003 30 6.6 2.6 J 2/14/2008 25 22 5.1 10/28/2008 44.5 29.4 7.6 2/14/2008 10/28/208 10/28/208 10/28/208 10/28/208 2/14/2008 0.87 2 0.31		10/28/2008	9.89			31.3	5.4		
7/1/2003 30 6.6 2.6 J 2/14/2008 25 22 5.1 10/28/2008 44.5 29.4 7.6 2/14/2008 10/28/208 10/28/208 10/28/208 2/14/2008 0.87 2 0.31		2/14/2008		0.58		1.7	0.85		
2/14/2008 25 22 5.1 10/28/2008 44.5 29.4 7.6 2/14/2008 10/28/208 10/28/208 10/28/208 2/14/2008 0.87 2 0.31		10/28/2008	0.46 J	6.49	0.52 J	5.66	12.7		
10/28/2008 44.5 29.4 7.6 2/14/2008		7/1/2003	30		1	6.6	2.6 J		
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10/28/208		10/28/2008	44.5			29.4	7.6		
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10/20/200		10/28/208							



UNITED STATES ARMY CORPS OF ENGINEERS

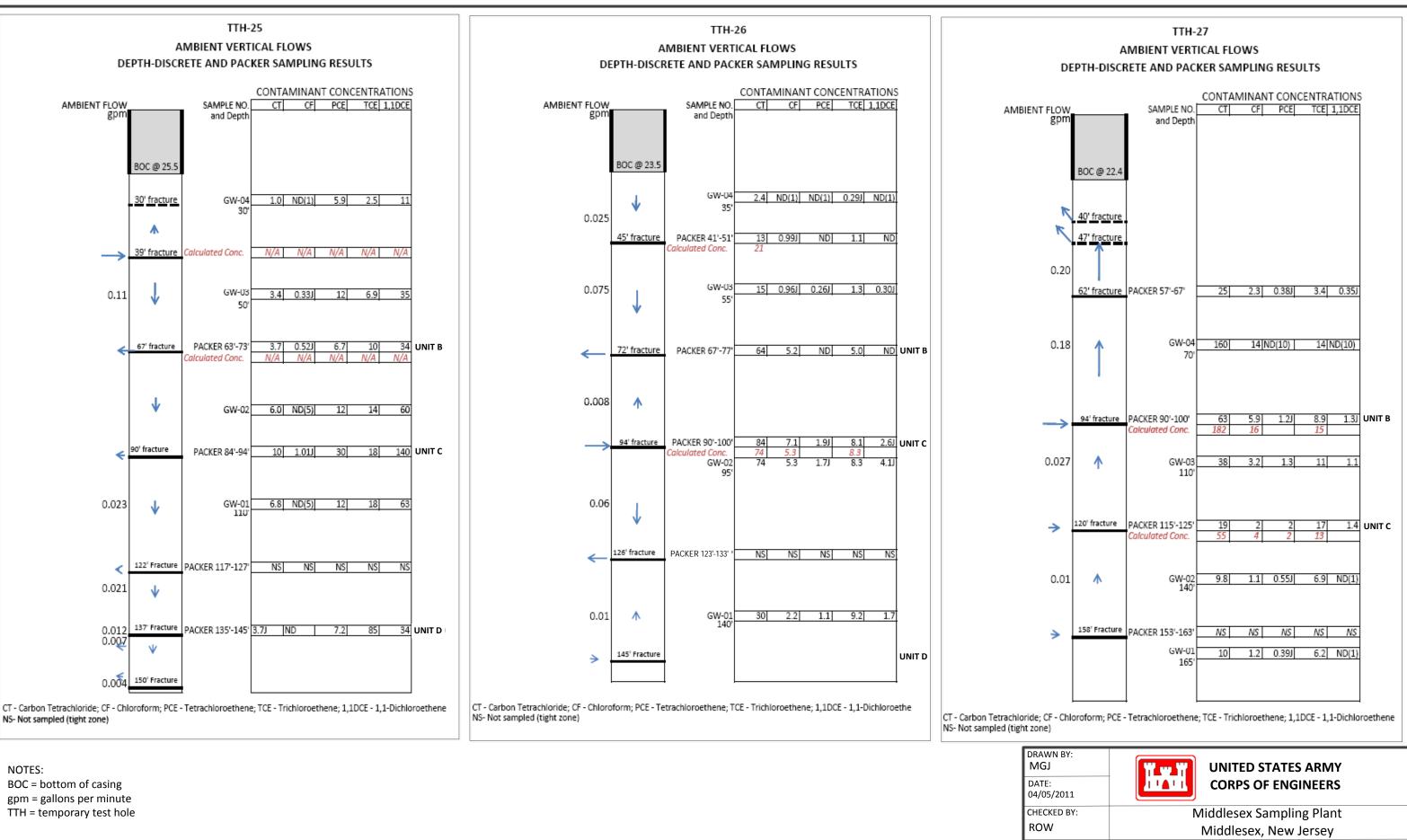
Middlesex Sampling Plant Middlesex, New Jersey

Figure 6 Offsite Monitoring Wells on **Properties Near the Site**







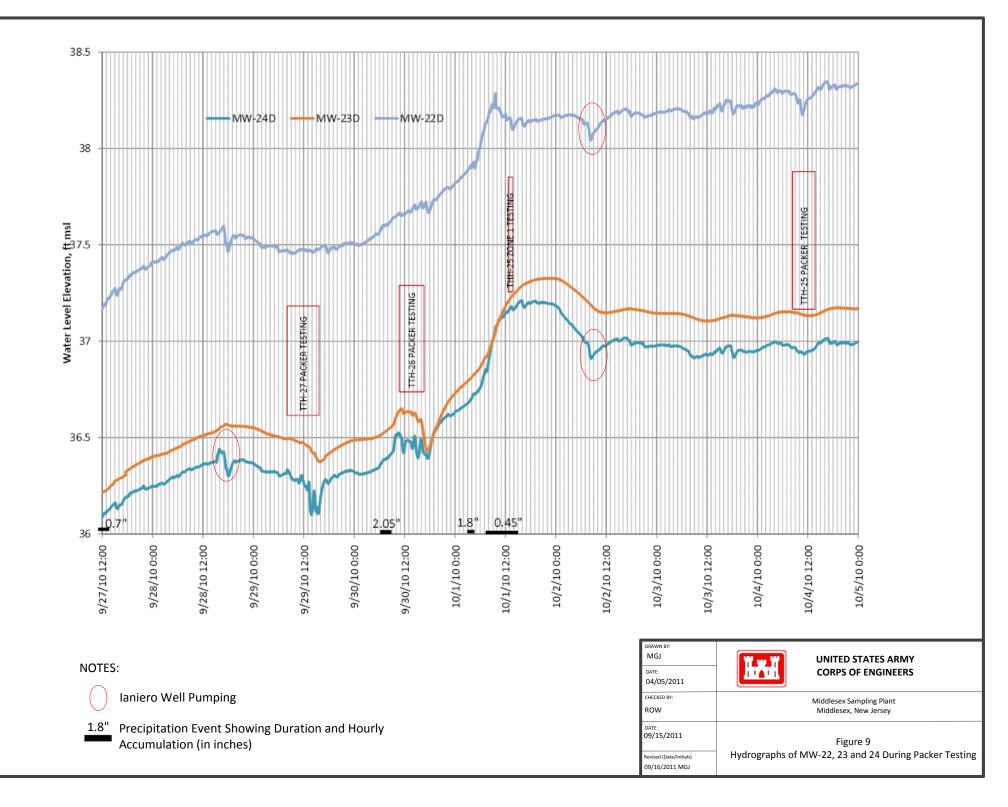


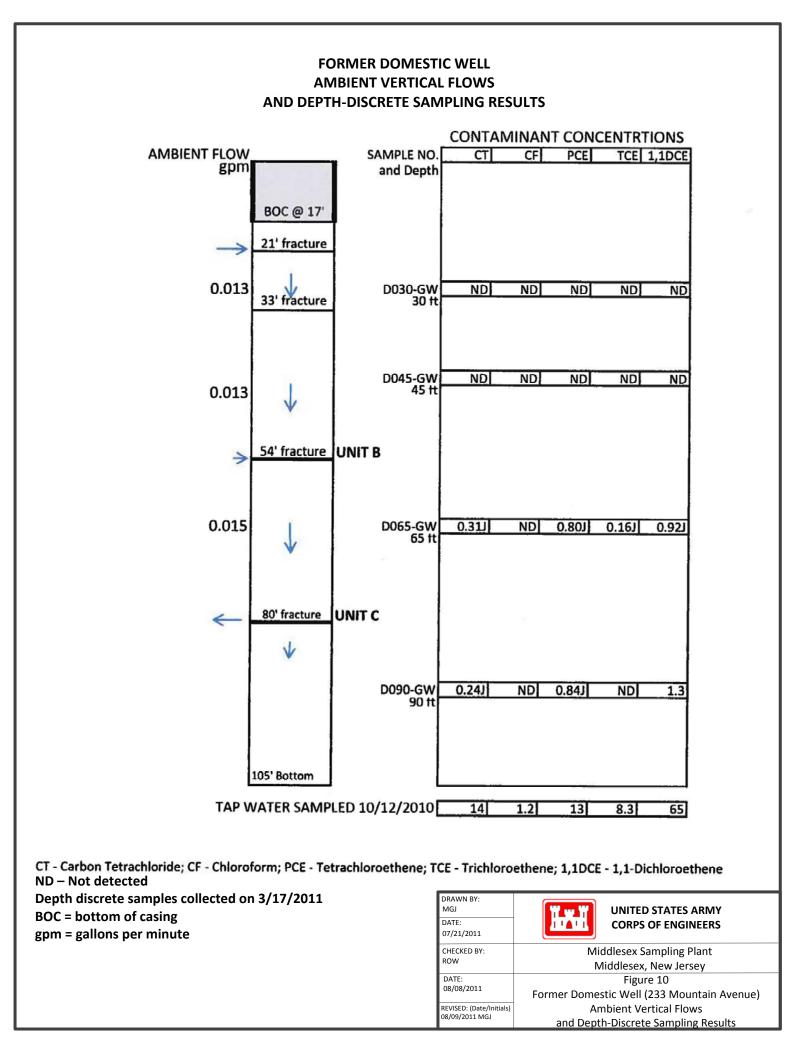
NOTES: BOC = bottom of casing gpm = gallons per minute

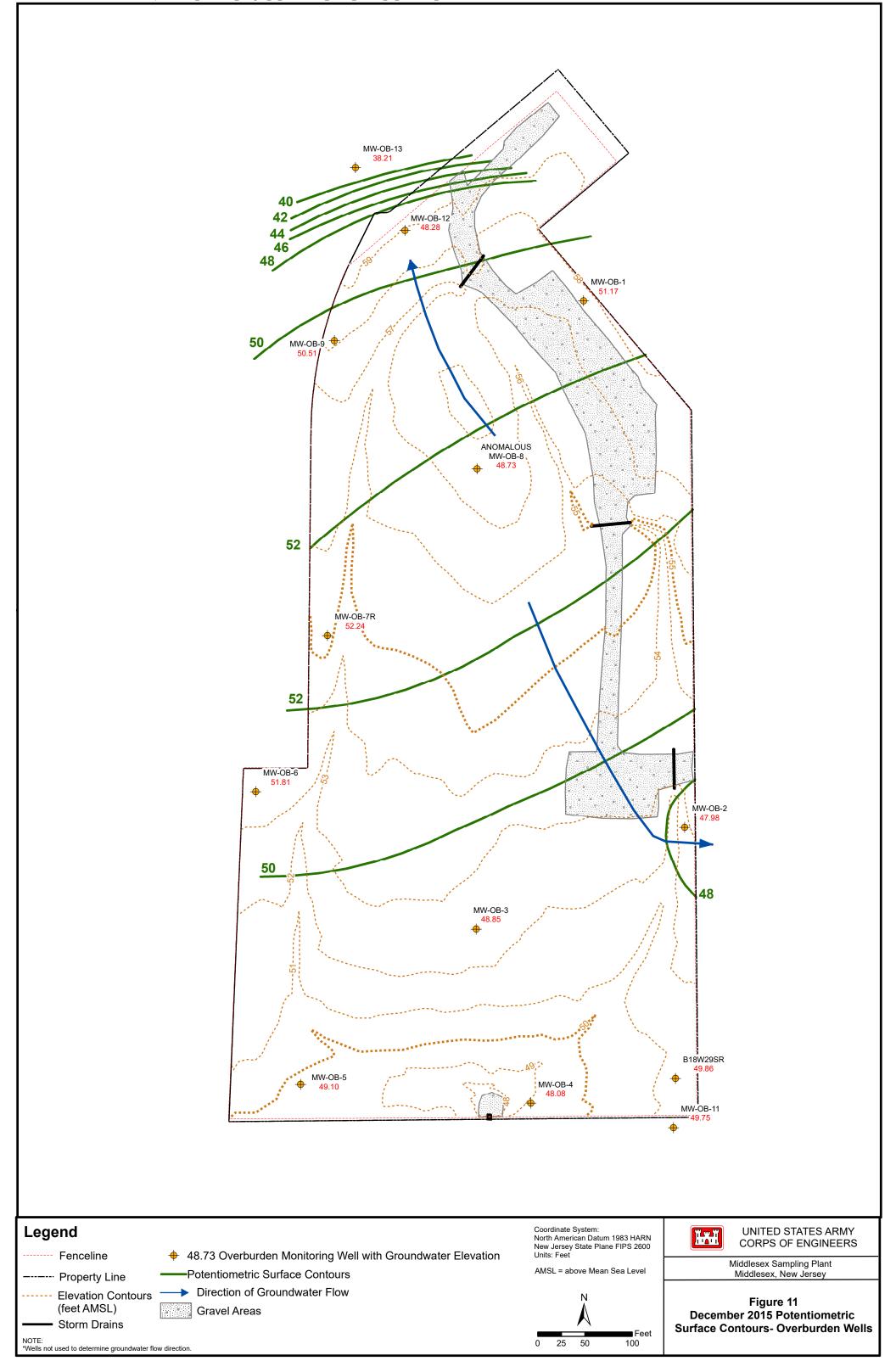
DATE: 04/11/2011 Revised (Date/Initials)

Figure 8 Test Hole Flow Tracing and Analytical Results for TTH-25, TTH-26, and TTH-27

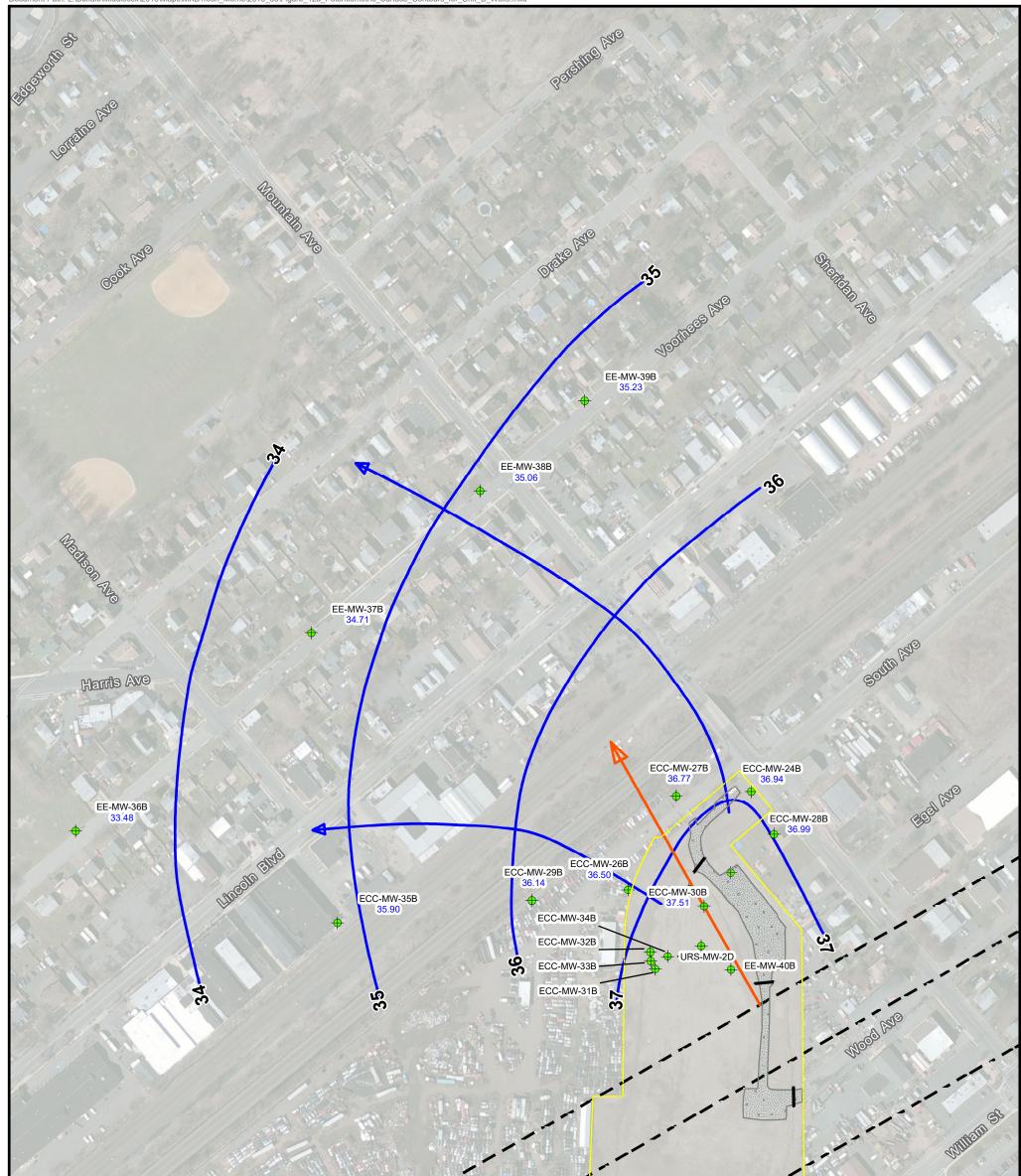
07/22/2011 MGJ





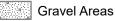


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Legend

- ---- Property Line
- Elevation Contours (feet AMSL)
 - Storm Drains



- NOTE: *Wells not used to determine groundwater flow direction.
- + 34.71 Unit B Monitoring Well with Groundwater Elevation

UNITD

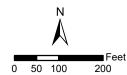
- Potentiometric Surface Contours for Unit B Wells
- - Approximate Location of Unit Subcrop Fracture/Bedding Plane
 - Direction of Groundwater Flow

UNITB

Direction of Bedding Dip

Coordinate System: North American Datum 1983 HARN New Jersey State Plane FIPS 2600 Units: Feet

AMSL = above Mean Sea Level



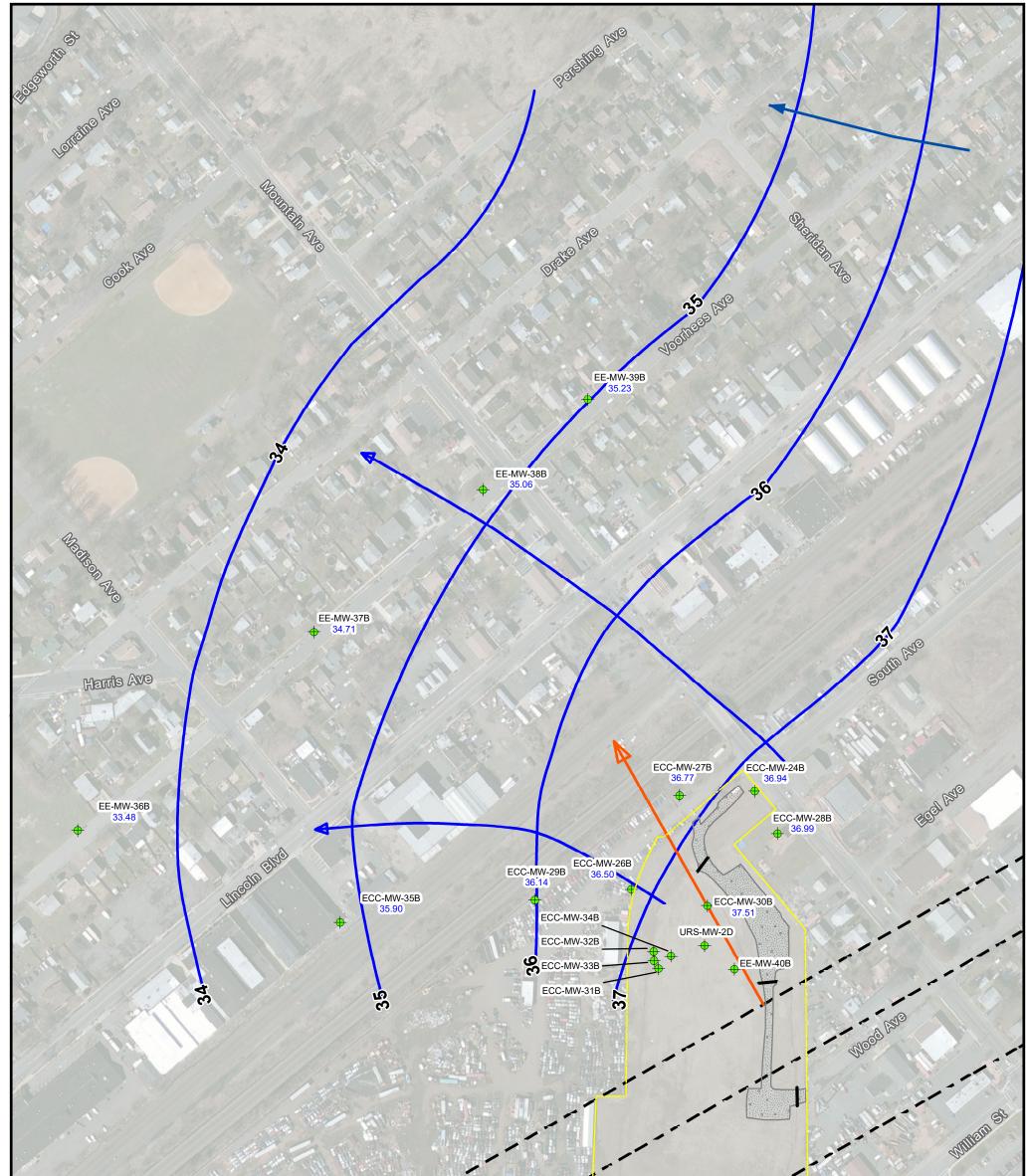


UNITED STATES ARMY CORPS OF ENGINEERS

Middlesex Sampling Plant Middlesex, New Jersey

Figure 12a Potentiometric Surface Contours for Unit B Wells (October 2014)

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Legend

- ---- Property Line
- Elevation Contours (feet AMSL)
 - Storm Drains



NOTE: *Wells not used to determine groundwater flow direction.

• 34.16 Unit B Monitoring Well with Groundwater Elevation

UNITD

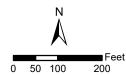
- -Potentiometric Surface Contours for Unit B Wells
- - Approximate Location of Unit Subcrop Fracture/Bedding Plane
- → Direction of Groundwater Flow

UNITB

Direction of Bedding Dip

Coordinate System: North American Datum 1983 HARN New Jersey State Plane FIPS 2600 Units: Feet

AMSL = above Mean Sea Level



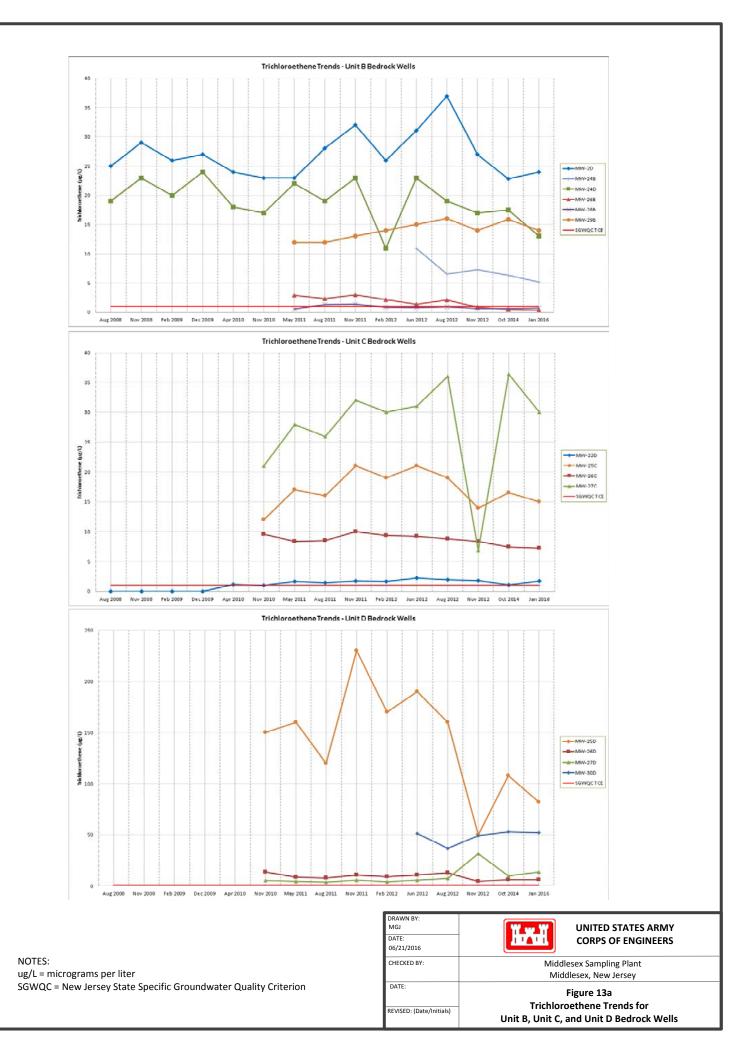


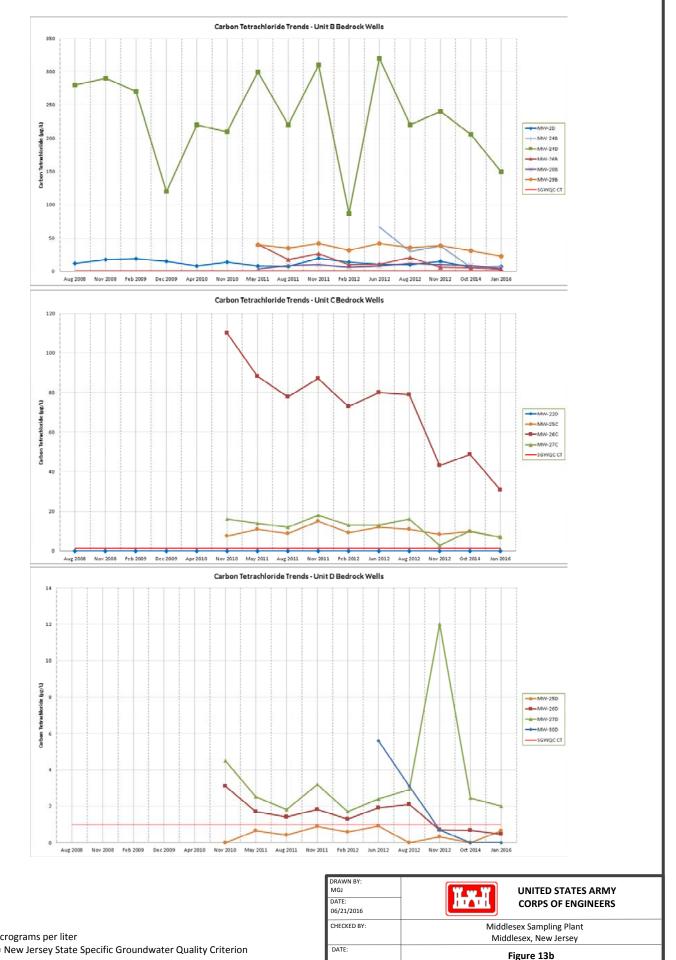
UNITED STATES ARMY CORPS OF ENGINEERS

Middlesex Sampling Plant Middlesex, New Jersey

Figure 12b Potentiometric Surface Contours for Unit B Wells (December 2015)

Chenos



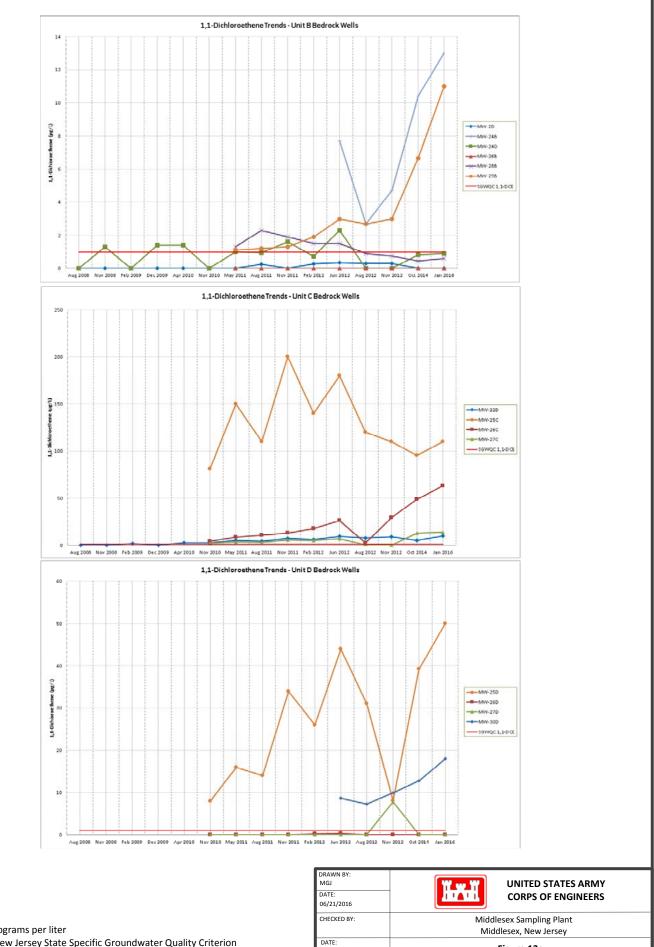


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ug/L = micrograms per liter SGWQC = New Jersey State Specific Groundwater Quality Criterion

NOTES:

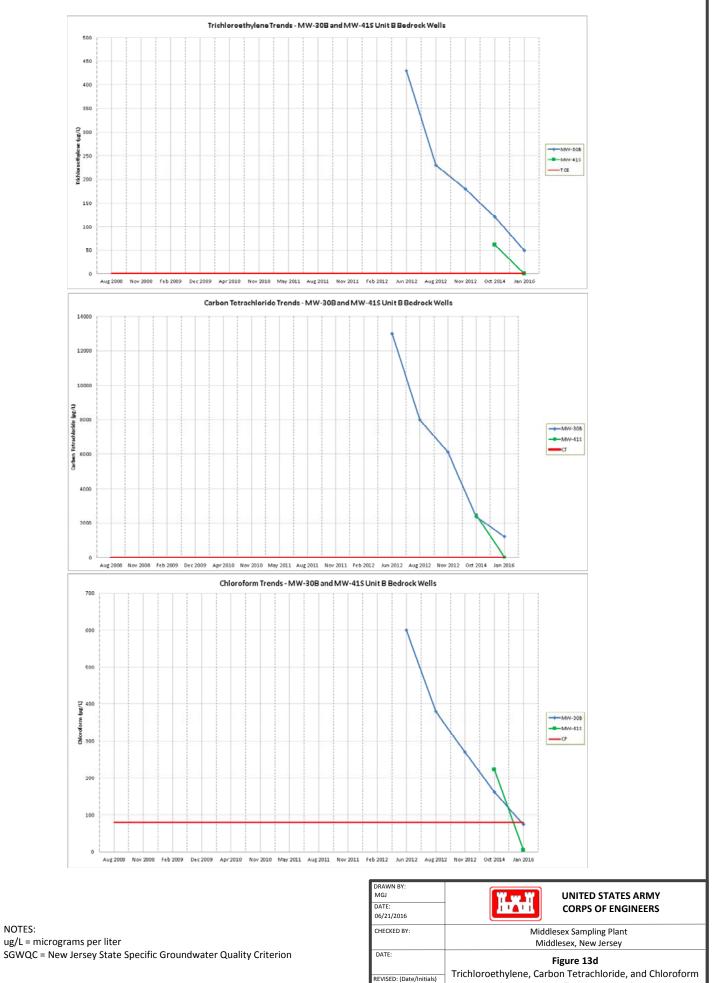
Carbon Trichloroethene Trends for Unit B, Unit C, and Unit D Bedrock Wells



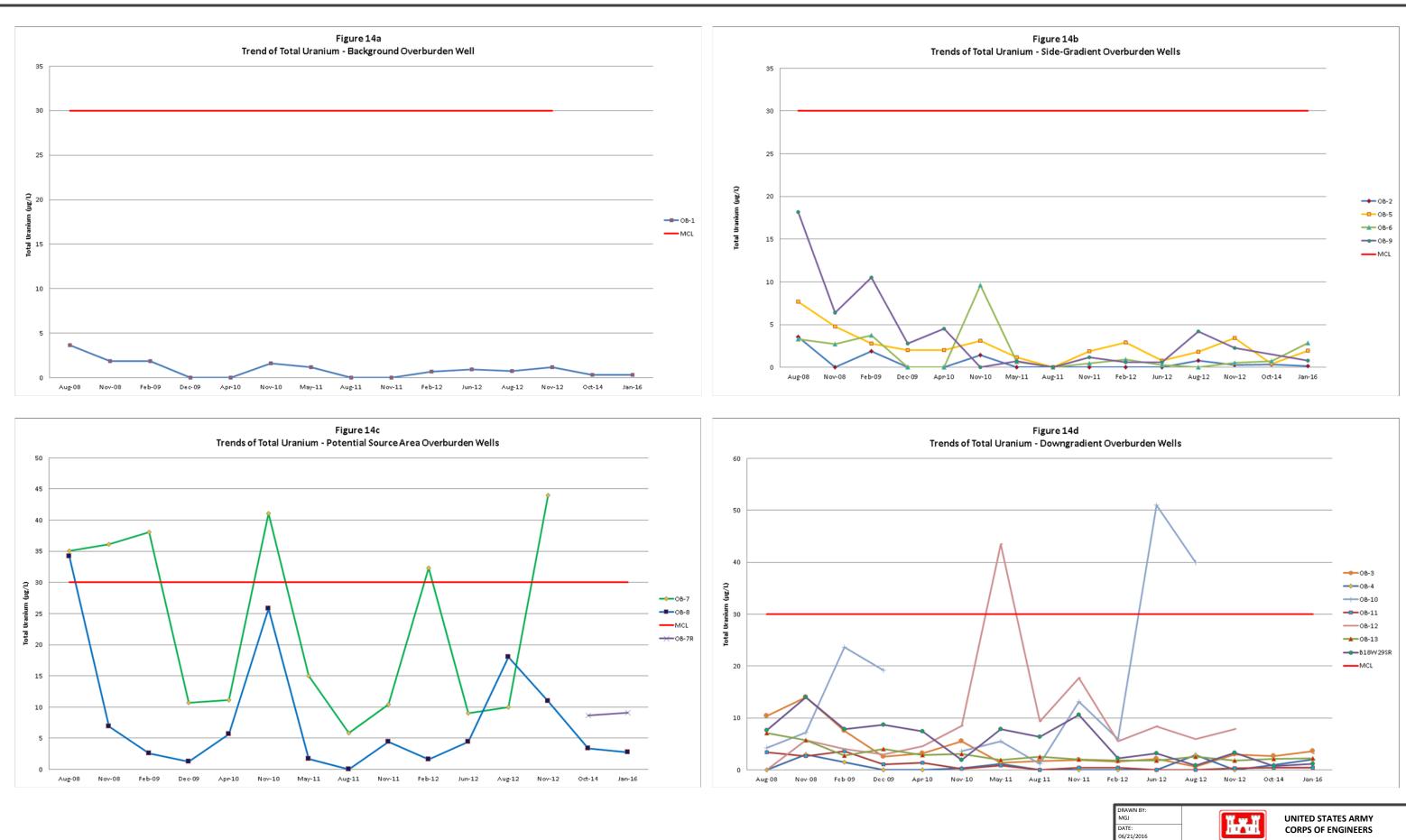
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NOTES: ug/L = micrograms per liter SGWQC = New Jersey State Specific Groundwater Quality Criterion

Figure 13c
1,1-Dichloroethene Trends for
Unit B, Unit C, and Unit D Bedrock Wells



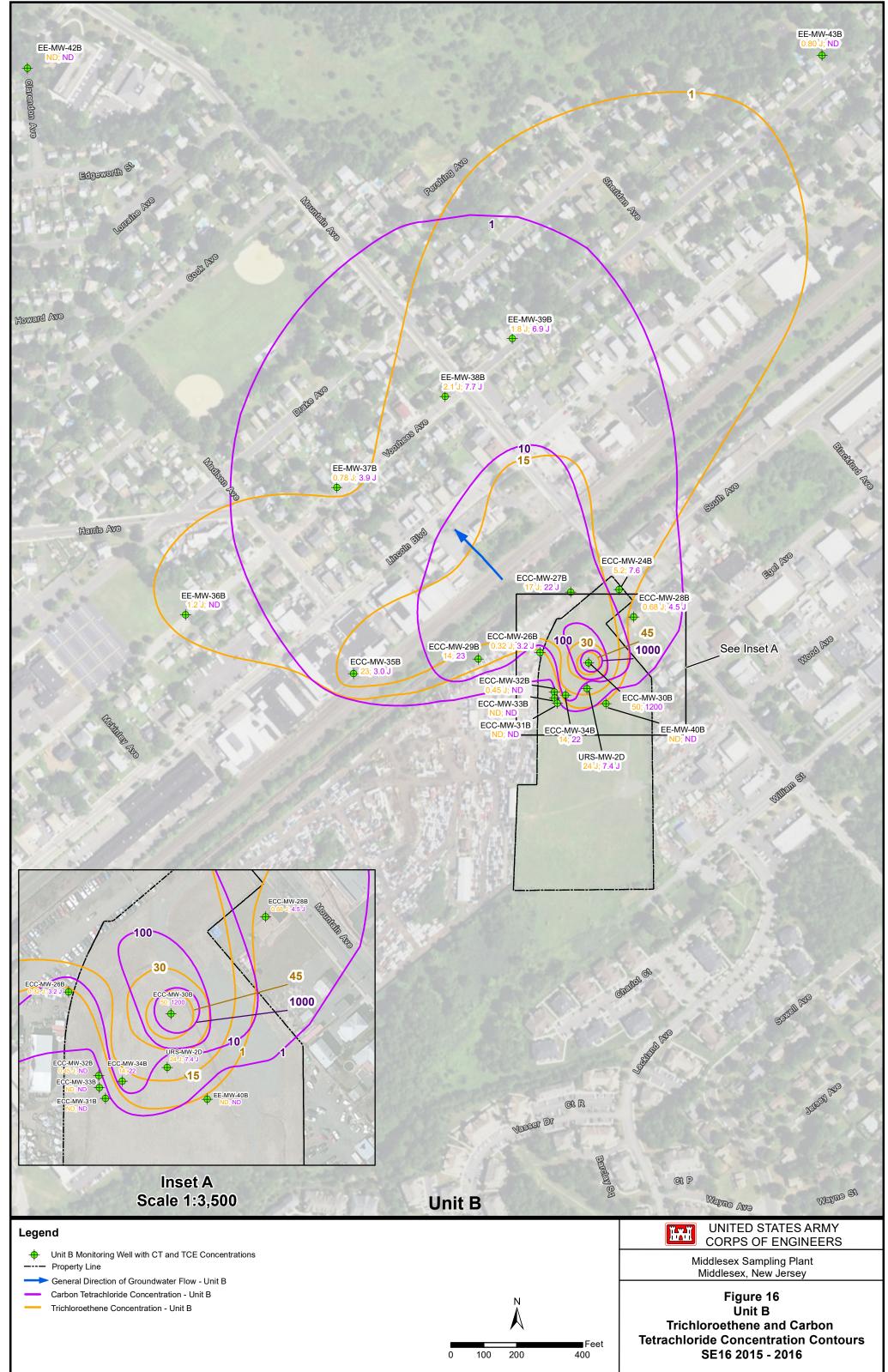
Trends in Unit B Wells MW-30B and MW-41S



06/21/2016	
CHECKED BY:	Middlesex Sampling Plant
ROW	Middlesex, New Jersey
DATE: 03/15/2013	Figure 14
REVISED: (Date/Initials)	Uranium Trends for
03/18/2013 MGJ	Overburden Wells

	•	1W-0B-1	3								1		N	W-OB-1		
			SE 15	SE 16											SE 15	SE 1
			2014	2015	37										2014	2015
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	N	W-OB-12	2									/				
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Jranium	30		0.698	2.82											2014	
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			SE 15 2014	SE 16 2015					SE 15 2014	SE 16 2015					SE 1	
Compound	MCL	NJDEP	2014 Result	2015 Result		Compound	MCL	NJDEP	Result	Result	13.5	Compo	ound		201 DEP Resu	
Uranium	30	NA	0.418	1.94		Uranium	30	NA	0.975	2.04	0/2	Urani		30 N		
EGEND:										cceeded the NJDEP) STATES /	
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APPENDIX A

SUPPLEMENTAL RISK ASSESSMENT

FINAL

SUPPLEMENTAL RISK ASSESSMENT

Middlesex Sampling Plant

Middlesex, New Jersey

August 2017

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ACRONYMS

AEC	United States Atomic Energy Commission
ADAF	age-dependent adjustment factors
AT	averaging time
ATSDR	Agency for Toxic Substances and Disease Registry
AWA	Age-weighted average
CA	contaminant concentration in air
Cal EPA	California Environmental Protection Agency
CENAN	USACE – New York District
CENWK	USACE – Kansas City District
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
COPC	contaminant of potential concern
CSF	cancer slope factor
CSM	Conceptual Site Model
CTE	central tendency exposure
DIL	Daily intake, averaged over a lifetime (mg/kg-day)
DOE	Department of Energy
EC	exposure concentration
ED	exposure duration
EF	exposure frequency
ET	exposure time
EPA	United States Environmental Protection Agency
EPC	exposure point concentration
FUSRAP	Formerly Utilized Sites Remedial Action Program
GI	gastrointestinal
GWITM	Groundwater Investigation Technical Memorandum
HEC	human equivalent concentration
HHRA	human health risk assessment
HI	hazard index
HQ	hazard quotient
IRIS	Integrated Risk Information System
IUR	inhalation unit risk
LADI	Lifetime average daily intake

MCL	maximum contaminant level
MED	Manhattan Engineering District
$\mu g/m^3$	micrograms per cubic meter
MMOA	Mutagenic Mode of Action
mg/kg/day	milligrams per kilogram per day
MRL	minimal risk level
MSP	Middlesex Sampling Plant
MTBE	methyl tert-butyl ether
NCP	National Contingency Plan
NHL	non-Hodgkin lymphoma
NJDEP	New Jersey Department of Environmental Protection
NOAEL	no-observed-adverse-effect level
NRC	National Research Council
OSWER	Office of Solid Waste and Emergency Response
PCE	tetrachloroethene
POET	Point of Entry Treatment
PPRTV	provisional peer reviewed toxicity value
QA/QC	quality assurance/quality control
Q-Q	quantile-quantile
RAGS	Risk Assessment Guidance for Superfund
RBA	relative bioavailability adjustment
RfC	reference concentration
RfD	reference dose
RME	reasonable maximum exposure
RSL	Regional Screening Levels
SF	slope factor
SLERA	screening-level ecological risk assessment
STSC	Superfund Health Risk Technical Support Center
TCE	trichloroethylene
UCL	upper confidence limit
UF	uncertainty factor
USACE	United States Army Corps of Engineers
VOC	volatile organic compound
VISL	vapor intrusion screening level

1 INTRODUCTON

This supplemental risk assessment was prepared for the United States Army Corps of Engineers (USACE) – New York District (CENAN) and Kansas City District (CENWK) for the Middlesex Sampling Plant (MSP) located in Middlesex, New Jersey. Site soil contamination has been remediated pursuant to the *Soils Operable Unit, Record of Decision for the Middlesex Sampling Plant Site* (USACE 2005) and is not addressed in this document. The remedial action for the soils was completed in the spring of 2008 with a final inspection performed by the United States Environmental Protection Agency (EPA) and the New Jersey Department of Environmental Protection (NJDEP) in July 2008. Remedial action is considered complete for Operable Unit 1.

This human health risk assessment (HHRA) estimated the potential risks from exposure to siterelated volatile organic compounds (VOCs) present in groundwater at the MSP site. The risk assessment was performed in the absence of institutional controls and evaluates both current and future cancer risks and non-cancer hazards. The HHRA followed NJDEP guidance documents and EPA guidelines, guidance, and policies, and more specifically the Risk Assessment Guidance for Superfund (RAGS) Part A through F developed for Superfund sites (EPA 1989, 1991a, 1991b, 2001, 2004, 2009). A screening level ecological risk assessment was not performed because recent investigations revealed that site-related VOCs are migrating off-site via bedrock bedding planes that do not discharge into surface water systems. The most contaminated bedding plane is at a depth of more than 75 feet below ground surface at the site boundary. Therefore, there is no pathway to ecological receptors. In addition, no ecological habitats have been identified at the MSP site.

1.1 Site Background and Setting

The MSP site is located in the Borough of Middlesex, New Jersey (see Figure 1 in the Groundwater Investigation Technical Memorandum [GWITM]). The MSP is bordered to the east by residential and commercial properties, to the north and west by a railroad right-of-way and a scrap metal facility, and to the south by a small parcel of vacant land. The property is fenced and public access is restricted. The MSP site is currently zoned commercial/industrial and there are no plans for the property to be converted for future residential use. The property is currently vacant; therefore, hypothetical future cancer risk and non-cancer hazards were determined for workers and residents in the absence of institutional controls to prevent the use of groundwater as drinking water. The local groundwater is classified in New Jersey as Class II-A, a provision of potable groundwater with conventional treatment at current water quality.

During the period 1943 to 1955, MSP was used primarily for sampling, analysis, storage, and shipment of uranium, thorium and beryllium ores by the United States Atomic Energy Commission (AEC) and the Manhattan Engineering District (MED). In 1967, AEC terminated site activities, decontaminated on-site structures to meet criteria applicable at the time and released the approximately 10-acre property to the United States Marine Corps. The site was used as a Marine Corps training center from 1969 to 1979.

In 1980, control was transferred to the United States Department of Energy (DOE), which began to remediate MSP vicinity properties and the Middlesex Municipal Landfill under the Formerly Utilized Sites Remedial Action Program (FUSRAP). The AEC, a predecessor to the DOE, established FUSRAP in 1974 to identify, remediate, or otherwise control sites contaminated with residual radioactivity resulting from activities of the MED and early operations of the AEC. The

goal of FUSRAP is remediation of sites contaminated as a result of the nation's early atomic energy program in accordance with CERCLA, as amended by the Superfund Amendments and Reauthorization Act. Responsibility for execution of response actions on sites included in FUSRAP was transferred from DOE to USACE in October 1997, and long-term programmatic authority was specifically provided to USACE in September 1999.

1.2 Groundwater Investigation

After implementation of the soils removal action (USACE 2005), a network of monitoring wells was installed followed by sampling and analysis of groundwater. Operable Unit 2 initially addressed radionuclides in the groundwater, although the groundwater data indicated elevated levels of VOCs. Sampling for VOCs began in 2008 and is ongoing. The VOC contamination is the focus of this report.

A hydrogeologic study of the shallow bedrock aquifer system beneath the northern portion of the site was conducted during September and October 2010. Three water producing zones, or hydrostratigraphic units, were identified and labeled as Unit B, Unit C, and Unit D.

Bedrock monitoring wells were installed and groundwater investigations were conducted from 2010 to 2016 to monitor Units B, C, and D; collect and analyze samples for VOCs; determine the origin of carbon tetrachloride in the on-site groundwater and delineate the extent and fate of the carbon tetrachloride plume; conduct an off-site investigation to focus on the extent of VOC migration off-site through Unit B; and conduct an on-site investigation to further delineate on-site contamination in the shallow bedrock above Unit B.

In general, VOC concentrations on the MSP site are relatively low and do not indicate that a significant and widespread source of contaminants are present at the site. The VOC detected with the highest concentrations on-site is carbon tetrachloride. Trichloroethylene (TCE) is typically detected in samples that contain carbon tetrachloride but at much lower concentrations. MSP is located in an industrial area where there are multiple contributors of contaminants to the bedrock aquifer. Contribution of carbon tetrachloride and TCE in the MSP off-site monitoring well network from off-site sources unrelated to MSP activities in groundwater is possible. Other VOCs detected in on-site wells were not found at concentrations that indicate an on-site source is present. Instead, it appears that some VOCs are migrating beneath the site in groundwater as best indicated by the presence of methyl tert-butyl ether (MTBE) in on-site monitoring wells, a gasoline additive introduced in 1979, after site operations had already ceased.

The release area for the carbon tetrachloride and TCE appears to be limited to a small sump that was located in the former Process Building. This sump was used for disposal of wastewater and could have been used for disposal of non-water residuals although site records do not indicate the use of solvents as part of site operations.

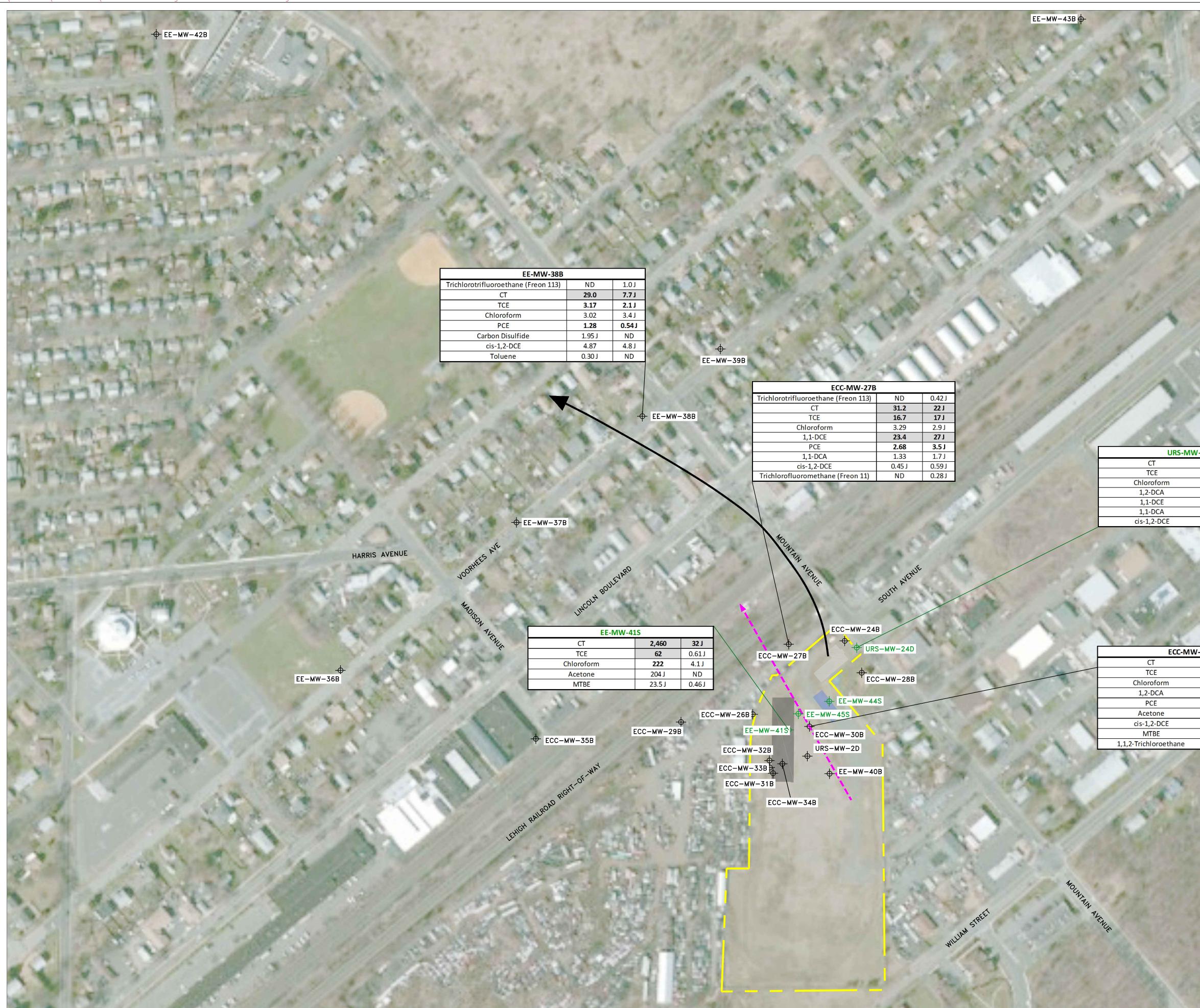
The GWITM presents a detailed discussion of the groundwater investigations and the groundwater flow conditions.

2 SAMPLE DATA

The groundwater data used in the risk assessment included VOC data collected during the October 2014 and November 2015 sampling events. The EPA recommends using data collected from the latest two rounds of sampling for each selected well within the core of the plume (EPA 2014a). Ten samples collected from five wells during 2014 and 2015 were used to assess groundwater contamination under these considerations. The contaminants of potential concern (COPCs) were determined from the dataset and used to calculate the risk for human health. The following monitoring wells were selected for this HHRA: ECC-MW-30B, EE-MW-41S, URS-MW-24D, ECC-MW-27B, and EE-MW-38B. The monitoring well locations are shown in Figure 2-1. These wells extend into the bedrock where VOC contamination is present and are expected to be representative of current conditions.

All groundwater data collected in 2014 and 2015 met the quality assurance/quality control (QA/QC) criteria for risk assessment as noted in the data usability worksheets in Appendix A. The qualified data to be used in the HHRA to evaluate risks were assessed as follows:

- Estimated values flagged with a J were treated as unqualified detected concentrations;
- Data qualified with an R (rejected) were not used in the risk assessment (1,4-dioxane was rejected during the November 2015 sampling event. The sample results were non-detect); and
- Field duplicate samples were not collected on the wells selected for risk assessment purposes.



LEGEND:		
 ЕСС-МW-27В- ф-	UNIT B MONITORING WELL LOCATION	
URS−MW−24D -	SHALLOW BEDROCK MONITORING WELL LOCATION PROPERTY LINE	
	PROPERTI LINE	
	DIRECTION OF BEDDING DIP	
	 GROUNDWATER FLOW DIRECTION 	
	FORMER PROCESS BUILDING	
	FORMER GARAGE	
	FORMER ADMINISTRATION BUILDING	
J	ESTIMATED VALUE	
MCL	FEDERAL DRINKING WATER CONTAMINANT MAXIMUM CONTAMINANT LEVELS	
PCE	TETRACHLOROETHYLENE	
TCE	TRICHLOROETHENE	
MTBE	METHYL TERT-BUTYL ETHER	
1,1-DCA	1,1-DICHLOROETHANE	
1,2-DCA	1,2-DICHLOROETHANE	
1,1-DCE	1,1-DICHLOROETHYLENE	
CIS-1,2-DCE	CIS-1,2-DICHLOROETHYLENE	
CT	CARBON TETRACHLORIDE	
NJDEP	NEW JERSEY DEPARTMENT OF ENVIRONMENTAL PROTECTION	
ND	NOT DETECTED	
ECC-MW-27B 2014 2015]	

ECC-MW-27B	2014	2015
Acetone	333	ND
TCE	ND	0.45 J

TEXT BOX RESULT EXPLANATION

NOTES:

- 1. AERIAL PHOTO SOURCE: ESRI 2014.
- 2. ALL DETECTED RESULTS ARE SHOWN FOR HHRA CORE OF THE PLUME WELLS.
- 3. ALL RESULTS SHOWN ARE IN ير/L.
- 4. BOLD VALUES EXCEEDED THE NJDEP CRITERIA.
- 5. SHADED VALUES EXCEEDED BOTH THE NJDEP CRITERIA AND USEPA MCLs.



APPROXIMATE SCALE IN FEET 150 300 450

3 HUMAN HEALTH RISK ASSESSMENT

The goal of the Superfund human health evaluation process is to provide a framework for developing the risk information needed to assist in the determination of possible remedial actions at the MSP site (EPA 1987, 1991b). The EPA uses risk assessment as a tool to characterize contaminants, evaluate the toxicity of the chemicals, assess the potential ways in which an individual may be exposed to the contaminants, and characterize the cancer risks and non-cancer health hazards and associated uncertainty (EPA 1989, 1992a, 1995, 2000). In accordance with EPA guidance, actions at Superfund sites are based on an estimate of the reasonable maximum exposure (RME) expected to occur under current and/or future conditions at the Site. The RME is defined as the highest exposure that is reasonably expected to occur at a site. EPA guidance also recommends estimating risks based on central tendency exposures (CTE) or average exposures at a site when RME risks are above acceptable levels (EPA 1992a, 1995, 2000). The RME and CTE are used to estimate cancer risks and non-cancer health hazards based on differences in exposure factors, although the RME is the basis for the Site remedial decision as outlined in the National Contingency Plan (NCP).

A systematic framework for human health risk assessment was first outlined in 1983 by the National Research Council (NRC) of the National Academy of Sciences (NRC 1983). Building upon that foundation, the risk assessment process described in EPA's *Risk Assessment Guidance for Superfund* [*RAGS*] *Volume I Human Health Evaluation Manual (Part A)* (EPA 1989) and subsequent Agency guidance, including RAGS Parts B through F, consists of the following components:

- **Data Collection and Evaluation** Involves gathering and evaluating data to define the nature and extent of contamination and location-specific COPCs.
- **Exposure Assessment** Entails an estimate of the magnitude of actual and/or potential human exposures, the frequency and duration of these exposures, and the pathways to which people could be potentially exposed. Actual and/or potential chemical release and transport mechanisms are identified, potentially exposed human populations and possible exposure pathways are described, concentrations of COPCs at potential points of human exposures are determined, and human exposures to the COPC are estimated.
- **Toxicity Assessment** Examines the type of adverse health effects associated with chemical exposure and the relationship of the magnitude of exposure to the health response. Qualitative and quantitative toxicity information for COPCs is summarized and toxicity values to characterize risks are identified.
- **Risk Characterization** Summarizes the results from the first three steps of the assessment (both quantitative and qualitative). The likelihood and magnitude of adverse health effects in the form of incremental lifetime cancer risks and non-cancer hazard quotients (HQs) are estimated. Sources of uncertainty in the HHRA are discussed.

3.1 Data Evaluation

Data collection and evaluation involves gathering and analyzing the MSP site data relevant to the risk assessment and identifying the chemicals found in environmental media at the site that are the focus of the risk assessment process. The data that were evaluated for the HHRA for the MSP site are described in this section.

Throughout the MSP site, there are 33 bedrock monitoring wells and 13 overburden monitoring wells. The groundwater within and surrounding the MSP site has been sampled extensively since the early 1980s; however, since 2014, nine additional bedrock wells have been installed and one overburden monitoring well has been replaced to refine the source area, and extent, fate, and transport of VOC contamination in the bedrock aquifers. Further details regarding the installation of new monitoring wells are provided in Section 3.0 of the GWITM. Two full rounds of monitoring well sampling has been performed for VOCs since 2014. The data from five bedrock wells in the core of the plume are used in this Supplemental HHRA (see Section 2.0).

3.1.1 Selection of Chemicals of Potential Concern

COPCs were identified using the screening process described in RAGS Parts A and D (EPA 1989, 1992b, 2001). Appendix B contains the tables consistent with RAGS Part D. Appendix B, Table 2.1, presents the selected COPCs. The general screening process is summarized in the following paragraphs.

The COPC selection process was conducted to identify the VOCs detected in groundwater within the bedrock that could pose a potential risk to human receptors. The EPA Regional Screening Levels (RSLs; EPA 2016a) for tap water were used as the health-based screening criteria to select COPCs. For screening purposes, a target HQ for non-cancer based RSLs of 0.1 was used (the published non-cancer values are set at a target HQ of 1.0). This was done to account for the potential additive effects of multiple contaminants impacting similar target organs. A target risk for cancer-based RSLs of one-in-a-million (expressed as 1 x 10^{-6}) was used. The lowest screening level, cancer or non-cancer, for each contaminant was used for COPC screening. The contaminants whose maximum detected concentrations exceeded their respective RSLs were retained as COPCs and evaluated in the risk assessment. If the maximum detected concentration for a contaminant was less than its RSL, that contaminant was eliminated from consideration as a COPC and was not evaluated further in the risk assessment.

The COPCs for the risk assessment were selected based on the analytical data from the five bedrock monitoring wells within the core of plume consistent with EPA guidance (EPA 2014a). Therefore, the COPCs for the MSP site include: 1,1,2-trichloroethane; 1,2-dichloroethane; carbon tetrachloride; chloroform; cis-1,2-dichloroethylene; tert-butyl methyl ether; and TCE.

3.2 Exposure Assessment

The exposure assessment estimates the nature, extent, and magnitude of potential exposure of human receptors to COPCs in groundwater considering its current and future use. The exposure assessment involves several steps:

- Evaluating the exposure setting, which includes describing the local land and water uses, and identifying the potentially exposed human populations;
- Developing the Conceptual Site Model (CSM) for human exposures, which includes identifying the source of contamination, contamination transport and release mechanisms, exposure media, exposure routes, and potentially exposed populations;
- Calculating exposure point concentrations (EPCs) for each COPC;
- Identifying the exposure models and parameters to calculate the exposure doses; and

• Calculating exposure doses.

3.2.1 Exposure Setting

Land use near the MSP site is a mix of residential, commercial, and industrial. The MSP property area is currently undeveloped. All historic structures have been removed. The MSP site is bordered to the east by residential and commercial properties, to the north and west by a railroad right-of-way and a scrap metal facility, and to the south by a small parcel of vacant land. The MSP property is fenced and public access is restricted.

Local groundwater use is of particular concern for this HHRA and is classified in New Jersey as Class II-A, a provision of potable groundwater with conventional treatment at current water quality. Previous MSP site reports were reviewed for information on the extent of VOC contamination in the bedrock within the vicinity of the MSP site. A former domestic well was located on a residential property adjacent to the MSP site, which has since been converted to MSP site monitoring well ECC-MW-28B, which is not located within the core of the plume. A groundwater sample from the domestic well was collected in 2010 and analyzed for VOCs that indicated carbon tetrachloride, PCE, TCE, and 1,1-dichloroethene were detected at concentrations above NJDEP criteria and EPA's MCLs. The USACE subsequently made the appropriate notifications to the EPA and NJDEP and installed a Point of Entry Treatment (POET) carbon filter treatment system. In February 2011, the residence was connected to a public water supply and the POET system was removed. The discovery of the domestic well adjacent to the MSP site.

The USACE used several resources to identify and locate supply wells that may still provide potable water to residents or local businesses. An on-line NJDEP well search resource was used to identify registered wells within a half-mile of the MSP site, which resulted in the identification of 12 properties with records of existing potable water wells. To investigate additional properties within the search area that may exist, but were not registered with the state, the USACE consulted with the Middlesex Department of Health to request a list of properties with either a well or a record of on-site contamination from the NJDEP. The list obtained from the NJDEP contained a small number of properties.

Middlesex tax maps were searched to identify all addresses within a half-mile radius of the MSP site that could potentially be impacted by contamination from or near the MSP site. Over 300 properties were identified. The address list was cross-checked with the New Jersey-American Water company in order to eliminate properties served by the public water supply. There were 42 properties that could not be verified as supplied by a public water source and these properties were investigated. A field reconnaissance effort conducted to investigate these 42 properties included drive-by inspections and door-to-door interviews to inquire whether each property had a potable well. The document search and field reconnaissance resulted in a list of eight properties (including the residential property adjacent to the MSP site discussed above) that were potential candidates for groundwater sampling. Samples were collected from the seven properties and analyzed for VOCs. All sample results exhibited VOC detections below the NJDEP drinking water criteria, and, therefore, are not discussed further in this report.

Groundwater within the area of the MSP site is not currently used and is not expected to be used in the future. However, the MSP site is zoned industrial/commercial and use of the groundwater by on-

site hypothetical future workers was evaluated in this HHRA. Additionally, use of groundwater by residents located near the MSP site was evaluated for risk.

3.2.2 Exposure Pathways and Receptors

Potential exposure pathways and receptors are summarized in Figure 3-1 and described in detail in Appendix B, Table 1. This table describes the land use, potential receptors, exposure routes, assessment type and the rationale. Potential receptors include:

<u>Workers</u> – Hypothetical future workers are adults greater than 18 years assumed to work indoors at the Site should it be developed for commercial or industrial use. Potential exposure pathways are through the ingestion of groundwater while at work; and

 $\underline{\text{Resident}}$ – Hypothetical future residents are adults, greater than 18 years, and children, birth to 6 years, assumed to live near the site. Potential exposure pathways are through the ingestion of groundwater, dermal contact during bathing/showering, and inhalation of vapors while showering.

These receptors are hypothetical as there is no exposure to the groundwater at the current time and no exposure is expected to occur in the future based on the assumption that an institutional control will be implemented. Risk was evaluated for the hypothetical future exposure scenarios in the absence of institutional controls.

Exposure factors used in the HHRA are presented in the RAGS Part D Series 4 Tables in Appendix B, Tables 4.1 and 4.2. Separate tables listing the exposure factors are provided for RME and CTE scenarios. Most exposure factor values were obtained from EPA's recently updated guidance on Standard Default Exposure Factors and the EPA *Exposure Factors Handbook* (EPA 2014b, 2011a). Some exposure factors (e.g., exposure frequencies for workers) are based on professional judgment.

3.2.3 Vapor Intrusion Pathway

VOCs present in unsaturated soil or in the dissolved phase in groundwater can act as a source for contaminant vapors that have the potential to migrate into indoor air. Vapors migrating upward can accumulate beneath relatively impermeable structures, such as buildings, and potentially migrate into buildings posing a health risk. For a health risk to be present, a source, a receptor, and a pathway must be present. Although a groundwater source and existing and potential future receptors are present, there is no pathway for vapor intrusion into indoor air, rendering potential human health risk non-existent. Figure 3-2 demonstrates a generalized vapor intrusion pathway CSM of site conditions. Although site records do not indicate the use of VOCs at the MSP site, bedrock wells contain VOCs, with carbon tetrachloride, TCE, and chloroform detected at the highest concentrations. The potential release point of these substances is believed to be a sump in the former Process Building that was used to dispose of wastewater. The sump was 12 feet long, by 6 feet wide, and 10 feet deep. The bottom of this sump was below the saturated overburden water table surface. Further discussion of the source, receptors, and pathway are provided below.

Sources for vapor intrusion may include:

- Soils: VOCs were not detected in soils removed from the MSP site during the OU1 remedial investigation in sufficient concentrations or frequency to consider them site contaminants (USACE 2004). In addition, unsaturated site soils were removed during the OU1 remedial excavation in 2008 and backfilled using clean fill (USACE 2010). Therefore, there is no source of VOCs in unsaturated soils on the MSP property that could produce vapors and this potential pathway does not exist and will not exist in the future on this site.
- Groundwater: VOCs were not detected in the overburden unit at concentrations greater than the EPA Vapor Intrusion Screening Levels or NJDEP Generic Vapor Intrusion Screening Levels for groundwater (EPA 2016b; NJDEP 2013). VOCs were detected in the bedrock aquifer at concentrations above both federal and state groundwater screening levels for vapor intrusion as shown in Table 3-1 below.

Potential vapor intrusion receptors may include:

- MSP Site: There are currently no buildings on the MSP property, and thus no current risks. Buildings could be placed on the site in the future as the site is zoned for commercial and industrial use; therefore, future potential receptors could exist.
- Off-site: Residential, commercial, and industrial buildings are located within 200 feet of the MSP site boundaries. Therefore, current potential receptors exist.

Pathway Analysis

VOCs are not present in site soils; therefore, this pathway does not exist at the MSP site.

Groundwater pathways include:

- The hydrogeologic model of the site includes two distinct groundwater flow regimes consisting of a perched saturated overburden unit sitting on top of a deeper multiunit bedrock aquifer system. The saturated overburden unit provides recharge to the bedrock aquifer system. The primary groundwater flow within the bedrock is downward along bedding planes that dip 11 degrees to the northwest. Water within the bedrock that is contaminated with VOCs follows this path, and as this water moves further from the source area it is carried deeper into the subsurface with the most contaminated bedding plane (Unit B) at a depth of more than 75 feet below ground surface at the site boundary. Three primary bedding planes were identified during the supplemental groundwater investigation (USACE 2016). These planes were called Units B, C, and D (see Figure 4a in the GWITM).
- VOCs present as site COCs have not been detected in monitoring wells of the saturated overburden unit. The VOCs detected in this unit, MTBE and PCE, are not COPCs (Section 3.1.1) and were detected at levels approximately 100 times (MTBE) and 20 times (PCE) below the NJDEP screening levels as shown in Table 3-1 (NJDEP 2013). The groundwater concentrations for MTBE and PCE were also compared with the EPA vapor intrusion screening levels (VISL) and did not exceed the screening level as shown in the Table 3-1. The saturated overburden unit meets the criteria for a clean water lens as described in the NJDEP Vapor Intrusion Guidance (NJDEP 2013), with an average depth of 3 to 5 feet. This clean water lens provides a barrier through which VOCs cannot migrate to unsaturated soils above or into an occupied building.

Table 3-1 Comparison of Overburden Well VOC Detection to EPA and NJDEP VISL			
Analyte	Maximum VOC Concentration in Overburden Wells	EPA VISL	NJDEP VISL
Methyl tert-butyl ether	4.6	450	580
Tetrachloroethylene	1.7	15	31
Units in µg/L.			

• The aquifer units containing COPCs at concentrations greater than groundwater screening levels occur within the bedrock bedding planes. Competent bedrock of low permeability overlaying the VOC-contaminated bedding planes further inhibits potential upward migration of vapors.

Since both a clean water lens is present and low permeability bedrock inhibits migration of vapors, there is no migration pathway from the areas of VOC contamination to potential current or hypothetical future receptors, either on the MSP site or off-site.

3.2.4 Derivation of Exposure Point Concentrations

EPCs were calculated using ProUCL version 5.1, a statistical software package for analysis of environmental datasets developed by the EPA. All of the possible statistical distributions available in the ProUCL's UCL calculations, normal, gamma, lognormal, and nonparametric, were considered in deriving the 95% UCL values. ProUCL recommends which of the available statistical procedures for calculating the 95% UCL is or are most appropriate based on the characteristics of the dataset under consideration. One of the statistics recommended by ProUCL was selected as the 95% UCL for the dataset. Consistent with EPA guidance, the lower of the 95% UCL and the maximum detected value was selected as the EPC. In the instance where there are too few detected values to support reliable statistical analysis, the maximum detected value was used as the EPC. EPCs are provided in the RAGS Part D Series 3 tables in Appendix B, Table 3.1.

3.3 Toxicity Assessment

The toxicity assessment provides an estimate of the relationship between the extent of exposure to a contaminant and the likelihood and/or severity of adverse effects. The toxicity assessment has two parts: hazard identification and dose-response assessment. Hazard identification is a qualitative description of the potential toxic properties of COPCs at the MSP site. The dose-response assessment is a process that results in a quantitative estimate of toxicity for each COPC. For carcinogenic effects, the slope factor (SF) is determined for oral and dermal exposure, and the inhalation unit risk (IUR) for inhalation exposure; for non-cancer effects, the reference dose (RfD) is used to evaluate oral and dermal exposures while the reference concentration (RfC) is used to evaluate inhalation exposures. Toxicity values are provided in the RAGS Part D Series 5 and 6 tables in Appendix B, Tables 5.1 and 5.2 and Tables 6.1 and 6.2.

3.3.1 Development of Toxicity Values

Carcinogenic and non-carcinogenic health effects are both evaluated quantitatively in the risk assessment. Endpoints for these two different types of effects are assessed differently because the mechanisms by which chemicals cause most cancers are fundamentally different from the process(es) that cause non-carcinogenic effects. Several chemicals are evaluated for both cancer and non-cancer health effects. The principal difference in the evaluation reflects the assumption that non-carcinogenic effects exhibit a threshold dose below which no adverse effects occur, whereas no such threshold has been shown to exist for most carcinogenic effects.

3.3.2 Classification of Chemicals as Carcinogens or Non-carcinogens

As used in the risk assessment, the term carcinogen refers to a chemical for which there is sufficient evidence that exposure may result in cancer in humans and/or animals. Conversely, the term non-carcinogen refers to a chemicals' health effects, such as changes in the normal functions of organs within the body (e.g., changes in the effectiveness of the immune system). Some chemicals can cause both cancer and non-cancer health effects and these effects are evaluated separately. The likelihood that a chemical is a human carcinogen is specified by the EPA's weight-of-evidence classification. Data derived from human and animal studies are reviewed and the chemical is characterized as follows:

The EPA classification system for the characterization of the overall weight of evidence for carcinogenicity (animal, human, and other supportive data) was issued in 1986 (EPA 1987). The classification system at that time included: Group A – Known Human Carcinogen; Groups B1 and B2 – Probable Human Carcinogen; Group C – Possible Human Carcinogen; Group D – Not Classifiable as to Human Carcinogenicity; and Group E – Evidence of Noncarcinogenicity for Humans. Many chemicals on the Integrated Risk Information System (IRIS), EPA's consensus toxicity database, maintain these classifications and these classifications will be updated when the chemical file is updated. The HHRA includes the classifications provided in the IRIS Chemical Files for chemicals that have not been reassessed or updated to include the new classifications based on the 2005 Cancer Guidelines described below (EPA 2005a).

The EPA 2005 Cancer Guidelines updated the cancer classifications for chemicals to include a narrative and the following recommended standard hazard descriptors: Carcinogenic to Humans, Likely to Be Carcinogenic to Humans, Suggestive Evidence of Carcinogenic Potential, Inadequate Information to Assess Carcinogenic Potential, and Not Likely to Be Carcinogenic to Humans (EPA 2005a). Based on the available information in IRIS, EPA's consensus database for toxicity information, the descriptions include classifications from the 1986 categories described above, and the updated narrative categories are provided for those chemicals updated since 2005. The IRIS category provided in the chemical file is presented in the RAGS Part D tables in Appendix B (Tables 6.1 and 6.2).

3.3.3 Assessment of Oral and Dermal Exposures

3.3.3.1 Assessment of Non-carcinogens

The potential for non-cancer adverse health effects (e.g., organ damage, immunological effects, developmental effects, skin irritation) is usually assessed by comparing the estimated Site-related

exposure expressed as an average daily exposure that is compared to the RfD. The RfD is defined as an estimate (with uncertainty spanning perhaps an order of magnitude or greater) of a daily exposure level for the human population, including sensitive subpopulations, that is likely to be without an appreciable risk of deleterious effects during a lifetime (EPA 1989). The EPA develops the chronic RfD by identifying the no-observed-adverse-effect level (NOAEL) or lowest-observed-adverse-effect level in the scientific literature, or a benchmark dose that corresponds to a small (1% to 10%), but defined, response in the studied population, and adjusting that value using uncertainty factors (UFs). The UFs reflect the data limitations of the critical study or studies and the uncertainties associated with differences between the study conditions and the human exposure situation (e.g., different species, doses, routes of exposure, and length of exposure) and variability in the human population, so that the resulting RfD is protective of the human population. RfDs are expressed in units of milligrams per kilogram per day (mg/kg-day).

The RfD is used as a reference point for identifying potential effects of other exposures. Generally, exposures that are less than the RfD are not likely to be associated with adverse health effects. As the exposure increases beyond the RfD and as the size of the excess increases, the potential for health effects also increases, although exceedance of the RfD does not predict a specific disease. Non-carcinogenic hazards are usually assessed by calculating an HQ for each chemical exposure by each exposure pathway, as follows:

$$HQ = CDI/RfD$$

where:

- HQ = Hazard quotient,
- CDI = Chronic daily intake, and
- RfD = Reference dose (mg/kg-day)

HQs are summed across all chemical and all exposure pathways to obtain an HI. If the HI is 1 or less, adverse non-cancer health effects are unlikely to occur. If the HI exceeds 1, consideration is given to separating the chemicals into groups based on effects on common target organs/systems. If the HIs for the groups of chemicals are 1 or less, then adverse non-cancer health effects on the target organs/systems associated with the specific chemical groups are again unlikely to occur. However, if the HI for a particular target organ/system is greater than 1, adverse non-cancer health effects may occur. An HQ or an HI does not predict any specific disease.

3.3.3.2 Assessment of Carcinogens

In contrast to non-carcinogenic effects for which thresholds are thought to exist, thresholds have not been demonstrated for most carcinogenic effects. Consequently, unless evidence exists that supports a nonlinear low dose extrapolation method, it is assumed that any exposure to a carcinogen entails some finite risk of cancer. However, depending on the potency of a specific carcinogen and the level of exposure, such a risk could be extremely small.

Several mathematical models have been developed to estimate low-dose carcinogenic risks from high-dose cancer bioassays. Unless evidence exists that supports a different low-dose extrapolation model, the EPA generally uses the linearized multi-stage model to estimate toxicity values and the

95% UCL of the slope of the dose-response curve to estimate low-dose SFs (EPA 2005a). The results of this procedure are unlikely to underestimate the actual SFs for humans. SFs are expressed as the inverse of the daily dose per unit body weight ([mg/kg-day]-1). The IRIS chemical file details the development of the SF along with the weight of evidence for the chemical.

Using SFs, excess lifetime cancer risks associated with each chemical exposure by each pathway can be estimated by:

$$Risk = LADI \times SF$$

where:

LADI = Lifetime average daily intake, and

SF = Slope factor $(mg/kg-day)^{-1}$.

However, this linear equation is valid only at moderate to low risk levels (i.e., below estimated cancer risks of 1×10^{-2} , a risk of one in a hundred). EPA (1989) recommends that if cancer risk estimates from the linear low-dose model exceed 1×10^{-2} , then an alternate calculation, the one-hit equations, are recommended to be used instead. The one-hit equation for high carcinogenic risk levels is:

Risk =
$$1 - e^{(-LADI \times SF)}$$

where:

e = The base of natural logarithms.

The separate cancer risks are summed across chemicals and exposure pathways that apply to a given receptor group to obtain the total excess lifetime cancer risk for that group.

3.3.3.3 Dermal Route Reference Doses and Slope Factors

Dermal exposures are calculated on an absorbed-dose basis (the amount of a substance that is absorbed through the skin and circulates throughout the body), whereas most oral RfDs and SFs are based on the dose administered by the oral route rather than the dose absorbed from the GI tract and distributed throughout the body. Therefore, if substantially less than 100% of the oral dose of a substance is actually absorbed from the GI tract, it is necessary to adjust oral RfDs and SFs to account for this incomplete oral absorption to obtain absorbed dose RfDs and SFs that are appropriate for use with the absorbed doses that result from dermal exposure (EPA 2004). This adjustment is made by multiplying oral RfDs and dividing oral SFs by the oral absorption fraction. The oral absorption factors (fractions) used to make this adjustment for each COPC are obtained from the EPA RAGS Part E document (EPA 2004) and are included in the toxicity worksheets (RAGS Part D, Tables 5.1 and 6.1) in the exposure and risk calculation in Appendix B, along with the resulting dermal route RfDs and SFs that are adjusted to reflect gastrointestinal (GI) absorption.

3.3.3.4 Route-to-Route Extrapolation of Reference Doses and Slope Factors

Oral RfDs and SFs may be used to evaluate inhalation route exposures (except in the case of exposure point effects) if inhalation RfDs and SFs are not available. RAGS Part F (EPA 2009) does not generally recommend conducting route-to-route extrapolations to develop inhalation values. Determinations regarding route to route extrapolations are made in the toxicity assessments including those conducted by IRIS.

3.3.4 Assessment of Inhalation Exposures

The EPA assesses exposures to airborne contaminants using the airborne concentrations directly rather than calculating a daily intake rate. The concentration in air is calculated using the Adelman method as modified by Schaum to evaluate the adult resident showering scenario (Schaum 1994). The calculated air concentration is then used in the equations described in RAGS Part F (EPA 2009) and is consistent with EPA's inhalation dosimetry methodology (EPA 1994). The methodology uses RfCs to assess non-cancer effects and IURs to assess carcinogenic effects.

3.3.4.1 Non-carcinogens

For non-carcinogens:

$$RfC = NOAEL_{[HEC]}/(UF)$$

where:

RfC (mg/m³) = Reference concentration

- NOAEL_[HEC] (mg/m³) = The NOAEL or analogous exposure level obtained with an alternate approach, dosimetrically adjusted to a human equivalent concentration (HEC); and
- UF = Uncertainty factor(s) applied to account for the extrapolations required from the characteristics of the experimental regimen.

An HEC is adjusted from animal toxicity data to take into account physiological differences between humans and the test species.

Exposure concentrations (ECs) are calculated as follows:

For acute exposures to non-carcinogens:

$$EC = CA$$

where:

EC (μ g/m³) = Exposure concentration (micrograms per cubic meter)

 $CA(\mu g/m^3) = Contaminant concentration in air$

and for subchronic or chronic exposures to non-carcinogens:

$$EC = (CA \times ET \times EF \times ED)/AT$$

where:

EC ($\mu g/m^3$) = Exposure concentration

 $CA (\mu g/m^3) = Contaminant concentration in air$

ET (hours/day) = Exposure time

EF (days/year) = Exposure frequency

ED (years) = Exposure duration

AT (ED in years x 365 days/year x 24 hours/day) = Averaging time

Note: If the duration of the exposure period is less than one year, the units in the above equation can be changed to the following: EF (days/week); ED (weeks/exposure period); and AT (hours/exposure period) (EPA 2009).

The HQ for the inhalation pathway can be calculated with the following general equation:

 $HQ = EC/(Toxicity Value x 1,000 \mu g/mg)$

where:

HQ (unitless) = Hazard quotient

EC ($\mu g/m^3$) = Exposure concentration

Toxicity Value (mg/m^3) = Inhalation toxicity value (e.g., RfC) that is appropriate for the exposure scenario (acute, subchronic, or chronic).

3.3.4.2 Carcinogens

For exposure to carcinogens:

$$IUR = 0.1/LEC_{10[HEC]}$$

where:

IUR $(\mu g/m^3)^{-1}$ = Inhalation unit risk and

LEC $_{10[\text{HEC}]}(\mu g/\text{m}^3)$ = the lowest effective concentration using a 10% response level, dosimetrically adjusted to an HEC.

ECs for assessing cancer risks are given by

$$EC = (CA \times ET \times EF \times ED)/AT$$

where:

EC ($\mu g/m^3$) = Exposure concentration

 $CA (\mu g/m^3) = Contaminant concentration in air$

ET (hours/day) = Exposure time

EF (days/year) = Exposure frequency

ED (years) = Exposure duration

AT (lifetime in years x 365 days/year x 24 hours/day) = Averaging time

ECs for mutagenic carcinogens are calculated for each age group separately and then summed (see Section 3.4.2).

The excess cancer risk for a receptor exposed via the inhalation pathway can be estimated with the following equation:

$$Risk = IUR \times EC$$

where:

IUR $(\mu g/m^3)^{-1}$ = Inhalation unit risk and

EC ($\mu g/m^3$) = Exposure concentration.

3.3.5 Quantitative Toxicity Values

The toxicological information used in this assessment is based on non-carcinogenic (threshold) and carcinogenic (non-threshold) effects caused by exposure to chemicals that have been observed in humans and/or laboratory animals associated with a particular dose of that compound. The toxicological information is used in conjunction with the exposure assessment to characterize risk associated with each COPC via the identified exposure pathways. Chemical-specific toxicological parameters (i.e., RfDs, RfCs, SFs, and IURs) were obtained from established EPA sources with the following priority (EPA 2003):

- **Tier 1.** IRIS (EPA 2016c);
- **Tier 2.** Provisional Peer Reviewed Toxicity Values (PPRTVs) from EPA's Superfund Health Risk Technical Support Center (STSC) at the National Center for Environmental Assessment; and
- **Tier 3.** Additional EPA and non-EPA sources of toxicity information. Priority should be given to those sources of information that are the most current, the basis for which is transparent and publicly available, and which have been peer reviewed.

The IRIS remains in the Tier 1 source in the recommended hierarchy as the generally preferred source of human health toxicity values. IRIS is an electronic database containing the most current descriptive and quantitative EPA regulatory toxicity information for various chemicals. Files maintained in IRIS contain information related to non-carcinogenic and carcinogenic health effects of chemicals. IRIS represents an EPA consensus toxicity database.

Tier 2 is EPA's PPRTVs. Generally, PPRTVs are derived for one of two reasons. First, the National Center for Environmental Assessment may nominate a chemical for evaluation or, secondly, regional Superfund offices may request a PPRTV for chemicals lacking a relevant IRIS value. The STSC uses the same methodologies to derive PPRTVs including EPA guidelines, guidance, and peer-review comparable to the procedures used by the IRIS program and consistent with EPA's peer-review process. Toxicity values derived from the PPRTV screen were not used for risk assessment purposes due to their high uncertainty.

Tier 3 includes other sources of information. Priority is given to sources that provide toxicity information based on similar methods and procedures as those used for Tier 1 and Tier 2 and contain toxicity values that are peer reviewed, are available to the public, and are transparent about the methods and processes used to develop the toxicity values. Additional sources may be identified for Tier 3. Toxicity values that fall within the third tier in the hierarchy include, but need not be limited to, the following sources:

- The California Environmental Protection Agency (Cal EPA) toxicity values are peer reviewed and address both cancer and non-cancer effects (Cal EPA 2016). Cal EPA toxicity values are available on the Cal EPA website at http://oehha.ca.gov/tcdb/index.asp.
- The Agency for Toxic Substances and Disease Registry (ATSDR) minimal risk levels (MRLs) are estimates of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse non-cancer health effects over a specified duration of exposure. The ATSDR MRLs are peer reviewed and are available at http://www.atsdr.cdc.gov/mrls/index.html (ATSDR 2016).
- The Health Effects Assessment Summary Tables (HEAST) (EPA 1997) are Tier 3 values. The HEAST values are available at: <u>http://cfpub.epa.gov/ncea/risk/recordisplay.cfm?deid=2877&CFID=48852498&CFTOKEN=98990701</u>.

Toxicity values were selected following the Office of Solid Waste and Emergency Response (OSWER) directive on toxicity hierarchy (EPA 2003). These values, along with associated metadata (e.g., toxicity values, health effects, and sources of toxicity information, are provided in Appendix B, Tables 5.1 through 6.2).

Exposure to some chemicals may result in both carcinogenic and non-carcinogenic effects. In those cases, both types of effects were considered and evaluated in the quantitative risk assessment.

3.4 Risk Characterization

The risk characterization involves combining exposure estimates with toxicity information to generate incremental lifetime cancer risks and non-cancer hazards for each of the human exposure scenarios evaluated in the HHRA. This subsection presents and discusses the cancer risks and non-cancer health hazards from the analysis for each exposure area and receptor. Risk and hazard estimates for the RME case will be described for all exposure areas and receptor groups. If either the risk or hazard estimates exceed generally acceptable levels, the corresponding estimates for the CTE case are also discussed.

3.4.1 Cancer Assessment

Cancer risks are expressed as the increased risk of developing cancer as a result of a given exposure to a given chemical. These "excess" cancer risks are summed across all carcinogenic chemicals and all exposure pathways for each receptor category. Cancer risks less than one in a million (expressed as 1×10^{-6}) are not considered further in the assessment. Risks greater than 1×10^{-4} are further evaluated for remedial action (EPA 1988, 1991b). Excess cancer risks between 1×10^{-4} (one in 10,000) and 1×10^{-6} (one in 1,000,000) are generally evaluated on a case-by-case basis, and the EPA may determine that risks in this range warrant remedial action or that they do not require remedial action. The excess risk of cancer from ingestion and dermal exposure to a chemical is calculated as follows (EPA 1989):

Excess cancer risk =
$$1 - \exp(-DIL \times SF)$$

where:

exp = the exponential

DIL = Daily intake, averaged over a lifetime (mg/kg-day)

SF = Slope factor $(mg/kg-day)^{-1}$

In most cases (except when the product of DIL x SF is larger than about 0.01), this equation may be accurately approximated by the following:

Excess cancer risk = DIL x SF

3.4.2 Evaluation of Carcinogens with a Mutagenic Mode of Action

For chemicals identified as having a Mutagenic Mode of Action (MMOA) for carcinogenesis, cancer risks were estimated in accordance with the *Supplemental Guidance for Assessing Susceptibility from Early-Life Exposure to Carcinogens* (EPA 2005b). In brief, because chemical-specific data are not available for these chemicals, the default age-dependent adjustment factors (ADAFs) were applied to the non-age-dependent cancer slope factor (CSF) to account for differences in potency that may occur from exposure during early life (up to age 16 years). The supplemental guidance further indicates that any grouping of ages in the exposure assessment will need to be integrated with the ADAF age groupings to derive age group-specific risk estimates (EPA 2005b).

Of the COPCs identified in this assessment, TCE is the only chemical identified as having a MMOA. Therefore, cancer risk for a young child (younger than six years) exposed to TCE in groundwater were calculated to account for early life susceptibility as follows:

$$Risk_i = C \times HIF_i \times SF \times ADAF_i$$

where:

Riski = Excess cancer risk for age interval 'i'

- C = Concentration of chemical in the exposure medium (e.g., micrograms per liter [µg/L] for groundwater)
- HIF_i = Human intake factor for the exposure medium for age interval 'i' (e.g., mg/kg-day for groundwater)
- SF = Cancer slope factor $(mg/kg-day)^{-1}$
- ADAF_i = Age-dependent adjustment factor for age interval 'i' (unitless).

The ADAFs recommended in EPA (2005b) were applied to the different age intervals as:

Age Interval (yrs)	ADAF
0 (birth) - < 2	10
2 - < 16	3
16+	1

Age-weighted average (AWA) ADAFs were calculated for each receptor group as follows and are presented below.

$$AWA ADAF = \frac{(ED_{0-<2} \times 10) + (ED_{2-<16} \times 3) + (ED_{16+} \times 1)}{(ED_{0-<2} + ED_{2-<16} + ED_{16+})}$$

where:

 $ED_{0-<2}$ = Years receptor spends in the 0 - <2 age range,

 $ED_{2-<1}$ = Years receptor spends in the 2 - <16 age range, and

 ED_{16+} = Years receptor spends in the 16 and greater age range.

Age Interval (yrs)	AWA ADAF
0 (birth) - < 6	5.3
6 - < 18	2.7
18+	1

For chemicals with a MMOA, the chemical's standard SF was multiplied by the receptor's AWA ADAF to obtain the receptor-specific SFs used to estimate cancer risks for that receptor. As discussed in the IRIS Toxicological Review of Trichloroethylene assessment (EPA 2011b), TCE is carcinogenic by an MMOA for induction of kidney tumors. There is also more limited evidence for non-Hodgkin lymphoma (NHL) and liver cancer. The risk for TCE was evaluated for each of the mutagenic cancer risks associated with kidney cancer and the non-mutagenic cancer risks associated with NHL and liver cancer. The kidney lifetime oral slope factor of 9.3 x 10⁻³ milligrams per kilogram per day (mg/kg/day) was subtracted from the total TCE lifetime slope factor of 4.6 x 10⁻² mg/kg/day to calculate the slope factor associated with NHL and liver cancer $(3.7 \times 10^{-2} \text{ mg/kg/day})$ (EPA 2011b). The TCE unit risk associated with NHL and liver cancer due to inhalation was calculated in a similar manner. The total lifetime unit risk for TCE in air is $4.1 \times 10^{-6} \,\mu g/m^3$ and the kidney lifetime unit risk is 1.0 x 10⁻⁶ for a calculated unit risk of 3.1 x 10⁻⁶ for NHL and liver cancer (EPA 2011b). Because cancer risk to the kidney is considered mutagenic, an AWA ADAF was applied to the slope factor associated with the kidney. Each risk is presented separately in Series 7 tables for groundwater, and the cancer risks are summed together and presented in the Series 9 tables (see Appendix B).

3.4.3 Non-cancer Health Effects

The potential for non-cancer health effects is evaluated by comparing the estimated exposure intake or dose for a receptor over a specified time period to an RfD that represents the threshold exposure below which it is unlikely for even sensitive populations to experience adverse health effects (EPA 1989). This ratio of estimated exposure dose to RfD is the HQ. If the HQ for a chemical is equal to or less than 1, there is less concern about non-cancer health effects. If the HQ exceeds 1, there is some possibility that non-cancer effects may occur. Non-cancer HQs for each chemical are calculated as described below (EPA 1989):

$$HQ = CDI/RfD$$

where:

CDI = Chronic daily intake (mg/kg-day)

RfD = Reference dose (mg/kg-day)

Exposure to multiple chemicals and multiple pathways were evaluated by summing the non-cancer hazard indices (HIs) across pathways and chemicals (EPA 1989). Pathways with an HI greater than the goal of protection of an HI = 1 were further evaluated based on health effects to determine if the health effects from multiple chemicals with the same health effect exceeded an HI = 1.

3.4.4 Risk Assessment Results

The cancer risk estimates refer to the overall excess risk of a cancer occurring during a lifetime attributable to the concentrations of COPCs measured in the environmental media to which exposures might occur. The cancer risk estimates are calculated on a lifetime basis so are additive for adults and children. For the residential receptor, the assessment was performed for young children (birth to six years of age), and adults (18 years and older). Consistent with guidance that provides exposure scenarios for a child exposed for six years and an adult exposed for 20 years, the

total cancer risks were calculated for the lifetime exposure of 26 years by summing the young child and adult risks. The non-cancer hazard estimates presented below are the overall estimates used for screening purposes. The non-cancer hazards are presented for the individual age groups; but the HIs are not additive across the age groups.

A summary of risks from each pathway and detailed estimates for particular tissues and organs are provided in the Series 9 RAGS Part D tables in Appendix B. A summary of total risks and hazards for each chemical with cancer risks greater than 1.0×10^{-4} and non-cancer hazards with an HI greater than 1 are provided in the Series 10 tables in Appendix B. Chemicals with an HI greater than 1 for the same organ are listed in the Table 10 series. These chemicals are considered to drive the risk for each scenario.

Table 3-2 below summarizes the cancer risk and non-cancer hazards for each receptor. A number of the risk and hazard estimates for specific chemicals and exposure pathways exceed the risk range established under the NCP of a cancer risk of 1 x 10^{-6} (1 in 1,000,000) to 1 x 10^{-4} (1 in 10,000) and/or the goal of protection of a non-cancer HQ or HI = 1 (EPA 1988, 1991b).

3.4.4.1 Future Worker Exposure to Groundwater

Table 3-2 presents the cancer risk and non-cancer hazard for the future worker exposure to groundwater. The total RME cancer risk of 1.4×10^{-3} exceeds the risk range and is primarily driven by carbon tetrachloride. The CTE cancer risk of 9.0×10^{-5} is within the acceptable risk range.

The RME non-cancer HI is 17.3 and the CTE non-cancer HI is 4.2, which exceed the goal of protection of HI = 1. The main contributors to the non-cancer HI are carbon tetrachloride and TCE. The primary target organ impacted by carbon tetrachloride is the liver and TCE impacts the developmental, cardiovascular, and immune systems. In both instances, the total HI exceeds 1 for the target organs, and the compounds drive the non-cancer risk for both the RME and CTE scenarios.

3.4.4.2 Future Residential Exposure to Groundwater

Child. Table 3-2 presents the cancer risk and non-cancer hazard for the future young child resident exposure to groundwater. The total RME cancer risk of 1.2×10^{-3} exceeds the risk range and is primarily driven by the ingestion of carbon tetrachloride. The CTE cancer risk of 2.5×10^{-4} also exceeds the risk range.

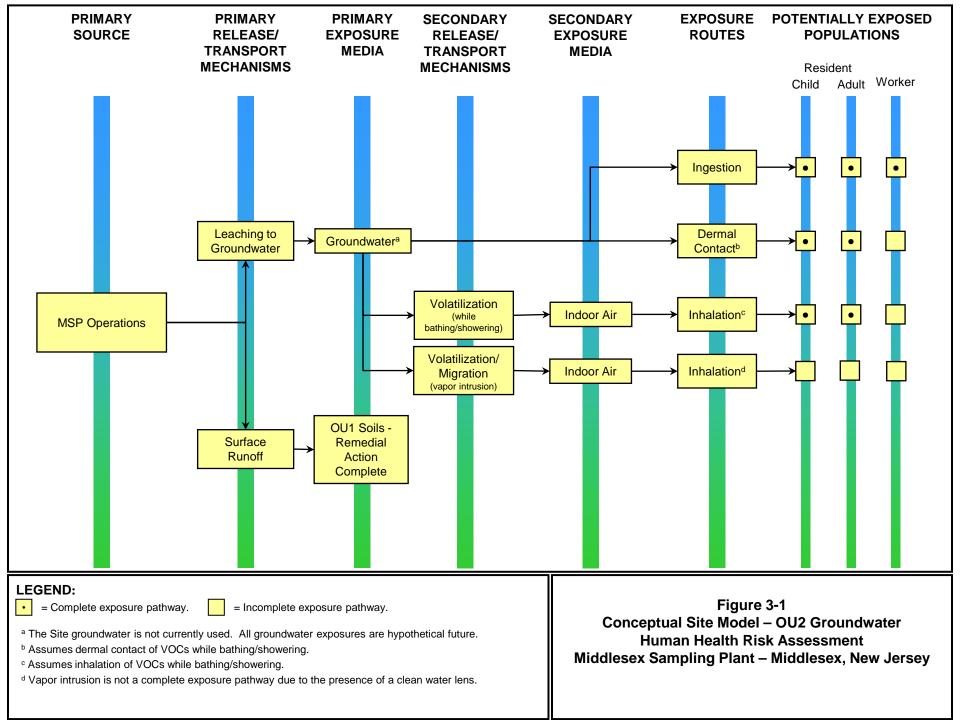
The RME non-cancer HI is 59.1 and the CTE non-cancer HI is 17.9, which exceed the goal of protection of HI = 1. The main contributors to the non-cancer HI are carbon tetrachloride, chloroform, and TCE through ingestion, dermal absorption, and inhalation of groundwater. The primary target organ impacted by carbon tetrachloride and chloroform is the liver and TCE impacts the developmental, cardiovascular, and immune systems. In both instances, the total HI exceeds 1 for the target organs, and the compounds drive the non-cancer hazard for both the RME and CTE scenarios.

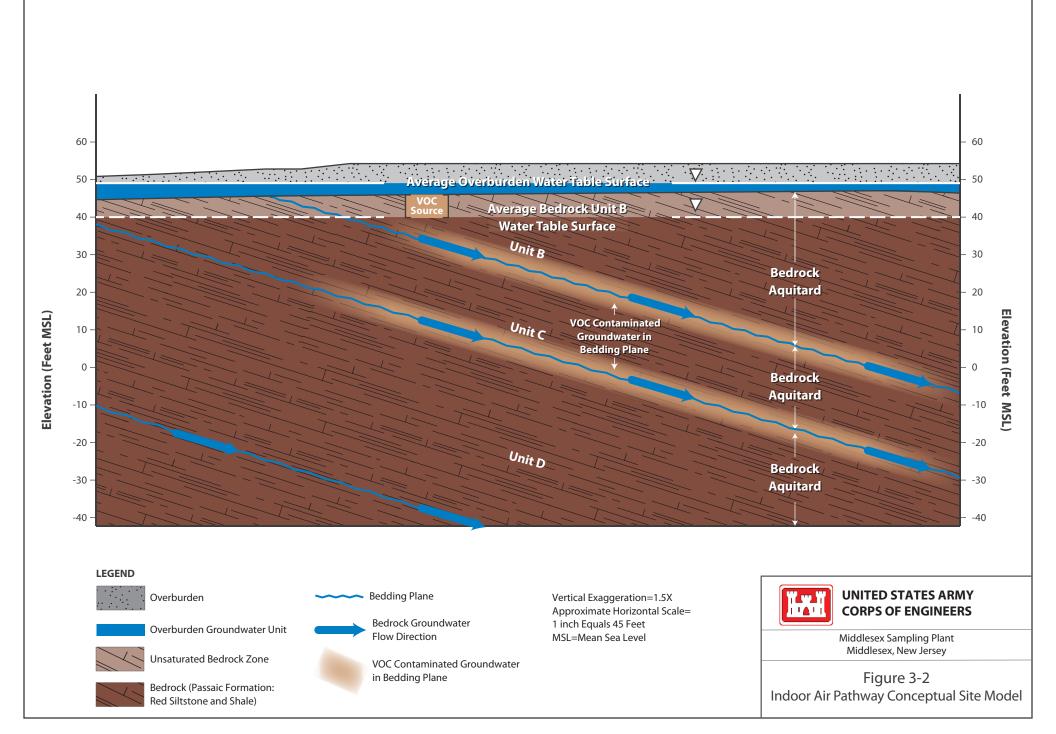
Adult. Table 3-2 presents the cancer risk and non-cancer hazard for the future adult resident exposure to groundwater. The total RME cancer risk of 3.4×10^{-3} exceeds the risk range and is primarily driven by the exposure of carbon tetrachloride and chloroform via ingestion, dermal absorption, and inhalation. The CTE cancer risk of 4.6×10^{-4} also exceeds the risk range.

The RME non-cancer HI is 48.6 and the CTE non-cancer HI is 15.9, which exceed the goal of protection of HI = 1. The main contributors to the non-cancer HI are carbon tetrachloride, chloroform, and TCE through ingestion, dermal absorption, and inhalation of groundwater. The primary target organ impacted by carbon tetrachloride and chloroform is the liver and TCE impacts the developmental, cardiovascular and immune systems. In both instances, the total HI exceeds 1 for the target organs, and the compounds drive the non-cancer risk for both the RME and CTE scenarios.

Future Adult and Child Resident Total. Considering exposure to groundwater, the total cancer risk to the RME adult and young child is 4.6×10^{-3} , which exceeds the risk range. The total cancer risk to the CTE adult and child is 7.1×10^{-4} , which also exceeds the risk range. In both instances, the risk is driven by carbon tetrachloride. The non-cancer HIs are not additive across the age groups.

				Reasonable Max	kimum Exposure	Central Tende	ency Exposure
Receptor	Age	Exposure Medium	Tables	Excess Cancer Risk	Non-cancer Hazard Index	Excess Cancer Risk	Non-cancer Hazard Index
Worker	Adult	Tap Water	9.1-RME/CTE	1.4E-03	17.3	9.0E-05	4.2
	Young Child	Tap Water	9.2-RME/CTE	1.2E-03	59.1	2.5E-04	17.9
Resident	Adult	Tap Water	9.3-RME/CTE	3.4E-03	48.6	4.6E-04	15.9
esident Young	Child + Adult Totals			4.6E-03	NA*	7.1E-04	NA*





4 UNCERTAINTY ANALYSIS

Quantitative evaluation of human health risks due to environmental contamination is frequently limited by uncertainty regarding a number of key inputs, including chemical concentrations in the environment, the level of human contact with contaminated media, and the dose-response relationships for non-cancer and cancer effects in humans. This uncertainty is usually addressed by making assumptions or estimates for uncertain parameters based on available information. Because of these assumptions and estimates, the results of non-cancer hazard and cancer risk calculations have some level of uncertainty. This information aids risk managers in the decision-making process. It is also aids the public in understanding the results of the HHRA. The following sections review the main sources of uncertainty in the non-cancer hazard and cancer risk calculations performed for the MSP site (see Appendix C).

4.1 **Outliers**

Before calculating EPCs, the statistical distributions of the COPC datasets were examined by preparing quantile-quantile (Q-Q) plots. These plots can reveal irregularities in the distribution of the data and are often used to examine data for the presence of outliers. Based on inspection of the Q-Q plots, datasets for a number of the COPCs appeared to include one or more high outliers. As discussed in the ProUCL Technical Guide, the presence of outliers can distort test statistics, including 95% UCL calculations (EPA 2016d). From the ProUCL Technical Guide:

A distorted estimate (e.g., UCL95) computed by accommodating a few low probability outliers (coming from far tails) tends to represent the population area represented by those outliers and not the main dominant population of interest.

As recommended by the technical guide, the approach considered the possible presence of outliers and elected not to exclude potential outliers from the EPC datasets, which is the more conservative and potentially health- protective approach. Nevertheless, inclusion of potential outliers in the EPC datasets may have led to EPC values that may be biased high (most often the 95% UCL value recommended by ProUCL). This adds uncertainty to the risk assessment process and risk and hazard estimates may be biased high.

For each chemical exceeding either the risk range of 1×10^{-4} or the goal of protection of an HI = 1, or significantly contributing to an organ HI greater than 1, an analysis was conducted to identify potential outliers. Below is a summary of the results of this analysis based on depth of contamination.

Sample ECC-MW-30B (collected in October 2014) was found to be an outlier for TCE at a significance level of 5 and 10%. No other outliers were found.

Samples, including field duplicate samples, were collected in accordance with the QA/QC procedures outlined in the site-specific QAPP. Because the field duplicates were collected from wells other than those later determined to be within the core of the plume, there is no confirmation to ensure homogeneity of the core of the plume samples. However, all samples were collected when stable water quality parameters were obtained during purging to ensure that the groundwater was in equilibrium and that formation water was being collected.

4.2 Background

The complexities of the bedrock groundwater flow dynamics at the site make it difficult to determine representative background concentrations of VOCs. Bedrock groundwater in the area is recharged from the saturated overburden unit and surface water at linear subcrops of dipping bedding planes that carry water downward along the angle of the bedding planes (~11°). MSP is located in an industrial area where there are multiple contributors of contaminants to the bedrock aquifer, and VOCs are not naturally occurring in the environment; therefore, contamination from upgradient sources are representative of anthropogenic contamination rather than naturally occurring chemicals.

A true background well does not exist for the site; however, monitoring well URS-MW-22D was considered for comparison of off-site contamination from upgradient sources to contamination from the core of the plume. However, a statistical comparison is hindered due the availability of only one well and an inadequate number of data points. Therefore, a simple comparison of the mean COPC values to the mean values of the upgradient well was performed. This method is listed as an option in EPA guidance *Role of Background in the CERCLA Cleanup Program* (EPA 2002), although it is not highly recommended due to the high level of uncertainty (see Table 4-1 below).

Table 4-1 Background Evaluation Comparison				
СОРС	Mean COPC Value	Mean Background Value	Difference Between COPC and Background Mean	
1,1,2-trichloro-1,2,2-trifluoroethane	0.71	ND		
1,1,2-trichloroethane	0.44	ND		
1,1-dichloroethane	0.96	1.91	0.95	
1,1-dichloroethene	13.0	7.57	-5.46	
1,2-dichloroethane	1.64	ND		
Acetone	287	ND		
Carbon disulfide	1.95	ND		
Carbon tetrachloride	650	ND		
Chloroform	51.6	ND		
cis-1,2-dichloroethylene	2.27	0.49	-1.78	
Methyl tert-butyl ether	6.18	2.79	-3.39	
Tetrachloroethylene	1.56	0.53	-1.03	
Toluene	0.30	ND		

Table 4-1 Background Evaluation Comparison					
СОРС	Mean COPC Value	Mean Background Value	Difference Between COPC and Background Mean		
Trichloroethylene 30.3 1.37 -28.9					
Trichlorofluoromethane 0.28 ND					
ND = Not Detected Units in μg/L. Shaded cells represent compounds that were selected as COPCs.					

Two risk drivers, carbon tetrachloride and chloroform, were not detected in the upgradient well, which indicates that the concentrations are likely representative of the site contamination. TCE was also determined to be a risk driver; however, the upgradient well exhibited low detections of the analyte. The mean concentration of TCE from within the core of plume was greater than 10 times the upgradient well detection, which indicates that the risk calculations are likely representative of the site contamination despite the small contribution from background.

Upgradient concentrations of MTBE, cis-1,2-dichloroethylene, 1,1-dichloroethane, and 1,1dichloroethene were similar to the mean concentrations from the core of the plume; therefore, they are likely representative of anthropogenic contamination. MTBE and cis-1,2-dichloroethylene exceeded the RSL, but did not exceed the acceptable risk range. 1,1,-dichloroethane did not exceed the RSL and was not considered as COPCs. 1,1-dichloroethene did not exceed the RSL, but did exceed the MCL. Risk was calculated for the compound, but did not exceed the acceptable risk range.

4.3 Monitoring Wells ECC-MW-30B and EE-MW-41S

The analytical results from ECC-MW-30B and EE-MW-41S were consistently the highest for carbon tetrachloride and TCE, the two major risk drivers in bedrock groundwater. The results for these wells from installation through 2015 are presented below in Table 4-2 and Table 4-3. ECC-MW-30B was first sampled in June 2012 and has since exhibited decreases in concentrations over the years. EE-MW-41S, which was installed in September 2014, exhibited elevated concentrations of carbon tetrachloride, chloroform, MTBE, and TCE after well placement, but drastically decreased during the next sampling round. The elevated concentrations were used for the risk assessment, which resulted in both cancer and non-cancer risks to all receptors. It is presumed that the VOC contamination is held in the bedrock and released to groundwater during drilling of the bedrock. In this case, the risks and hazards in groundwater may be overestimated.

СОРС	June 2012 Result	August 2012 Result	November 2012 Result	February 2013 Result	October 2014 Result	November 2015 Result
Carbon Tetrachloride	13,000	8,000	6,100	3,600	2,360	1,200
Chloroform	600	380	270	190	161	75
TCE	430	230	180	130	121	50

Table 4-3 EE-MW-41S Concentration Trend			
СОРС	October 2014 Result	November 2015 Result	
Carbon Tetrachloride	2,460	32	
Chloroform	222	4.1	
MTBE	23.5	0.46	
TCE	62	0.61	
Units in µg/L.			

4.4 Human Exposure Parameters

Many of the exposure parameters used to calculate exposure doses/intakes are estimated from the published literature and are based on the *Exposure Factors Handbook* (EPA 2011a) and the updated Superfund standard default exposure assumptions (EPA 2014b). Some parameters, for example, the quantity of groundwater ingested by a site worker, are estimates often based on professional judgment. In general, when exposure data were limited or absent, the exposure parameters were selected to be health-protective. This approach is intended to produce results that are more likely to overestimate than underestimate actual exposure and cancer risks or non-cancer hazards.

4.5 Uncertainties in Toxicity Values

Toxicity information for many chemicals is often limited. Consequently, there are varying degrees of uncertainty associated with toxicity values (i.e., SFs, RfDs). For example, uncertainties can arise from the following sources:

- Extrapolation from animal studies to humans;
- Extrapolation from high dose to low dose;
- Extrapolation from continuous exposure to intermittent exposure; and

• Limited or inconsistent toxicity studies.

The EPA uses health-protective approaches to develop toxicity factors to ensure that any uncertainties are more likely to result in an overestimation, rather than an underestimation, of non-cancer hazard or cancer risk. The toxicity values were selected consistent with the Superfund program's toxicity hierarchy (EPA 2003). For chemicals with toxicity values, the risks and hazards are not anticipated to be underestimated. However, there were several chemicals identified during sampling that do not have toxicity values for specific exposure pathways. In this case, the risks and hazards may be underestimated.

4.6 Uncertainties in Risk Estimates

Because cancer risk or non-cancer hazard estimates for a chemical are derived by combining uncertain estimates of exposure and toxicity, the risk or hazard estimates for each chemical are more uncertain than either the exposure estimate or the toxicity estimate alone. Additional uncertainty arises from the issue of how to combine risk or hazard estimates across different chemicals. In some cases, the effects caused by one chemical do not influence the effects caused by other chemicals. In other cases, the effects of one chemical may interact with effects of other chemicals, causing responses that are approximately additive, greater than additive (synergistic), or less than additive (antagonistic). In most cases, available toxicity data are not sufficient to define what type of interaction can be expected, so the EPA generally assumes that effects are additive for carcinogens that act on all target organs/tissues and for non-carcinogens that act on the same target organ/tissue (EPA 2000).

5 SUMMARY AND CONCLUSIONS

The HHRA performed for the MSP site evaluated the potential risks associated with exposure to VOCs in groundwater. The receptors evaluated in the HHRA were hypothetical future on-site workers and off-site residents because the groundwater is not currently used or planned to be used as a source of potable water.

The results of the HHRA indicate that estimated RME cancer risks and non-cancer hazards to on-site adult workers, and off-site young child and adult residents exceed EPA's acceptable risk range and non-cancer HI of 1. The estimated CTE cancer risks and non-cancer hazards also exceeded EPA's acceptable risk range and non-cancer HI of 1 with one exception; the on-site adult worker cancer risk was within EPA's acceptable risk range.

The cancer risks and non-cancer hazards are primarily driven by carbon tetrachloride, chloroform, and TCE. Evaluation of the upgradient well indicates that these contaminants are most likely representative of site contamination. Low level concentrations of MTBE, cis-1,2-dichloroethylene, 1,1-dichloroethane, and 1,1-dichloroethene were detected in both the upgradient well and the core of the plume wells indicating a potential off-site source. These analytes did not, however, contribute to excess risk or non-cancer hazards at the MSP site.

Vapor intrusion into indoor air was considered as a potential exposure point; however, the downward gradient water flow through the bedrock, absence of significant VOC detections in the overburden groundwater unit, and the presence of a clean water lens precludes the migration of VOCs from the bedrock aquifer to the ground surface.

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A DATA USABILITY WORKSHEETS

DATA USABILITY WORKSHEET Site: Middlesex Sampling Plant Medium: 2014 Groundwater

Activity	Comment			
Field sampling and data evaluation were conducted according to the Final Work Plan for the Groundwater Operable Unit (OU) – Additional Data Gathering for Comple of the Feasibility Study Report Middlesex Sampling Plant FUSRAP Site, Middlesex, New Jersey, Au 2014.				
Field Sampling				
Discuss sampling problems and field conditions that affect data useability.	In the case where monitoring wells were purged dry, the well was allowed to recharge and sampled within 24 hours.			
Are samples representative of receptor exposure for this medium (e.g. sample depth, grab vs composite, filtered vs unfiltered, low flow, etc.)?	All samples are representative of the receptor exposure and collected from within the screen depth of each bedrock monitoring well. The samples were unfiltered and analyzed for volatiles.			
Assess the effect of field QC results on data useability.	There was a positive detection for methylene chloride and acetone in the trip blank and rinsate blank. Several low level sample detections were qualified as non- detect due to the blank detections. The blank detections are likely laboratory contamination. The analytes are not a site contaminants. There is no impact data useability for the HHRA.			
Summarize the effect of field sampling issues on the risk assessment, if applicable.	Field samples were collected consistent with the QAPP. There are no field sampling issues that should affect the HHRA.			
Analytical	Techniques			
Were the analytical methods appropriate for quantitative risk assessment?	Yes. The samples analysis was performed per the SW-846 analytical method <i>Test Methods for Evaluating Solid</i> <i>Waste, Physical/Chemical Methods.</i>			
Were detection limits adequate?	Yes, the detection limits were adequate. In one instance sample EE-MW-41S was analyzed at a high dilution due to very high target analyte detections. Elevated reporting limits were provided. The non-detect values were not used in the risk assessment.			
Summarize the effect of analytical technique issues on the risk assessment, if applicable.	The analytical methods met the requirements outlined in the QAPP and are appropriate for use in the HHRA.			

DATA USABILITY WORKSHEET (continued) Site: Middlesex Sampling Plant Medium: 2014 Groundwater

Data Quality Objectives				
Precision – How were duplicates handled?	Method precision was assessed in the laboratory by performing Laboratory Control Spike and Laboratory Control Spike Duplicate (LCS/LCSD) or Matrix Spike and Matrix Spike Duplicate (MS/MSD) analysis. Precision was also assessed in field duplicates results. Precision was assessed as described in the QAPP or as noted in the report.			
Accuracy – How were split samples handled?	Accuracy was evaluated through the use of analytical standards, QC samples such as spikes and LCSs, and blank samples.			
Representativeness – Indicate any problems associated with data representativeness (e.g., trip blank or rinsate blank contamination, chain of custody problems, etc.).	Trip blanks were included in the sample coolers containing samples for volatiles analysis. There was a positive detection for methylene chloride and acetone in the trip blank and rinsate blank. Several low level sample detections were qualified as non-detect due to the blank detections. The blank detections are likely laboratory contamination. The analytes are not site contaminants. There is no impact to the risk assessment.			
Completeness – Indicate any problems associated with data completeness (e.g., incorrect sample analysis, incomplete sample records, problems with field procedures, etc.).	Data completeness was evaluated in the data validation memos. Rejected sample results are not used in the HHRA.			
Comparability – Indicate any problems associated with data comparability.	Low levels of methylene chloride were detected in the method blanks. If the results were less than 10X the blank detection, then the results were qualified as non-detect. Many of the samples were qualified as non-detect; however, methylene chloride is not a site contaminant and the detections are likely related to laboratory contamination. There is no impact to data useability.			
Were the DQOs specified in the QAPP satisfied?	Yes.			
Summarize the effect of DQO issues on the risk assessment, if applicable.	There are no DQO issues that impact the use of data for the HHRA.			

DATA USABILITY WORKSHEET (continued) Site: Middlesex Sampling Plant Medium: 2014 Groundwater

Data Validation and Interpretation				
What are the data validation requirements?	Specific criteria for QC limits were obtained from the project QAPP.			
What method or guidance was used to validate the data?	USEPA Region 2 validation SOPs were used as validation guidance. SOP No. HW-34, Rev. 3, Trace Volatile Data Validation			
Was the data validation method consistent with guidance? Discuss any discrepancies.	Yes, the data validation method was consistence with the guidance.			
Were all data qualifiers defined? Discuss those which were not.	All data qualifiers were defined.			
Which qualifiers represent useable data?	J = Estimated value UJ = Estimated value/Non-detect U = Non-detect			
Which qualifiers represent unuseable data?	No data was deemed unuseable.			
How are tentatively identified compounds handled?	TICs were not collected for the dataset.			
Summarize the effect of data validation and interpretation issues on the risk assessment, if applicable.	The data meets the requirements outlined in the QAPP, the data was validated, and meets the requirements for use in the risk assessment.			
Additional notes:				

DATA USABILITY WORKSHEET Site: Middlesex Sampling Plant Medium: 2015 Groundwater

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Activity	Comment			
Field sampling and data evaluation were conducted according to the <i>Final Work Plan for the Groundwater Operable Unit (OU) – Additional Data Gathering for Completion</i> <i>of the Feasibility Study Report Middlesex Sampling Plant FUSRAP Site</i> , Middlesex, New Jersey, August 2014.				
Field Sa	ampling			
Discuss sampling problems and field conditions that affect data useability.	In the case where monitoring wells were purged dry, the well was allowed to recharge and sampled within 24 hours.			
Are samples representative of receptor exposure for this medium (e.g. sample depth, grab vs composite, filtered vs unfiltered, low flow, etc.)?	All samples are representative of the receptor exposure and collected from within the screen depth of each bedrock monitoring well. The samples were unfiltered and analyzed for volatiles.			
Assess the effect of field QC results on data useability.	There were positive detections for acetone, carbon disulfide, toluene, trichloroethylene (TCE), and 2- butanone in the trip blank and/or rinsate blank. Several low level sample detections of acetone, carbon disulfide and 2-butanone were qualified as non-detect due to the blank detections. Low level detections for TCE were not qualified as it is a site contaminant and the sample results were consistent with historical trends. The TCE data was used for risk assessment purposes.			
Summarize the effect of field sampling issues on the risk assessment, if applicable.	Fifteen samples were received outside of the recommended temperature of $4 \pm 2^{\circ}$ C. The samples were shipped on ice and the temperature was recorded to be 8.7°C. The sample results were qualified as estimated, and were considered useable for the HHRA. Field samples were collected consistent with the QAPP. There are no field sampling issues that should affect the HHRA.			
Analytical	Techniques			
Were the analytical methods appropriate for quantitative risk assessment?	Yes. The samples analysis was performed per the SW-846 analytical method <i>Test Methods for Evaluating Solid</i> <i>Waste, Physical/Chemical Methods.</i>			
Were detection limits adequate?	Yes, the detection limits were adequate.			

DATA USABILITY WORKSHEET (continued) Site: Middlesex Sampling Plant Medium: 2015 Groundwater

Activity	Comment
Summarize the effect of analytical technique issues on the risk assessment, if applicable.	The analytical methods met the requirements outlined in the QAPP and are appropriate for use in the HHRA.
Data Quality Objectives	
Precision – How were duplicates handled?	Method precision was assessed in the laboratory by performing Laboratory Control Spike and Laboratory Control Spike Duplicate (LCS/LCSD) or Matrix Spike and Matrix Spike Duplicate (MS/MSD) analysis. Precision was also assessed in field duplicates results. Precision was assessed as described in the QAPP or as noted in the report.
Accuracy – How were split samples handled?	Accuracy was evaluated through the use of analytical standards, QC samples such as spikes and LCSs, and blank samples.
Representativeness – Indicate any problems associated with data representativeness (e.g., trip blank or rinsate blank contamination, chain of custody problems, etc.).	Trip blanks were included in the sample coolers containing samples for volatiles analysis. There were positive detections for acetone, carbon disulfide, toluene, trichloroethylene (TCE), and 2-butanone in the trip blank and/or rinsate blank. Several low level sample detections of acetone, carbon disulfide and 2- butanone were qualified as non-detect due to the blank detections. Low level detections for TCE were not qualified as it is a site contaminant and the sample results were consistent with historical trends. The TCE data was used for risk assessment purposes.
Completeness – Indicate any problems associated with data completeness (e.g., incorrect sample analysis, incomplete sample records, problems with field procedures, etc.).	Data completeness was evaluated in the data validation memos. Rejected sample results are not used in the HHRA.
Comparability – Indicate any problems associated with data comparability.	Low levels of 1,2,4-trichlorobenzene were detected in the method blanks. The associated sample results were non-detect for the analyte. There is no impact to data useability. 1,4-Dioxane was rejected due to initial calibration failures. The associated sample results were non-detect and not useable for the HHRA.
Were the DQOs specified in the QAPP satisfied?	Yes.

DATA USABILITY WORKSHEET (continued) Site: Middlesex Sampling Plant Medium: 2015 Groundwater

Data Quality Obj	ectives (continued)
Summarize the effect of DQO issues on the risk assessment, if applicable.	There are no DQO issues that impact the use of data for the HHRA.
Data Validation a	and Interpretation
What are the data validation requirements?	Specific criteria for QC limits were obtained from the project QAPP.
What method or guidance was used to validate the data?	USEPA Region 2 validation SOPs were used as validation guidance. SOP No. HW-34, Rev. 3, Trace Volatile Data Validation
Was the data validation method consistent with guidance? Discuss any discrepancies.	Yes, the data validation method was consistence with the guidance.
Were all data qualifiers defined? Discuss those which were not.	All data qualifiers were defined.
Which qualifiers represent useable data?	J = Estimated value UJ = Estimated value/Non-detect U = Non-detect
Which qualifiers represent unuseable data?	R/UR = Rejected
How are tentatively identified compounds handled?	TICs were not collected for the dataset.
Summarize the effect of data validation and interpretation issues on the risk assessment, if applicable.	The data meets the requirements outlined in the QAPP, the data was validated, and meets the requirements for use in the risk assessment.
Additional notes:	

B RAGS PART D TABLES

TABLE 1 SELECTION OF EXPOSURE PATHWAYS FOR HUMAN HEALTH RISK ASSESSMENT Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Timeframe	Medium	Exposure Medium	Exposure Point	Receptor Population	Receptor Age	Exposure Route	Type of Analysis	Ratio
	Groundwater	Tap Water	Core of the Plume	Worker	Adult	Ingestion	Quantitative	Currently, individuals re system. On-site ground used in the future. How drinking water is quantit industrial/commercial.
Hypothetical Future	Groundwater	Tap Water	Core of the Plume	Resident	Child	Ingestion Dermal Inhalation	Quantitative	Currently, individuals re system. This pathway w future exposure pathway ingestion of groundwate inhalation of vapors whi
	Groundwater	Tap Water	Core of the Plume	Resident	Adult	Ingestion Dermal Inhalation	Quantitative	Currently, individuals re system. This pathway w future exposure pathway ingestion of groundwate inhalation of vapors whi

ionale for Selection or Exclusion of Exposure Pathway

s receive their drinking water from a public water supply ndwater is currently not used and is not expected to be owever, the hypothetical future use of groundwater for ntitatively evaluated because the land is zoned l. The route of exposure for the adult worker includes ater while at work. s receive their drinking water from a public water supply y will be quantitatively evaluated as a hypothetical

yill be quantitatively evaluated as a hypothetical yay. Routes of exposure for the child resident include ater, dermal contact during bathing/showering, and while bathing/showering.

s receive their drinking water from a public water supply will be quantitatively evaluated as a hypothetical way. Routes of exposure for the adult resident include ater, dermal contact during bathing/showering, and while bathing/showering.

TABLE 2.1

OCCURRENCE, DISTRIBUTION, AND SELECTION OF CHEMICALS OF POTENTIAL CONCERN Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Medium: Groundwater

Exposure Medium: Tap Water Exposure Point: Core of the Plume

CAS Number	Chemicals of Potential Concern	Minimum Concentration	Minimum Qualifier (1)			Units	Location of Maximum Concentration	Detection Frequency	Range of Detection Limits	Concentration Used for Screening (2)	Background Value	Screening Toxicity Value (3)	Basis for Toxicity Value C/NC (3)	Potential ARAR/TBC Value	Potential ARAR/TBC Source	COPC Flag (Y/N)	Rationale for Selection or Deletion (4)
VOCs																	
76-13-1	1,1,2-TRICHLORO-1,2,2-TRIFLUOROETHANE	4.20E-01	J	1.00E+00	J	µg/L	EE-MW-38B-NOV15	2/10	3.10E-01 - 2.00E+01	1.00E+00	NA	5.50E+03	NC	NA	NA	NO	BSL
79-00-5	1,1,2-TRICHLOROETHANE	4.40E-01	J	4.40E-01	J	μg/L	ECC-MW-30B-OCT14	1/10	3.00E-01 - 1.50E+01	4.40E-01	NA	4.10E-02	NC	NA	NA	YES	ASL
75-34-3	1,1-DICHLOROETHANE	3.50E-01	J	1.70E+00	J	µg/L	ECC-MW-27B-NOV15	4/10	2.00E-01 - 1.50E+01	1.70E+00	NA	2.80E+00	С	NA	NA	NO	BSL
75-35-4	1,1-DICHLOROETHENE	8.20E-01	J	2.70E+01	J	µg/L	ECC-MW-27B-NOV15	4/10	3.00E-01 - 1.50E+01	2.70E+01	NA	2.80E+01	NC	NA	NA	NO	BSL
107-06-2	1,2-DICHLOROETHANE	3.70E-01	J	2.74E+00		μg/L	ECC-MW-30B-OCT14	3/10	3.00E-01 - 1.50E+01	2.74E+00	NA	1.70E-01	С	NA	NA	YES	ASL
67-64-1	ACETONE	2.04E+02	J	3.70E+02		µg/L	ECC-MW-30B-OCT14	2/10	1.50E+00 - 3.30E+00	3.70E+02	NA	1.40E+03	NC	NA	NA	NO	BSL
75-15-0	CARBON DISULFIDE	1.95E+00	J	1.95E+00	J	µg/L	MW-38B-OCT14	1/10	2.20E-01 - 7.50E+01	1.95E+00	NA	8.10E+01	NC	NA	NA	NO	BSL
56-23-5	CARBON TETRACHLORIDE	7.70E+00	J	2.46E+03		μg/L	MW-41S-OCT14	10/10	No NDs	2.46E+03	NA	4.60E-01	С	NA	NA	YES	ASL
67-66-3	CHLOROFORM	2.90E+00	J	2.22E+02		μg/L	MW-41S-OCT14	10/10	No NDs	2.22E+02	NA	2.20E-01	С	NA	NA	YES	ASL
156-59-2	CIS-1,2-DICHLOROETHYLENE	4.50E-01	J	4.87E+00		μg/L	MW-38B-OCT14	8/10	1.50E+01 - 1.50E+01	4.87E+00	NA	3.60E+00	NC	NA	NA	YES	ASL
1634-04-4	METHYL TERT-BUTYL ETHER	3.70E-01	J	2.35E+01	J	μg/L	MW-41S-OCT14	4/10	2.90E-01 - 3.00E-01	2.35E+01	NA	1.40E+01	С	NA	NA	YES	ASL
127-18-4	TETRACHLOROETHYLENE	5.20E-01	J	3.50E+00	J	µg/L	ECC-MW-27B-NOV15	6/10	3.00E-01 - 3.00E-01	3.50E+00	NA	4.10E+00	NC	NA	NA	NO	BSL
108-88-3	TOLUENE	3.00E-01	J	3.00E-01	J	µg/L	MW-38B-OCT14	1/10	2.00E-01 - 1.50E+01	3.00E-01	NA	1.10E+02	NC	NA	NA	NO	BSL
79-01-6	TRICHLOROETHYLENE	6.10E-01	J	1.21E+02	J	μg/L	ECC-MW-30B-OCT14	10/10	No NDs	1.21E+02	NA	2.80E-01	NC	NA	NA	YES	ASL
75-69-4	TRICHLOROFLUOROMETHANE	2.80E-01	J	2.80E-01	J	µg/L	ECC-MW-27B-NOV15	1/10	2.00E-01 - 1.50E+01	2.80E-01	NA	5.20E+02	NC	NA	NA	NO	BSL

(1) Minimum and Maximum Qualifiers used in the Table include: J = estimated

(2) The maximum detected concentration was used for screening.

(3) Screening levels represent concentrations associated with residential exposure set at the lower of the risk associated with a cancer risk of 1 x 10-6 or a Hazard Quotient (HQ) HQ = 0.1. The Regional Screening Level Tables for residential tapwater were used as Screening Levels and were updated in May 2016. C = Carcinogenic; NC = Noncarcinogenic

(4) The rationale for selecting or not selecting Chemicals of Potential Concern included: ASL - Above Toxicity Screening Levels; BSL - Below Toxicity Screening Levels

TABLE 3.1-RME EXPOSURE POINT CONCENTRATION SUMMARY REASONABLE MAXIMUM EXPOSURE

Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Medium: Groundwater

Exposure Medium: Tap Water

Exposure Point	Chemical of Potential Concern		Arithmetic Mean of Detected Values	Maximum Detected Concentration	Statistical Distribution (1)	95% UCL	Exposure Point Concentration Statistic (2)	n Rationale (3)
Core of the Plume	1,1,2-TRICHLOROETHANE 1,2-DICHLOROETHANE CARBON TETRACHLORIDE CHLOROFORM CIS-1,2-DICHLOROETHYLENE METHYL TERT-BUTYL ETHER TRICHLOROETHYLENE	μg/L μg/L μg/L μg/L μg/L μg/L	4.40E-01 1.64E+00 6.50E+02 5.16E+01 2.27E+00 6.18E+00 3.03E+01	4.40E-01 2.74E+00 2.46E+03 2.22E+02 4.87E+00 2.35E+01 1.21E+02	Not Discernable Normal Gamma Gamma Normal Not Discernable Gamma	NA 1.38E+00 2.64E+03 1.78E+02 3.24E+00 NA 8.61E+01	Single Detected Value 95% KM (t) UCL 95% Adjusted Gamma UCL 95% Adjusted Gamma UCL 95% KM (t) UCL Nonparametric 95% Adjusted Gamma UCL	Max Detect ProUCL v5.1 ProUCL v5.1 ProUCL v5.1 ProUCL v5.1 Max Detect ProUCL v5.1

Notes:

(1) Order of preference for calculation of 95% UCL statistic: Normal > Gamma > Nonparametric ("Not Discernable") > Lognormal per ProUCL Output and Technical Guide.

(2) Statistical method recommended by ProUCL for calculation of 95% UCL statistic.

(3) The lesser of the 95% UCL or the maximum detected concentration is used as the Exposure Point Concentration value.

NA: Not Applicable or Not Available

Scenario Timeframe: Hypothetical Future

Medium: Groundwater

Exposure Medium: Tap water

Exposure Point	Receptor Population	Receptor Age	Exposure Route	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Core of the Plume	Worker	Adult	Ingestion	CW	Chemical Conc. In Groundwater	Table 3.1-RME	μg/L	Table 3.1-RME	Chronic Daily Intake (CDI) (mg/kg-day) =
				IR	Ingestion Rate	2.5	L/day	EPA 2014	CW x IR x EF x ED x CF
				EF	Exposure Frequency	250	days/yr	EPA 2014	x 1/BW x 1/AT
				ED	Exposure Duration	25	years	EPA 2014	
				CF	Conversion Factor	0.001	mg/µg		
				BW	Body Weight	80	kg	EPA 2014	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA 2014	
				AT-N	Averaging Time (Noncancer)	9,125	days	EPA 2014	

References:

EPA 2014: OSWER Directive 9200.1-120, Update of Standard Default Exposure Factors, February 6, 2014.

Scenario Timeframe: Hypothetical Future

Medium: Groundwater

Exposure Medium: Tap water

Exposure Point	Receptor Population	Receptor Age	Exposure Route	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Core of the Plume	Worker	Adult	Ingestion	CW	Chemical Conc. In Groundwater	Table 3.1-RME	μg/L	Table 3.1-RME	Chronic Daily Intake (CDI) (mg/kg-day) =
				IR	Ingestion Rate	1.23	L/day	EPA 2011 Table 3-1	CW x IR x EF x ED x CF
				EF	Exposure Frequency	125	days/yr	EPA 2014 (1)	x 1/BW x 1/AT
				ED	Exposure Duration	6.6	years	EPA 2011 Table 16-103	
				CF	Conversion Factor	0.001	mg/µg		
				BW	Body Weight	80	kg	EPA 2014	
				AT-C	Averaging Time (Cancer)	25,550	days	EPA 2014	
				AT-N	Averaging Time (Noncancer)	2,409	days	EPA 2014	

Notes:

(1) Professional judgment; one-half of the RME value of 250 days.

References:

EPA 2011: Exposure Factors Handbook, 2011 Edition, EPA/600/R-090/052F, September.

EPA 2014: OSWER Directive 9200.1-120, Update of Standard Default Exposure Factors, February 6, 2014.

Scenario Timeframe: Hypothetical Future Medium: Groundwater

Exposure Point	Receptor Population	Receptor Age	Exposure Route	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Core of the Plume	Resident	Young Child	Ingestion	IR EF CF BW AT-C	Chemical Conc. In Groundwater Drinking Water Ingestion Rate Exposure Frequency Exposure Duration Conversion Factor Body Weight Averaging Time (Cancer) Averaging Time (Noncancer)	Table 3.1-RME 0.78 350 6 0.001 15 25,550 2,190	μg/L L/day days/yr years mg/μg kg days days	Table 3.1-RME EPA 2014 EPA 2014 EPA 2014 EPA 2014 EPA 2014 EPA 2014	Chronic Daily Intake (CDI) (mg/kg-day) = CW x IR x EF x ED x CF x 1/BW x 1/AT
Core of the Plume	Resident	Adult	Ingestion	IR EF CF BW AT-C	Chemical Conc. In Groundwater Drinking Water Ingestion Rate Exposure Frequency Exposure Duration Conversion Factor Body Weight Averaging Time (Cancer) Averaging Time (Noncancer)	Table 3.1-RME 2.5 350 20 0.001 80 25,550 7,300	μg/L L/day days/yr years mg/μg kg days days	Table 3.1-RME EPA 2014 EPA 2014 EPA 2014 EPA 2014 EPA 2014 EPA 2014	Chronic Daily Intake (CDI) (mg/kg-day) = CW x IR x EF x ED x CF x 1/BW x 1/AT

Scenario Timeframe: Hypothetical Future Medium: Groundwater

Exposure Point	Receptor Population	Receptor Age	Exposure Route	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Oran of the Dhame	Desident	Vera Okild	Damal	0.11	Ohenvisel Oene la Onumburdur		- ()		
Core of the Plume	Resident	Young Child	Dermal	CW	Chemical Conc. In Groundwater	Table 3.1-RME	μg/L	Table 3.1-RME	Chronic Daily Intake (CDI) (mg/kg-day) = DA _{event} x SA x EV x EF x ED x CF1
				DA _{event} FA	Dermally Absorbed Dose per Event Fraction absorbed water	Calculated Chemical specific	mg/cm ² -event unitless	Calculated EPA 2004	x 1/BW x 1/AT
					Permeability Coefficient	Chemical specific	cm/hr	EPA 2004	x 1/6w x 1/A1
				Кр	Lag time	Chemical specific	hr/event	EPA 2004 EPA 2004	Inorganics:
					-	Chemical specific			DA _{event} = Kp x CW x t _{event} x CF2
				t*	Time to reach steady state	· ·	hours	EPA 2004 EPA 2004	$DA_{event} = KP X CW X t_{event} X CF2$
				В	Epidermis	Chemical specific	unitless		Ormerica
				t _{event}	Event Duration	0.54	hr/event	EPA 2014	Organics:
				SA	Skin Surface Area Available for Contact	6,378	cm ²	EPA 2014	$t_{event} < t^*$:
				EV	Event Frequency	1	events/day	EPA 2004	$DA_{event} = 2 \times FA \times Kp \times CW \times C$
				EF	Exposure Frequency	350	days/yr	EPA 2014	(sqrt((6 x τ x t _{event})/π))) x CF2
				ED	Exposure Duration	6	years	EPA 2014	
				BW	Body Weight	15	kg	EPA 2014	$t_{event} > t^*$:
				AT-C	Averaging Time (Cancer)	25,550	days	EPA 2014	DA _{event} = FA x Kp x CW x
				AT-N	Averaging Time (Noncancer)	2,190	days	EPA 2014	(t _{event} /(1+B) + 2 x т x
				CF1	Conversion Factor 1	0.001	mg/μg		((1 + 3B + 3B ²)/(1 + B ²))) x CF2
				CF2	Conversion Factor 2	0.001	L/cm ³		
Core of the Plume	Resident	Adult	Dermal	CW	Chemical Conc. In Groundwater	Table 3.1-RME	μg/L	Table 3.1-RME	Chronic Daily Intake (CDI) (mg/kg-day) =
				DA _{event}	Dermally Absorbed Dose per Event	Calculated	mg/cm ² -event	Calculated	DA _{event} x SA x EV x EF x ED x CF1
				FA	Fraction absorbed water	Chemical specific	unitless	EPA 2004	x 1/BW x 1/AT
				Кр	Permeability Coefficient	Chemical specific	cm/hr	EPA 2004	
				т	Lag time	Chemical specific	hr/event	EPA 2004	Inorganics:
				t*	Time to reach steady state	Chemical specific	hours	EPA 2004	$DA_{event} = Kp \times CW \times t_{event} \times CF2$
				В	Epidermis	Chemical specific	unitless	EPA 2004	
				÷	Event Duration	0.71	hr/event	EPA 2014	Organics:
				SA	Skin Surface Area Available for Contact	20,900	cm ²	EPA 2014	t _{event} < t*:
				EV	Event Frequency	1	events/day	EPA 2014 EPA 2004	DA _{event} = 2 x FA x Kp x CW x
				EF	Exposure Frequency	350	days/yr	EPA 2004 EPA 2014	$DA_{event} = 2 \times FA \times RP \times CW \times$ (sqrt((6 x T x t _{event})/TT))) x CF2
									(Sqrt((0 x 1 x levent)/11))) X OF2
				ED	Exposure Duration	20	years	EPA 2014	4
				BW	Body Weight	80	kg	EPA 2014	$t_{event} > t^*$:
				AT-C	Averaging Time (Cancer)	25,550	days	EPA 2014	$DA_{event} = FA \times Kp \times CW \times ((1 + D) + Q)$
				AT-N	Averaging Time (Noncancer)	7,300	days	EPA 2014	(t _{event} /(1+В) + 2 х т х

Scenario Timeframe: Hypothetical Future Medium: Groundwater

Exposure Point	Receptor Population	Receptor Age	Exposure Route	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
					Conversion Factor 1 Conversion Factor 2	0.001 0.001	mg/μ g L/cm ³		((1 + 3B + 3B ²)/(1 + B ²))) x CF2

Scenario Timeframe: Hypothetical Future Medium: Groundwater

Exposure Medium: Tap water

Exposure Point	Receptor Population	Receptor Age	Exposure Route	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Core of the Plume	Resident	Young Child	Inhalation	CW	Chemical Conc. In Groundwater	Table 3.1-RME	μg/L	Table 3.1-RME	Chronic Daily Intake (CDI) (μg/m ³) =
				CA	Chemical Conc. In Bathroom Air Maximum concentration	Calculated	mg/m ³	Schaum 1994 Equation 3 Schaum 1994	(CA x ET x EF x ED)/AT
				CA _{max}	in bathroom air	Calculated	µg/m³	Equation 4	
				t1	Time in Shower	0.24	hrs/event	Schaum 1994	CA Calculated based on CGW
				t2	Time in Bathroom after Shower	0.30	hrs/event	Schaum 1994	using Andelman model as
				f	Fraction of CGW volatilized	0.9	unitless	Schaum 1994	modified by Schaum et al.
				Fw	Shower Water Flow Rate	750	L/hr	Schaum 1994	$CA = ((CA_{max}/2) \times t1 + CA_{max} \times t2)$
				Va	Bathroom Volume	16	m³	Schaum 1994	x 1/(t1 + t2)
				ET	Exposure Time	0.54	hrs/day	EPA 2014	CA _{max} = CGW x f x Fw x t1 x 1/Va
				EF	Exposure Frequency	350	days/yr	EPA 2014	
				ED	Exposure Duration	6	years	EPA 2014	
				AT-C	Averaging Time (Cancer)	613,200	hours	EPA 2014	
				AT-N	Averaging Time (Noncancer)	52,560	hours	EPA 2014	
Core of the Plume	Resident	Adult	Inhalation	CW	Chemical Conc. In Groundwater	Table 3.1-RME	μg/L	Table 3.1-RME	Chronic Daily Intake (CDI) (µg/m ³) =
Core of the Fidine	Resident	Addit	IIIIdidi011	CA	Chemical Conc. In Bathroom Air	Calculated	mg/m ³	Schaum 1994 Equation 3 Schaum 1994	(CA x ET x EF x ED)/AT
				CA _{max}	Maximum concentration	Calculated	µg/m³	Schaum 1994 Equation 4	
				t1	Time in Shower	0.305	hrs/event	Schaum 1994	CA Calculated based on CGW
				t2	Time in Bathroom after Shower	0.405	hrs/event	Schaum 1994	using Andelman model as
				f	Fraction of CGW volatilized	0.9	unitless	Schaum 1994	modified by Schaum et al.
				Fw	Shower Water Flow Rate	750	L/hr	Schaum 1994	$CA = ((CA_{max}/2) \times t1 + CA_{max} \times t2)$
				Va	Bathroom Volume	16	m ³	Schaum 1994	x 1/(t1 + t2)
				ET	Exposure Time	0.71	hrs/day	EPA 2014	CA _{max} = CGW x f x Fw x t1 x 1/Va
				EF	Exposure Frequency	350	days/yr	EPA 2014	
				ED	Exposure Duration	20	years	EPA 2014	
				AT-C	Averaging Time (Cancer)	613,200	hours	EPA 2014	
				AT-N	Averaging Time (Noncancer)	175,200	hours	EPA 2014	

References:

EPA 2004: RAGS Part E, Dermal Assessment Manual

EPA 2014: OSWER Directive 9200.1-120, Update of Standard Default Exposure Factors, February 6, 2014.

Schaum, et al, 1994, Estimating Dermal and Inhalation Exposure to Volatile Chemicals in Domestic Water,

in Water Contamination and Health, Ed.: Wang, R.G.M., Marcel Dekker, Inc. New York.

Scenario Timeframe: Hypothetical Future

Medium: Groundwater

Exposure Point	Receptor Population	Receptor Age	Exposure Route	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Core of the Plume	Resident	Young Child	Ingestion	IR EF ED CF	Chemical Conc. In Groundwater Drinking Water Ingestion Rate Exposure Frequency Exposure Duration Conversion Factor Body Weight Averaging Time (Cancer) Averaging Time (Noncancer)	Table 3.1-RME 0.37 175 4 0.001 15 25,550 1,460	μg/L L/day days/yr years mg/μg kg days days	Table 3.1-RME EPA 2011 Table 3-1 EPA 2014 (1) EPA 2011 Table 16-5 EPA 2014 EPA 2014 EPA 2014	Chronic Daily Intake (CDI) (mg/kg-day) = CW x IR x EF x ED x CF x 1/BW x 1/AT
Core of the Plume	Resident	Adult	Ingestion	IR EF ED	Chemical Conc. In Groundwater Drinking Water Ingestion Rate Exposure Frequency Exposure Duration Conversion Factor Body Weight Averaging Time (Cancer) Averaging Time (Noncancer)	Table 3.1-RME 1.23 175 8 0.001 80 25,550 2,920	μg/L L/day days/yr years mg/μg kg days days	Table 3.1-RME EPA 2011 Table 3-1 EPA 2014 (1) EPA 2011 Table 16-5 EPA 2014 EPA 2014 EPA 2014	Chronic Daily Intake (CDI) (mg/kg-day) = CW x IR x EF x ED x CF x 1/BW x 1/AT

Scenario Timeframe: Hypothetical Future

Medium: Groundwater

Exposure Point	Receptor Population	Receptor Age	Exposure Route	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Core of the Plume	Resident	Young Child	Dermal	CW	Chemical Conc. In Groundwater	Table 3.1-RME	μg/L	Table 3.1-RME	Chronic Daily Intake (CDI) (mg/kg-day) =
	Resident	Toung Child	Dennai		Dermally Absorbed Dose per Event	Calculated	µg/∟ mg/cm²-event	Calculated	DA _{event} x SA x EV x EF x ED x CF1
				FA	Fraction absorbed water	Chemical specific	unitless	EPA 2004	x 1/BW x 1/AT
				Кр	Permeability Coefficient	Chemical specific	cm/hr	EPA 2004	
				т	Lag time	Chemical specific	hr/event	EPA 2004	Inorganics:
				t*	Time to reach steady state	Chemical specific	hours	EPA 2004	$DA_{event} = Kp \times CW \times t_{event} \times CF2$
				В	Epidermis	Chemical specific	unitless	EPA 2004	Drevent - rp x GW x tevent x GI 2
					Event Duration	0.33		EPA 2004 EPA 2004	Organiza
				t _{event} SA	Skin Surface Area Available for Contact		hr/event	EPA 2004 EPA 2014	Organics:
					-	6,378	cm ²		t _{event} < t*: DA _{event} = 2 x FA x Kp x CW x
					Event Frequency	1	events/day	EPA 2004	
				EF	Exposure Frequency	175	days/yr	EPA 2014 (1)	(sqrt((6 x τ x t _{event})/π))) x CF2
				ED	Exposure Duration	4	years	EPA 2011 Table 16-5	A
					Body Weight	15	kg	EPA 2014	$t_{event} > t^*$:
				AT-C	Averaging Time (Cancer)	25,550	days	EPA 2014	$DA_{event} = FA \times Kp \times CW \times Kp \times CW \times C$
				AT-N	Averaging Time (Noncancer)	1,460	days	EPA 2014	(t _{event} /(1+В) + 2 х т х
					Conversion Factor 1	0.001	mg/μg		((1 + 3B + 3B ²)/(1 + B ²))) x CF2
				CF2	Conversion Factor 2	0.001	L/cm ³		
Core of the Plume	Resident	Adult	Dermal	CW	Chemical Conc. In Groundwater	Table 3.1-RME	μg/L	Table 3.1-RME	Chronic Daily Intake (CDI) (mg/kg-day) =
Core of the Fidme	Resident	Addit	Dennai		Dermally Absorbed Dose per Event	Calculated	mg/cm ² -event	Calculated	DA _{event} x SA x EV x EF x ED x CF1
				FA	Fraction absorbed water	Chemical specific	unitless	EPA 2004	x 1/BW x 1/AT
								EPA 2004	x 1/6W x 1/AT
				Кр	Permeability Coefficient	Chemical specific	cm/hr		
				T	Lag time	Chemical specific	hr/event	EPA 2004	
				t*	Time to reach steady state	Chemical specific	hours	EPA 2004	$DA_{event} = Kp \times CW \times t_{event} \times CF2$
				В	Epidermis	Chemical specific	unitless	EPA 2004	
					Event Duration	0.25	hr/event		Organics:
					Skin Surface Area Available for Contact	20,900	cm ²	EPA 2014	t _{event} < t*:
					Event Frequency	1	events/day	EPA 2004	$DA_{event} = 2 \times FA \times Kp \times CW \times (100)$
				EF	Exposure Frequency	175	days/yr	EPA 2014 (1)	(sqrt((6 x τ x t _{event})/π))) x CF2
				ED	Exposure Duration	8	years	EPA 2011 Table 16-5	
					Body Weight	80	kg	EPA 2014	t _{event} > t*:
					Averaging Time (Cancer)	25,550	days	EPA 2014	DA _{event} = FA x Kp x CW x
				AT-N	Averaging Time (Noncancer)	2,920	days	EPA 2014	(t _{event} /(1+B) + 2 x т x
				CF1	Conversion Factor 1	0.001	mg/µg		((1 + 3B + 3B ²)/(1 + B ²))) x CF2

Scenario Timeframe: Hypothetical Future

Medium: Groundwater

Exposure Point	Receptor Population	Receptor Age	Exposure Route	Parameter Code	Parameter Definition	Value	Units	Rationale Reference
				CF2	Conversion Factor 2	0.001	L/cm ³	

ile/	Intake Equation/
ice	Model Name

Scenario Timeframe: Hypothetical Future

Medium: Groundwater

Exposure Medium: Tap water

Exposure Point	Receptor Population	Receptor Age	Exposure Route	Parameter Code	Parameter Definition	Value	Units	Rationale/ Reference	Intake Equation/ Model Name
Core of the Plume	Resident	Young Child	Inhalation	CW CA CA _{max} t1 t2 f Fw Va ET EF ED AT-C AT-N	Chemical Conc. In Groundwater Chemical Conc. In Bathroom Air Maximum concentration in bathroom air Time in Shower Time in Bathroom after Shower Fraction of CGW volatilized Shower Water Flow Rate Bathroom Volume Exposure Time Exposure Time Exposure Frequency Exposure Duration Averaging Time (Cancer) Averaging Time (Noncancer)	Table 3.1-RME Calculated 0.24 0.3 0.9 750 16 0.54 175 4 613,200 35,040	μg/L μg/m ³ μg/m ³ hrs/event hrs/event unitless L/hr m ³ hrs/day days/yr years hours hours	Table 3.1-RME Schaum 1994 Equation 3 Schaum 1994 Equation 4 EPA 2011 Table 16-1 Schaum 1994 Schaum 1994 Schaum 1994 EPA 2011 EPA 2011 EPA 2014 (1) EPA 2014 EPA 2014	Chronic Daily Intake (CDI) $(\mu g/m^3) =$ (CA x ET x EF x ED)/AT CA Calculated based on CGW using Andelman model as modified by Schaum et al CA = ((CA _{max} /2) x t1 + CA _{max} x t2) x 1/(t1 + t2) CA _{max} = CGW x f x Fw x t1 x 1/Va
Core of the Plume	Resident	Adult	Inhalation	CW CA CA _{max} t1 t2 f Fw Va ET EF ED AT-C AT-N	Chemical Conc. In Groundwater Chemical Conc. In Bathroom Air Maximum concentration in bathroom air Time in Shower Time in Bathroom after Shower Fraction of CGW volatilized Shower Water Flow Rate Bathroom Volume Exposure Time Exposure Time Exposure Frequency Exposure Duration Averaging Time (Cancer) Averaging Time (Noncancer)	Table 3.1-RME Calculated Calculated 0.28 0.4 0.9 750 16 0.68 175 8 613,200 70,080	μg/L μg/m ³ μg/m ³ hrs/event hrs/event unitless L/hr m ³ hrs/day days/yr years hours hours hours	Table 3.1-RME Schaum 1994 Fourtion 3 Schaum 1994 Equation 4 EPA 2011 Table 16-1 Schaum 1994 Schaum 1994 Schaum 1994 EPA 2011 EPA 2011 EPA 2014 (1) EPA 2014 EPA 2014 EPA 2014	Chronic Daily Intake (CDI) (μg/m ³) = (CA x ET x EF x ED)/AT CA Calculated based on CGW using Andelman model as modified by Schaum et al CA = ((CA _{max} /2) x t1 + CA _{max} x t2) x 1/(t1 + t2) CA _{max} = CGW x f x Fw x t1 x 1/Va

Notes:

(1) Professional judgment; one-half of the RME value of 350 days.

References:

EPA 2004: RAGS Part E, Dermal Assessment Manual

EPA 2011: Exposure Factors Handbook, 2011 Edition, EPA/600/R-090/052F, September.

Scenario Timeframe: Hypothetical Future

Medium: Groundwater

Exposure Medium: Tap water

Exposure Point	Receptor Population	Receptor Age	Exposure Route	Parameter Code	Parameter Definition	Value	Units	Rationale, Reference
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EPA 2014: OSWER Directive 9200.1-120, Update of Standard Default Exposure Factors, February 6, 2014.

Schaum, et al, 1994, Estimating Dermal and Inhalation Exposure to Volatile Chemicals in Domestic Water, in Water Contamination and Health, Ed.: Wang, R.G.M., Marcel Dekker, Inc. New York.

ale/ nce	Intake Equation/ Model Name	

TABLE 5.1

NON-CANCER TOXICITY DATA -- ORAL/DERMAL Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Chemical of Potential	Chronic/ Subchronic	Oral RfD		Oral Absorption Efficiency for	Absorbed RfD for Dermal		Primary Target	Combined Uncertainty/	RfD:Target Organ(s)	
Concern		Value	Units	Dermal [†]	Value	Units	Organ(s)	Modifying Factors	Source(s)	Date(s)
1,1,2-TRICHLOROETHANE	Chronic	4.00E-03	mg/kg-day	1	4.00E-03	mg/kg-day	Hematoglogic, Immune	1000 / 1	IRIS	6/2016
	Subchronic		mg/kg-day		4.00E-03	mg/kg-day	Liver, Immune	1000 / NA	PPRTV	4/2011
1,2-DICHLOROETHANE	Chronic	NA								
	Subchronic	2.00E-02	mg/kg-day	1	2.00E-02	mg/kg-day	Kidney	3000 / NA	PPRTV	10/2011
CARBON TETRACHLORIDE	Chronic	4.00E-03	mg/kg-day	1	4.00E-03	mg/kg-day	Liver	1000 / 1	IRIS	6/2016
	Subchronic	7.00E-03	mg/kg-day	1	7.00E-03	mg/kg-day	Liver	100 / NA	ATSDR	8/205
CHLOROFORM	Chronic	1.00E-02	mg/kg-day	1	1.00E-02	mg/kg-day	Liver	100 / 1	IRIS	6/2016
	Subchronic	1.00E-01	mg/kg-day	1	1.00E-01	mg/kg-day	Liver	100 / NA	ATSDR	9/1997
CIS-1,2-DICHLOROETHYLENE	Chronic	2.00E-03	mg/kg-day	1	2.00E-03	mg/kg-day	Urinary, Whole Body	3000 / 1	IRIS	6/2016
	Subchronic	2.00E-02	mg/kg-day	1	2.00E-02	mg/kg-day	Kidney	300 / NA	PPRTV	3/2011
METHYL TERT-BUTYL ETHER	Chronic	NA								
	Subchronic	3.00E-01	mg/kg-day	1	3.00E-01	mg/kg-day	Liver	300 / NA	ATSDR	8/1996
TRICHLOROETHYLENE	Chronic		mg/kg-day		1.00E-01	mg/kg-day	Developmental, Cardiovascular, Immunological	Multiple / 1	IRIS	6/2016
	Subchronic	NA								

NA = Not available

mg/kg-day = milligram per kilogram per day

RfD = Reference dose

+ = Source: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment (Final). Section 4.2 and Exhibit 4-1. USEPA recommends that the oral RfD should not be adjusted to estimate the absorbed dose for compounds when the absorption efficiency is greater than 0.5. Constituents with oral absorption efficiencies greater than 0.5, or without reported oral absorption efficiencies, are shown with an oral absorption efficiency of 1. Adjusted Dermal RfD = RfD (oral) x Oral to Dermal Adjustment Factor.

Sources:

ATSDR = Agency for Toxic Substances & Disease Registry. Source date indicates the dat of ASTR document. The subchronic value is based on the MRL intermediate value.

IRIS = Integrated Risk Information System. Source date indicates the date IRIS was searched.

PPRTV = Provisional Peer Reviewed Toxicity Values for Superfund. Source date indicates the date of the PPRTV document.

TABLE 5.2 NON-CANCER TOXICITY DATA -- INHALATION Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Chemical of Potential	Chronic/ Subchronic	Inhalati	ion RfC	Primary Target	Combined Uncertainty/	RfC : Target Organ(s)		
Concern		Value	Units	Organ(s)	Modifying Factors	Source(s)	Date(s)	
1,1,2-TRICHLOROETHANE	Chronic	NA						
	Subchronic	NA						
1,2-DICHLOROETHANE	Chronic	7.00E-03	mg/m ³	Neurological	3000 / NA	PPRTV	10/2010	
	Subchronic	7.00E-02	mg/m ³	Neurological	300 / NA	PPRTV	10/2010	
CARBON TETRACHLORIDE	Chronic	1.00E-01	mg/m ³	Liver	100 / 1	IRIS	6/2016	
	Subchronic	1.89E-01	mg/m ³	Liver	100 / NA	ATSDR	8/2005	
CHLOROFORM	Chronic	9.77E-02	mg/m ³	Liver	100 / NA	ATSDR	9/1997	
	Subchronic	2.44E-01	mg/m ³	Liver	100 / NA	ATSDR	9/1997	
CIS-1,2-DICHLOROETHYLENE	Chronic	NA						
	Subchronic	NA						
METHYL TERT-BUTYL ETHER	Chronic	3.00E+00	mg/m ³	Kidney, Liver, Ocular	100 / 1	IRIS	6/2016	
	Subchronic	2.52E+00	mg/m ³	Neurological	300 / NA	ATSDR	8/1996	
TRICHLOROETHYLENE	Chronic	2.00E-03	mg/m ³	Developmental, Cardiovascular, Immunological	Multiple / 1	IRIS	6/2016	
	Subchronic	NA						

NA = Not available

mg/m³ = milligram per cubic meter

RfC = Reference concentration

Sources:

ATSDR = Agency for Toxic Substances & Disease Registry. Source date indicates the date of ASTR document. The subchronic value is based on the MRL intermediate value.

IRIS = Integrated Risk Information System. Source date indicates the date IRIS was searched.

PPRTV = Provisional Peer Reviewed Toxicity Values for Superfund. Source date indicates the date of the PPRTV document.

TABLE 6.1 CANCER TOXICITY DATA -- ORAL/DERMAL Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Chemical of Potential	Oral Cancer	Oral Cancer Slope Factor			ancer Slope or Dermal	Weight of Evidence/ Cancer Guideline	Oral Cancer Slope I	
Concern	Value	Units	Dermal ^(†)	Value Units		Description	Source(s)	Date(s)
1,1,2-TRICHLOROETHANE	5.70E-02	(mg/kg-day) ⁻¹	1	5.70E-02	(mg/kg-day) ⁻¹	C (Possible human carcinogen).	IRIS	6/2016
1,2-DICHLOROETHANE	9.10E-02	(mg/kg-day) ⁻¹	1	9.10E-02	(mg/kg-day) ⁻¹	B2 (Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals)	IRIS	6/2016
CARBON TETRACHLORIDE	7.00E-02	(mg/kg-day) ⁻¹	1	7.00E-02	(mg/kg-day) ⁻¹	Likely to be carcinogenic to humans	IRIS	6/2016
CHLOROFORM	3.10E-02	(mg/kg-day) ⁻¹	1	3.10E-02	(mg/kg-day) ⁻¹	B2 (Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals)	Cal EPA	6/2016
CIS-1,2-DICHLOROETHYLENE	NA			-				
METHYL TERT-BUTYL ETHER	1.80E-03	(mg/kg-day) ⁻¹	1	1.80E-03	(mg/kg-day) ⁻¹	Considered, but not listed.	Cal EPA	6/2016
TRICHLOROETHYLENE	4.60E-02	(mg/kg-day) ⁻¹	1	4.60E-02	(mg/kg-day) ⁻¹	Carcinogenic to humans.	IRIS	6/2016

NA = Not available

mg/kg-day = milligram per kilogram per day

⁺ = Source: Risk Assessment Guidance for Superfund. Volume 1: Human Health Evaluation Manual, Part E, Supplemental Guidance for Dermal Risk Assessment (Final). Section 4.2 and Exhibit 4-1. USEPA recommends that the oral RfD should not be adjusted to estimate the absorbed dose for compounds when the absorption efficiency is greater than 0.5. Constituents with oral absorption efficiencies greater than 0.5, or without reported oral absorption efficiencies, are shown with an oral absorption efficiency of 1. Adjusted Dermal RfD = RfD (oral) / Oral to Dermal Adjustment Factor.

Sources:

Cal EPA = California EPA. Source date indicates the date Cal EPA was searched.

IRIS = Integrated Risk Information System. Source date indicates the date IRIS was searched.

TABLE 6.2 CANCER TOXICITY DATA -- INHALATION Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Chemical of Potential	Unit	Risk	Inhalation Cano	er Slope Factor	Weight of Evidence/ Cancer Guideline	Unit Risk: Inhalation Cancer Slope Factor		
Concern	Value	Value Units Value Units Descript		Description	Source(s)	Date(s)		
1,1,2-TRICHLOROETHANE	1.60E-05	(µg/m ³) ⁻¹	1.60E-05	(µg/m ³) ⁻¹	C (Possible human carcinogen).	IRIS	6/2016	
1,2-DICHLOROETHANE	2.60E-05	(µg/m ³) ⁻¹	2.60E-05	(µg/m ³) ⁻¹	B2 (Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals)	IRIS	6/2016	
CARBON TETRACHLORIDE	6.00E-06	(µg/m ³) ⁻¹	6.00E-06	(µg/m ³) ⁻¹	Likely to be carcinogenic to humans	IRIS	6/2016	
CHLOROFORM	2.30E-05	(µg/m ³) ⁻¹	2.30E-05	(µg/m ³) ⁻¹	B2 (Probable human carcinogen - based on sufficient evidence of carcinogenicity in animals)	IRIS	6/2016	
CIS-1,2-DICHLOROETHYLENE	NA							
METHYL TERT-BUTYL ETHER	2.60E-07	(µg/m ³) ⁻¹	2.60E-07	(µg/m ³) ⁻¹	Considered, but not listed.	Cal EPA	6/2016	
TRICHLOROETHYLENE	4.10E-06	(µg/m ³) ⁻¹	4.10E-06	(µg/m ³) ⁻¹	Carcinogenic to humans.	IRIS	6/2016	

NA = Not available

 μ g/m³ = microgram per cubic meter

RfC = Reference concentration

Sources:

Cal EPA = California EPA. Source date indicates the date Cal EPA was searched.

IRIS = Integrated Risk Information System. Source date indicates the date IRIS was searched.

TABLE 7.1-RME Worker CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS REASONABLE MAXIMUM EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Worker Receptor Age: Adult

	_				E	PC		Ca	ncer Risk Calculat	tions					Non-Cancer Ha	azard Calculations	
Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	Value	Units	Intake/Exposu	Intake/Exposure Concentration		CSF/Unit Risk		Intake/Exposure Concentration		RfD/RfC		Critical Effect	Hazard Quotient
					value	Units	Value	Units	Value	Units	Cancer Risk	Value	Units	Value	Units	Chucar Enect	Hazard Quotient
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	3.4E-06	mg/kg-day	5.7E-02	(mg/kg-day) ⁻¹	1.9E-07	9.4E-06	mg/kg-day	4.0E-03	mg/kg-day	Hematologic, Immune	2.4E-03
				1,2-DICHLOROETHANE	1.4E+00	µg/L	1.1E-05	mg/kg-day	9.1E-02	(mg/kg-day) ⁻¹	9.6E-07	2.9E-05	mg/kg-day	NA	mg/kg-day	NA	NA
			CARBON TETRACHLORIDE	2.5E+03	µg/L	1.9E-02	mg/kg-day	7.0E-02	(mg/kg-day) ⁻¹	1.3E-03	5.3E-02	mg/kg-day	4.0E-03	mg/kg-day	Liver	1.3E+01	
			Incestion	CHLOROFORM	1.8E+02	µg/L	1.4E-03	mg/kg-day	3.1E-02	(mg/kg-day) ⁻¹	4.2E-05	3.8E-03	mg/kg-day	1.0E-02	mg/kg-day	Liver	3.8E-01
	Tap Water	Core of the Plume	Ingestion	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	2.5E-05	mg/kg-day	NA	(mg/kg-day) ⁻¹	NA	6.9E-05	mg/kg-day	2.0E-03	mg/kg-day	Urinary, Whole Body	3.5E-02
Groundwater	rap water			METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	1.8E-04	mg/kg-day	1.8E-03	(mg/kg-day) ⁻¹	3.2E-07	5.0E-04	mg/kg-day	NA	mg/kg-day	NA	NA
				TRICHLOROETHYLENE	8.6E+01	µg/L	6.6E-04	mg/kg-day	9.3E-03	(mg/kg-day) ⁻¹	6.1E-06	1.8E-03	mg/kg-day	5.0E-04	mg/kg-day	Developmental, Cardiovascular, Immunological	3.7E+00
				TRICHLOROETHYLENE	8.6E+01	µg/L	6.6E-04	mg/kg-day	3.7E-02	(mg/kg-day) ⁻¹	2.4E-05		mg/kg-day		mg/kg-day		NA
			Exposure Route	Total							1.4E-03						1.7E+01
		Exposure Point	Total								1.4E-03						1.7E+01
	Exposure Medium Total										1.4E-03						1.7E+01
Medium Total for	Medium Total for Child										1.4E-03						1.7E+01
	Total of Receptor Risks Across All Media 1.4E-0										1.4E-03	Total of Receptor Hazards Across All Media					1.7E+01

Notes:

CSF = Cancer Slope Factor

EPC = Exposure Point Concentration

HI = Hazard Index

NA = Not Applicable or Not Available

RfD/RfC = Reference Dose/Reference Concentration

Trichloroethylene was evaluated for both mutagenic risk to the kidney and non-mutagenic risk to the liver. The total risk for trichloroethylene is summed in Table 9.1-RME

Age-weighted average (AWA) age-dependent adjustment factors (ADAFs) were applied to cancer CSF for constituents acting via a mutagenic mode of action (MMOA).

Total Development, Immune & Cardiovascular HI Across All Media =
--

Total Hematologic and Immune HI Across	All Media =

Total Live	HI Across	All Media =

3.7.E+00
2.4.E-03
1.4.E+01
3.5.E-02

TABLE 7.1-CTE Worker CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS CENTRAL TENDENCY EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Worker Receptor Age: Adult

					EI	PC		Ca	ncer Risk Calcula	tions					Non-Cancer Ha	zard Calculations	
Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	Value Units		Intake/Exposu	ntake/Exposure Concentration CSF/Unit Risk		Jnit Risk	Cancer Risk	Intake/Exposure Concentration		RfD/RfC		Critical Effect	Hazard Quotient
					value	UTIILS	Value	Units	Value	Units	Calicel Kisk	Value	Units	Value	Units	Childai Ellect	Hazaru Quotient
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	2.2E-07	mg/kg-day	5.7E-02	(mg/kg-day)-1	1.25E-08	2.3E-06	mg/kg-day	4.0E-03	mg/kg-day	Hematologic, Immune	5.8E-04
				1,2-DICHLOROETHANE	1.4E+00	µg/L	6.8E-07	mg/kg-day	9.1E-02	(mg/kg-day) ⁻¹	6.23E-08	7.3E-06	mg/kg-day	NA	mg/kg-day	NA	NA
				CARBON TETRACHLORIDE	2.5E+03	µg/L	1.2E-03	mg/kg-day	7.0E-02	(mg/kg-day) ⁻¹	8.55E-05	1.3E-02	mg/kg-day	4.0E-03	mg/kg-day	Liver	3.2E+00
			Ingestion	CHLOROFORM	1.8E+02	µg/L	8.8E-05	mg/kg-day	3.1E-02	(mg/kg-day) ⁻¹	2.74E-06	9.4E-04	mg/kg-day	1.0E-02	mg/kg-day	Liver	9.4E-02
	Tap Water	Core of the Plume	ingestion	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	1.6E-06	mg/kg-day	NA	(mg/kg-day)-1	NA	1.7E-05	mg/kg-day	2.0E-03	mg/kg-day	Urinary, Whole Body	8.5E-03
Groundwater	rap water			METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	1.2E-05	mg/kg-day	1.8E-03	(mg/kg-day) ⁻¹	2.10E-08	1.2E-04	mg/kg-day	NA	mg/kg-day	NA	NA
				TRICHLOROETHYLENE	8.6E+01	µg/L	4.3E-05	mg/kg-day	9.3E-03	(mg/kg-day) ⁻¹	3.97E-07	4.5E-04	mg/kg-day	5.0E-04	mg/kg-day	Developmental, Cardiovascular, Immunological	9.1E-01
				TRICHLOROETHYLENE	8.6E+01	µg/L	4.3E-05	mg/kg-day	3.7E-02	(mg/kg-day) ⁻¹	1.58E-06		mg/kg-day		mg/kg-day		NA
			Exposure Route T	otal							9.0E-05						4.2E+00
		Exposure Point T	Fotal								9.0E-05						4.2E+00
	Exposure Mediu	im Total									9.0E-05						4.2E+00
Medium Total fo	r Child										9.0E-05						4.2E+00
								Total	of Receptor Risk	s Across All Media	9.0E-05					Total of Receptor Hazards Across All Media	4.2E+00

Notes:

CSF = Cancer Slope Factor

EPC = Exposure Point Concentration

HI = Hazard Index

NA = Not Applicable or Not Available

RfD/RfC = Reference Dose/Reference Concentration

Trichloroethylene was evaluated for both mutagenic risk to the kidney and non-mutagenic risk to the liver. The total risk for trichloroethylene is summed in Table 9.1-CTE

Age-weighted average (AWA) age-dependent adjustment factors (ADAFs) were applied to cancer CSF for constituents acting via a mutagenic mode of action (MMOA).

Total Development	Immune & Cardiovascular	HI Across All Media =

Total Hematologic & Immune HI Across All Media =	

ic & Immune HI Across All Media =	5.8.E-04
Total Liver HI Across All Media =	3.3.E+00

9.1.E-01

TABLE 7.2-RME Resident CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS REASONABLE MAXIMUM EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident

Receptor Age: Young Child

					E	PC		Car	ncer Risk Calculat	ions					Non-Cancer H	azard Calculations	
Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	Value	Units	Intake/Exposur	e Concentration	CSF/L	Jnit Risk	Cancer Risk	Intake/Exposur	re Concentration	RfE	D/RfC	Critical Effect	
	modulin				value	Units	Value	Units	Value	Units	Cancer Risk	Value	Units	Value	Units	Critical Effect	Hazard Quotient
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	1.9E-06	mg/kg-day	5.7E-02	(mg/kg-day) ⁻¹	1.1E-07	2.2E-05	mg/kg-day	4.0E-03	mg/kg-day	Hematologic, Immune	5.5E-03
				1,2-DICHLOROETHANE	1.4E+00	µg/L	5.9E-06	mg/kg-day	9.1E-02	(mg/kg-day) ⁻¹	5.4E-07	6.9E-05	mg/kg-day	NA	mg/kg-day	NA	NA
				CARBON TETRACHLORIDE	2.5E+03	µg/L	1.1E-02	mg/kg-day	7.0E-02	(mg/kg-day) ⁻¹	7.4E-04	1.2E-01	mg/kg-day	4.0E-03	mg/kg-day	Liver	3.1E+01
			Ingestion	CHLOROFORM	1.8E+02	µg/L	7.6E-04	mg/kg-day	3.1E-02	(mg/kg-day) ⁻¹	2.4E-05	8.9E-03	mg/kg-day	1.0E-02	mg/kg-day	Liver	8.9E-01
			ingestion	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	1.4E-05	mg/kg-day	NA	(mg/kg-day) ⁻¹	NA	1.6E-04	mg/kg-day	2.0E-03	mg/kg-day	Urinary, Whole Body	8.1E-02
				METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	1.0E-04	mg/kg-day	1.8E-03	(mg/kg-day) ⁻¹	1.8E-07	1.2E-03	mg/kg-day	NA	mg/kg-day	NA	NA
				TRICHLOROETHYLENE	8.6E+01	µg/L	3.7E-04	mg/kg-day	5.0E-02	(mg/kg-day) ⁻¹	1.8E-05	4.3E-03	mg/kg-day	5.0E-04	mg/kg-day	Developmental, Cardiovascular, Immunological	8.6E+00
				TRICHLOROETHYLENE	8.6E+01	µg/L	3.7E-04	mg/kg-day	3.7E-02	(mg/kg-day) ⁻¹	1.4E-05		mg/kg-day		mg/kg-day		NA
			Exposure Route	Total							7.9E-04						4.0E+01
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	1.2E-07	mg/kg-day	5.7E-02	(mg/kg-day) ⁻¹	6.9E-09	1.4E-06	mg/kg-day	4.0E-03	mg/kg-day	Hematologic, Immune	3.5E-04
				1,2-DICHLOROETHANE	1.4E+00	µg/L	2.5E-07	mg/kg-day	9.1E-02	(mg/kg-day) ⁻¹	2.3E-08	2.9E-06	mg/kg-day	NA	mg/kg-day	NA	NA
				CARBON TETRACHLORIDE	2.5E+03	µg/L	2.5E-03	mg/kg-day	7.0E-02	(mg/kg-day) ⁻¹	1.7E-04	2.9E-02	mg/kg-day	4.0E-03	mg/kg-day	Liver	7.3E+00
			Dermal	CHLOROFORM	1.8E+02	µg/L	6.0E-05	mg/kg-day	3.1E-02	(mg/kg-day) ⁻¹	1.9E-06	7.0E-04	mg/kg-day	1.0E-02	mg/kg-day	Liver	7.0E-02
	Tap Water	Core of the Plume	Dermai	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	1.5E-06	mg/kg-day	NA	(mg/kg-day) ⁻¹	NA	1.8E-05	mg/kg-day	2.0E-03	mg/kg-day	Urinary, Whole Body	8.9E-03
Groundwater	rap water			METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	2.0E-06	mg/kg-day	1.8E-03	(mg/kg-day) ⁻¹	3.6E-09	2.4E-05	mg/kg-day	NA	mg/kg-day	NA	NA
				TRICHLOROETHYLENE	8.6E+01	µg/L	5.4E-05	mg/kg-day	5.0E-02	(mg/kg-day) ⁻¹	2.7E-06	6.3E-04	mg/kg-day	5.0E-04	mg/kg-day	Developmental, Cardiovascular, Immunological	1.3E+00
				TRICHLOROETHYLENE	8.6E+01	µg/L	5.4E-05	mg/kg-day	3.7E-02	(mg/kg-day) ⁻¹	2.0E-06		mg/kg-day		mg/kg-day		NA
			Exposure Route	Total							1.8E-04						8.6E+00
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	5.6E-03	μg/m ³	1.6E-05	(µg/m ³) ⁻¹	8.9E-08	6.5E-05	mg/m ³	NA	mg/m ³	NA	NA
				1,2-DICHLOROETHANE	1.4E+00	µg/L	1.7E-02	μg/m³	2.6E-05	(µg/m ³) ⁻¹	4.5E-07	2.0E-04	mg/m ³	7.0E-03	mg/m ³	CNS	2.9E-02
				CARBON TETRACHLORIDE	2.5E+03	µg/L	3.1E+01	μg/m³	6.0E-06	(µg/m ³) ⁻¹	1.9E-04	3.6E-01	mg/m ³	1.0E-01	mg/m ³	Liver	3.6E+00
			Inhalation	CHLOROFORM	1.8E+02	µg/L	2.3E+00	μg/m ³	2.3E-05	(µg/m ³) ⁻¹	5.2E-05	2.6E-02	mg/m ³	9.8E-02	mg/m ³	Liver	2.7E-01
			Thindiation	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	4.1E-02	μg/m ³	NA	(µg/m ³) ⁻¹	NA	4.8E-04	mg/m ³	NA	mg/m ³	NA	NA
				METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	3.0E-01	μg/m ³	2.6E-07	(µg/m ³) ⁻¹	7.7E-08	3.5E-03	mg/m ³	3.0E+00	mg/m ³	Kidney, Liver, Ocular	1.2E-03
				TRICHLOROETHYLENE	8.6E+01	µg/L	1.1E+00	μg/m ³	5.3E-06	(µg/m ³) ⁻¹	5.8E-06	1.3E-02	mg/m ³	2.0E-03	mg/m ³	Developmental, Cardiovascular, Immunological	6.3E+00
				TRICHLOROETHYLENE	8.6E+01	µg/L	1.1E+00	μg/m ³	3.1E-06	(µg/m ³) ⁻¹	3.4E-06		mg/m ³		mg/m ³		NA

TABLE 7.2-RME Resident CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS REASONABLE MAXIMUM EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident Receptor Age: Young Child

	_				E	PC		Ca	ncer Risk Calculati	ions		Non-Cancer Hazard Calculations							
Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	m v.		Intake/Exposure Concentration CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		n RfD/RfC		Critical Effect	Hazard Quotient				
					Value	Units	Value	Units	Value	Units	Cancer Risk	Value	Units	Value	Units	Chucar Enect	Hazard Quotient		
	Exposure Route Total										2.5E-04								
		Exposure Point	Total								1.2E-03								
	Exposure Mediu	ım Total									1.2E-03						5.9E+01		
Medium Total fo	r Child										1.2E-03						5.9E+01		
	Total of Receptor Risks Across All Me										1.2E-03					Total of Receptor Hazards Across All Media	5.9E+01		

Notes:

CNS = Central Nervous System

CSF = Cancer Slope Factor

EPC = Exposure Point Concentration

HI = Hazard Index

NA = Not Applicable or Not Available

RfD/RfC = Reference Dose/Reference Concentration

Trichloroethylene was evaluated for both mutagenic risk to the kidney and non-mutagenic risk to the liver. The total risk for trichloroethylene is summed in Table 9.3-RME

Age-weighted average (AWA) age-dependent adjustment factors (ADAFs) were applied to cancer CSF for constituents acting via a mutagenic mode of action (MMOA).

1.6.E+01
5.8.E-03
1.2.E-03
4.3.E+01
9.0.E-02

Total Development, Immune & Cardiovascular HI Across All Media =

Total Hematologic & Immune HI Across All Media =

Total Kidney, Liver & Ocular HI Across All Media =

Total Liver HI Across All Media =

TABLE 7.2-CTE Resident CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS CENTRAL TENDENCY EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident

Receptor Age: Young Child

					E	PC		Ca	ncer Risk Calculat	ions					Non-Cancer Ha	azard Calculations	
Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	Makia	Linha	Intake/Exposur	e Concentration	CSF/L	Jnit Risk	Cancer Risk	Intake/Exposur	re Concentration	RfD/RfC		Critical Effect	Hazard Quotient
	mealam				Value	Units	Value	Units	Value	Units	Cancer Risk	Value	Units	Value	Units	Critical Effect	Hazard Quotient
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	2.9E-07	mg/kg-day	5.7E-02	(mg/kg-day) ⁻¹	1.7E-08	5.1E-06	mg/kg-day	4.0E-03	mg/kg-day	Hematologic, Immune	1.3E-03
				1,2-DICHLOROETHANE	1.4E+00	µg/L	9.2E-07	mg/kg-day	9.1E-02	(mg/kg-day) ⁻¹	8.4E-08	1.6E-05	mg/kg-day	NA	mg/kg-day	NA	NA
				CARBON TETRACHLORIDE	2.5E+03	µg/L	1.6E-03	mg/kg-day	7.0E-02	(mg/kg-day) ⁻¹	1.1E-04	2.9E-02	mg/kg-day	4.0E-03	mg/kg-day	Liver	7.2E+00
			Ingestion	CHLOROFORM	1.8E+02	µg/L	1.2E-04	mg/kg-day	3.1E-02	(mg/kg-day) ⁻¹	3.7E-06	2.1E-03	mg/kg-day	1.0E-02	mg/kg-day	Liver	2.1E-01
			ingestion	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	2.2E-06	mg/kg-day	NA	(mg/kg-day) ⁻¹	NA	3.8E-05	mg/kg-day	2.0E-03	mg/kg-day	Urinary, Whole Body	1.9E-02
				METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	1.6E-05	mg/kg-day	1.8E-03	(mg/kg-day) ⁻¹	2.8E-08	2.7E-04	mg/kg-day	NA	mg/kg-day	NA	NA
				TRICHLOROETHYLENE	8.6E+01	µg/L	5.7E-05	mg/kg-day	5.0E-02	(mg/kg-day) ⁻¹	2.8E-06	1.0E-03	mg/kg-day	5.0E-04	mg/kg-day	Developmental, Cardiovascular, Immunological	2.0E+00
				TRICHLOROETHYLENE	8.6E+01	µg/L	5.7E-05	mg/kg-day	3.7E-02	(mg/kg-day) ⁻¹	2.1E-06		mg/kg-day		mg/kg-day		NA
			Exposure Route	Total							1.2E-04						9.4E+00
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	3.1E-08	mg/kg-day	5.7E-02	(mg/kg-day) ⁻¹	1.8E-09	5.5E-07	mg/kg-day	4.0E-03	mg/kg-day	Hematologic, Immune	1.4E-04
				1,2-DICHLOROETHANE	1.4E+00	µg/L	6.6E-08	mg/kg-day	9.1E-02	(mg/kg-day) ⁻¹	6.0E-09	1.1E-06	mg/kg-day	NA	mg/kg-day	NA	NA
				CARBON TETRACHLORIDE	2.5E+03	µg/L	6.5E-04	mg/kg-day	7.0E-02	(mg/kg-day) ⁻¹	4.5E-05	1.1E-02	mg/kg-day	4.0E-03	mg/kg-day	Liver	2.8E+00
			Dermal	CHLOROFORM	1.8E+02	µg/L	1.6E-05	mg/kg-day	3.1E-02	(mg/kg-day) ⁻¹	4.9E-07	2.8E-04	mg/kg-day	1.0E-02	mg/kg-day	Liver	2.8E-02
	Tap Water	Core of the Plume		CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	4.0E-07	mg/kg-day	NA	(mg/kg-day) ⁻¹	NA	7.0E-06	mg/kg-day	2.0E-03	mg/kg-day	Urinary, Whole Body	3.5E-03
Groundwater	Tap Water			METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	5.3E-07	mg/kg-day	1.8E-03	(mg/kg-day) ⁻¹	9.5E-10	9.2E-06	mg/kg-day	NA	mg/kg-day	NA	NA
				TRICHLOROETHYLENE	8.6E+01	µg/L	1.4E-05	mg/kg-day	5.0E-02	(mg/kg-day) ⁻¹	6.9E-07	2.4E-04	mg/kg-day	5.0E-04	mg/kg-day	Developmental, Cardiovascular, Immunological	4.9E-01
				TRICHLOROETHYLENE	8.6E+01	µg/L	1.4E-05	mg/kg-day	3.7E-02	(mg/kg-day) ⁻¹	5.2E-07		mg/kg-day		mg/kg-day		NA
			Exposure Route	Total							4.7E-05						3.4E+00
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	1.9E-03	μg/m ³	1.6E-05	(µg/m ³) ⁻¹	3.0E-08	3.2E-05	mg/m ³	NA	mg/m ³	NA	NA
				1,2-DICHLOROETHANE	1.4E+00	µg/L	5.8E-03	μg/m ³	2.6E-05	(µg/m ³) ⁻¹	1.5E-07	1.0E-04	mg/m ³	7.0E-03	mg/m ³	CNS	1.5E-02
				CARBON TETRACHLORIDE	2.5E+03	µg/L	1.0E+01	μg/m ³	6.0E-06	(µg/m ³) ⁻¹	6.2E-05	1.8E-01	mg/m ³	1.0E-01	mg/m ³	Liver	1.8E+00
			Inhalation	CHLOROFORM	1.8E+02	µg/L	7.5E-01	μg/m ³	2.3E-05	(µg/m ³) ⁻¹	1.7E-05	1.3E-02	mg/m ³	9.8E-02	mg/m ³	Liver	1.3E-01
			minalation	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	1.4E-02	μg/m ³	NA	(µg/m ³) ⁻¹	NA	2.4E-04	mg/m ³	NA	mg/m ³	NA	NA
				METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	9.9E-02	μg/m ³	2.6E-07	(µg/m ³) ⁻¹	2.6E-08	1.7E-03	mg/m ³	3.0E+00	mg/m ³	Kidney, Liver, Ocular	5.8E-04
				TRICHLOROETHYLENE	8.6E+01	µg/L	3.6E-01	μg/m ³	5.3E-06	(µg/m ³) ⁻¹	1.9E-06	6.3E-03	mg/m ³	2.0E-03	mg/m ³	Developmental, Cardiovascular, Immunological	3.2E+00
				TRICHLOROETHYLENE	8.6E+01	µg/L	3.6E-01	μg/m ³	3.1E-06	(µg/m ³) ⁻¹	1.1E-06		mg/m ³		mg/m ³		NA

TABLE 7.2-CTE Resident CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS CENTRAL TENDENCY EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident Receptor Age: Young Child

	_				E	PC		Ca	ncer Risk Calculati	ions		Non-Cancer Hazard Calculations								
Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	Value	Units	Intake/Exposur	Intake/Exposure Concentration CSF/Unit Risk		Cancer Risk	Intake/Exposure Concentration		n RfD/RfC		Critical Effect	Hazard Quotient				
					value	Units	Value	Units	Value	Units	Cancer Risk	Value	Units	Value	Units	Chucar Enect	Hazard Quotient			
			Exposure Route	Fotal							8.3E-05						5.1E+00			
		Exposure Point	Total								2.5E-04									
	Exposure Mediu	ım Total									2.5E-04						1.8E+01			
Medium Total fo	r Child										2.5E-04						1.8E+01			
	Total of Receptor Risks Across All Me										2.5E-04					Total of Receptor Hazards Across All Media	1.8E+01			

Notes:

CNS = Central Nervous System

CSF = Cancer Slope Factor

EPC = Exposure Point Concentration

HI = Hazard Index

NA = Not Applicable or Not Available

RfD/RfC = Reference Dose/Reference Concentration

Trichloroethylene was evaluated for both mutagenic risk to the kidney and non-mutagenic risk to the liver. The total risk for trichloroethylene is summed in Table 9.3-CTE

Age-weighted average (AWA) age-dependent adjustment factors (ADAFs) were applied to cancer CSF for constituents acting via a mutagenic mode of action (MMOA).

5.7.E+00
1.4.E-03
5.8.E-04
1.2.E+01
2.2.E-02

Total Development, Immune & Cardiovascular HI Across All Media =

Total Hematologic & Immune HI Across All Media =

Total Kidney, Liver & Ocular HI Across All Media =

Total Liver HI Across All Media =

TABLE 7.3-RME Resident CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS REASONABLE MAXIMUM EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident

Receptor Age: Adult

	_				E	PC		Car	ncer Risk Calculat	ions					Non-Cancer H	azard Calculations	
Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	Value	Units	Intake/Exposur	e Concentration	CSF/L	Jnit Risk	Cancer Risk	Intake/Exposu	re Concentration	RfD	D/RfC	Critical Effect	Hazard Quotient
					value	Units	Value	Units	Value	Units	Cancer Risk	Value	Units	Value	Units		Hazard Quotient
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	3.8E-06	mg/kg-day	5.7E-02	(mg/kg-day) ⁻¹	2.1E-07	1.3E-05	mg/kg-day	4.0E-03	mg/kg-day	Hematologic, Immune	3.3E-03
				1,2-DICHLOROETHANE	1.4E+00	µg/L	1.2E-05	mg/kg-day	9.1E-02	(mg/kg-day) ⁻¹	1.1E-06	4.1E-05	mg/kg-day	NA	mg/kg-day	NA	NA
				CARBON TETRACHLORIDE	2.5E+03	µg/L	2.1E-02	mg/kg-day	7.0E-02	(mg/kg-day) ⁻¹	1.5E-03	7.4E-02	mg/kg-day	4.0E-03	mg/kg-day	Liver	1.8E+01
			Ingestion	CHLOROFORM	1.8E+02	µg/L	1.5E-03	mg/kg-day	3.1E-02	(mg/kg-day) ⁻¹	4.7E-05	5.3E-03	mg/kg-day	1.0E-02	mg/kg-day	Liver	5.3E-01
			ingestion	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	2.8E-05	mg/kg-day	NA	(mg/kg-day) ⁻¹	NA	9.7E-05	mg/kg-day	2.0E-03	mg/kg-day	Urinary, Whole Body	4.9E-02
				METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	2.0E-04	mg/kg-day	1.8E-03	(mg/kg-day) ⁻¹	3.6E-07	7.0E-04	mg/kg-day	NA	mg/kg-day	NA	NA
				TRICHLOROETHYLENE	8.6E+01	µg/L	7.4E-04	mg/kg-day	9.3E-03	(mg/kg-day) ⁻¹	6.9E-06	2.6E-03	mg/kg-day	5.0E-04	mg/kg-day	Developmental, Cardiovascular, Immunological	5.2E+00
				TRICHLOROETHYLENE	8.6E+01	µg/L	7.4E-04	mg/kg-day	3.7E-02	(mg/kg-day) ⁻¹	2.7E-05		mg/kg-day		mg/kg-day		NA
			Exposure Route 1	Fotal							1.6E-03						2.4E+01
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	2.8E-07	mg/kg-day	5.7E-02	(mg/kg-day) ⁻¹	1.6E-08	9.9E-07	mg/kg-day	4.0E-03	mg/kg-day	Hematologic, Immune	2.5E-04
				1,2-DICHLOROETHANE	1.4E+00	µg/L	5.9E-07	mg/kg-day	9.1E-02	(mg/kg-day) ⁻¹	5.4E-08	2.1E-06	mg/kg-day	NA	mg/kg-day	NA	NA
				CARBON TETRACHLORIDE	2.5E+03	µg/L	5.8E-03	mg/kg-day	7.0E-02	(mg/kg-day) ⁻¹	4.1E-04	2.0E-02	mg/kg-day	4.0E-03	mg/kg-day	Liver	5.1E+00
			Dermal	CHLOROFORM	1.8E+02	µg/L	1.4E-04	mg/kg-day	3.1E-02	(mg/kg-day) ⁻¹	4.4E-06	5.0E-04	mg/kg-day	1.0E-02	mg/kg-day	Liver	5.0E-02
	Tap Water	Core of the Plume		CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	3.6E-06	mg/kg-day	NA	(mg/kg-day) ⁻¹	NA	1.3E-05	mg/kg-day	2.0E-03	mg/kg-day	Urinary, Whole Body	6.3E-03
Groundwater	Tap Water			METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	4.7E-06	mg/kg-day	1.8E-03	(mg/kg-day) ⁻¹	8.5E-09	1.7E-05	mg/kg-day	NA	mg/kg-day	NA	NA
				TRICHLOROETHYLENE	8.6E+01	µg/L	1.3E-04	mg/kg-day	9.3E-03	(mg/kg-day) ⁻¹	1.2E-06	4.4E-04	mg/kg-day	5.0E-04	mg/kg-day	Developmental, Cardiovascular, Immunological	8.8E-01
				TRICHLOROETHYLENE	8.6E+01	µg/L	1.3E-04	mg/kg-day	3.7E-02	(mg/kg-day) ⁻¹	4.7E-06		mg/kg-day		mg/kg-day		NA
			Exposure Route 1	Fotal		-					4.2E-04						6.1E+00
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	3.3E-02	μg/m ³	1.6E-05	(µg/m ³) ⁻¹	5.3E-07	1.2E-04	mg/m ³	NA	mg/m ³	NA	NA
				1,2-DICHLOROETHANE	1.4E+00	µg/L	1.0E-01	μg/m ³	2.6E-05	(µg/m ³) ⁻¹	2.7E-06	3.6E-04	mg/m ³	7.0E-03	mg/m ³	CNS	5.2E-02
				CARBON TETRACHLORIDE	2.5E+03	µg/L	1.9E+02	μg/m ³	6.0E-06	(µg/m ³) ⁻¹	1.1E-03	6.5E-01	mg/m ³	1.0E-01	mg/m ³	Liver	6.5E+00
			Inhalation	CHLOROFORM	1.8E+02	µg/L	1.3E+01	μg/m ³	2.3E-05	(µg/m ³) ⁻¹	3.1E-04	4.7E-02	mg/m ³	9.8E-02	mg/m ³	Liver	4.8E-01
			minalation	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	2.4E-01	μg/m³	NA	(µg/m ³) ⁻¹	NA	8.5E-04	mg/m ³	NA	mg/m ³	NA	NA
				METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	1.8E+00	μg/m³	2.6E-07	(µg/m ³) ⁻¹	4.6E-07	6.2E-03	mg/m ³	3.0E+00	mg/m ³	Kidney, Liver, Ocular	2.1E-03
				TRICHLOROETHYLENE	8.6E+01	µg/L	6.5E+00	μg/m ³	1.0E-06	(µg/m ³) ⁻¹	6.5E-06	2.3E-02	mg/m ³	2.0E-03	mg/m ³	Developmental, Cardiovascular, Immunological	1.1E+01
				TRICHLOROETHYLENE	8.6E+01	µg/L	6.5E+00	μg/m ³	3.1E-06	(µg/m ³) ⁻¹	2.0E-05		mg/m ³		mg/m ³		NA

TABLE 7.3-RME Resident CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS REASONABLE MAXIMUM EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident Receptor Age: Adult

	_	Exposure		EPC Cancer Risk Calculations							Non-Cancer Hazard Calculations								
Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	Value	Value	Value	Lipite	Intake/Exposur	Intake/Exposure Concentration		CSF/Unit Risk		Intake/Exposur	re Concentration	RfD/RfC		Critical Effect	Hazard Quotient
					value	Value Units		Units	Value	Units	Cancer Risk	Value	Units	Value	Units	Chucar Enect	Hazard Quotient		
	Exposure Route Total									1.5E-03						1.8E+01			
		Exposure Point	Fotal								3.4E-03								
	Exposure Mediu	ım Total									3.4E-03								
Medium Total fo	Total for Child										3.4E-03						4.9E+01		
								Total	of Receptor Risks	Across All Media	3.4E-03	Total of Receptor Hazards Across All Me				Total of Receptor Hazards Across All Media	4.9E+01		

Notes:

CNS = Central Nervous System

CSF = Cancer Slope Factor

EPC = Exposure Point Concentration

HI = Hazard Index

NA = Not Applicable or Not Available

RfD/RfC = Reference Dose/Reference Concentration

Trichloroethylene was evaluated for both mutagenic risk to the kidney and non-mutagenic risk to the liver. The total risk for trichloroethylene is summed in Table 9.3-RME

Age-weighted average (AWA) age-dependent adjustment factors (ADAFs) were applied to cancer CSF for constituents acting via a mutagenic mode of action (MMOA).

1.7.E+01
3.5.E-03
2.1.E-03
3.1.E+01
5.5.E-02

Total Development, Immune & Cardiovascular HI Across All Media =

Total Hematologic & Immune HI Across All Media =

Total Kidney, Liver & Ocular HI Across All Media =

Total Liver HI Across All Media =

TABLE 7.3-CTE Resident CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS CENTRAL TENDENCY EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident

Receptor Age: Adult

					E	PC		Car	ncer Risk Calculat	ions					Non-Cancer Ha	azard Calculations	
Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	Value	Units	Intake/Exposur	e Concentration	CSF/L	Jnit Risk	Cancer Risk	Intake/Exposur	re Concentration	RfD	0/RfC	Critical Effect	Hazard Quotient
					value	OTIKS	Value	Units	Value	Units	Cancel Risk	Value	Units	Value	Units	Childai Enect	Hazard Quotient
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	3.7E-07	mg/kg-day	5.7E-02	(mg/kg-day) ⁻¹	2.1E-08	3.2E-06	mg/kg-day	4.0E-03	mg/kg-day	Hematologic, Immune	8.1E-04
				1,2-DICHLOROETHANE	1.4E+00	µg/L	1.2E-06	mg/kg-day	9.1E-02	(mg/kg-day) ⁻¹	1.1E-07	1.0E-05	mg/kg-day	NA	mg/kg-day	NA	NA
				CARBON TETRACHLORIDE	2.5E+03	µg/L	2.1E-03	mg/kg-day	7.0E-02	(mg/kg-day) ⁻¹	1.4E-04	1.8E-02	mg/kg-day	4.0E-03	mg/kg-day	Liver	4.5E+00
			Ingestion	CHLOROFORM	1.8E+02	µg/L	1.5E-04	mg/kg-day	3.1E-02	(mg/kg-day) ⁻¹	4.6E-06	1.3E-03	mg/kg-day	1.0E-02	mg/kg-day	Liver	1.3E-01
			ingestion	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	2.7E-06	mg/kg-day	NA	(mg/kg-day) ⁻¹	NA	2.4E-05	mg/kg-day	2.0E-03	mg/kg-day	Urinary, Whole Body	1.2E-02
				METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	2.0E-05	mg/kg-day	1.8E-03	(mg/kg-day) ⁻¹	3.6E-08	1.7E-04	mg/kg-day	NA	mg/kg-day	NA	NA
				TRICHLOROETHYLENE	8.6E+01	µg/L	7.2E-05	mg/kg-day	9.3E-03	(mg/kg-day) ⁻¹	6.7E-07	6.3E-04	mg/kg-day	5.0E-04	mg/kg-day	Developmental, Cardiovascular, Immunological	1.3E+00
				TRICHLOROETHYLENE	8.6E+01	µg/L	7.2E-05	mg/kg-day	3.7E-02	(mg/kg-day) ⁻¹	2.7E-06		mg/kg-day		mg/kg-day		NA
		[Exposure Route	Total							1.5E-04						5.9E+00
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	3.4E-08	mg/kg-day	5.7E-02	(mg/kg-day) ⁻¹	1.9E-09	2.9E-07	mg/kg-day	4.0E-03	mg/kg-day	Hematologic, Immune	7.4E-05
				1,2-DICHLOROETHANE	1.4E+00	µg/L	7.0E-08	mg/kg-day	9.1E-02	(mg/kg-day) ⁻¹	6.4E-09	6.1E-07	mg/kg-day	NA	mg/kg-day	NA	NA
				CARBON TETRACHLORIDE	2.5E+03	µg/L	6.9E-04	mg/kg-day	7.0E-02	(mg/kg-day) ⁻¹	4.9E-05	6.1E-03	mg/kg-day	4.0E-03	mg/kg-day	Liver	1.5E+00
				CHLOROFORM	1.8E+02	µg/L	1.7E-05	mg/kg-day	3.1E-02	(mg/kg-day) ⁻¹	5.2E-07	1.5E-04	mg/kg-day	1.0E-02	mg/kg-day	Liver	1.5E-02
	T	Core of the Plume	Dermal	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	4.3E-07	mg/kg-day	NA	(mg/kg-day) ⁻¹	NA	3.7E-06	mg/kg-day	2.0E-03	mg/kg-day	Urinary, Whole Body	1.9E-03
Groundwater	Tap Water	1 Millio		METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	5.6E-07	mg/kg-day	1.8E-03	(mg/kg-day) ⁻¹	1.0E-09	4.9E-06	mg/kg-day	NA	mg/kg-day	NA	NA
				TRICHLOROETHYLENE	8.6E+01	µg/L	1.5E-05	mg/kg-day	9.3E-03	(mg/kg-day) ⁻¹	1.4E-07	1.3E-04	mg/kg-day	5.0E-04	mg/kg-day	Developmental, Cardiovascular, Immunological	2.6E-01
				TRICHLOROETHYLENE	8.6E+01	µg/L	1.5E-05	mg/kg-day	3.7E-02	(mg/kg-day) ⁻¹	5.5E-07		mg/kg-day		mg/kg-day		NA
		[Exposure Route	Total							5.0E-05						1.8E+00
				1,1,2-TRICHLOROETHANE	4.4E-01	µg/L	5.9E-03	μg/m ³	1.6E-05	(µg/m ³) ⁻¹	9.4E-08	5.1E-05	mg/m ³	NA	mg/m ³	NA	NA
				1,2-DICHLOROETHANE	1.4E+00	µg/L	1.8E-02	μg/m ³	2.6E-05	(µg/m ³) ⁻¹	4.8E-07	1.6E-04	mg/m ³	7.0E-03	mg/m ³	CNS	2.3E-02
				CARBON TETRACHLORIDE	2.5E+03	µg/L	3.3E+01	μg/m ³	6.0E-06	(µg/m ³) ⁻¹	2.0E-04	2.9E-01	mg/m ³	1.0E-01	mg/m ³	Liver	2.9E+00
			lab eletion	CHLOROFORM	1.8E+02	µg/L	2.4E+00	μg/m ³	2.3E-05	(µg/m ³) ⁻¹	5.5E-05	2.1E-02	mg/m ³	9.8E-02	mg/m ³	Liver	2.1E-01
			Inhalation	CIS-1,2-DICHLOROETHYLENE	3.2E+00	µg/L	4.3E-02	μg/m ³	NA	(µg/m ³) ⁻¹	NA	3.8E-04	mg/m ³	NA	mg/m ³	NA	NA
				METHYL TERT-BUTYL ETHER	2.4E+01	µg/L	3.1E-01	μg/m ³	2.6E-07	(µg/m ³) ⁻¹	8.2E-08	2.7E-03	mg/m ³	3.0E+00	mg/m ³	Kidney, Liver, Ocular	9.2E-04
				TRICHLOROETHYLENE	8.6E+01	µg/L	1.1E+00	μg/m ³	1.0E-06	(µg/m ³) ⁻¹	1.1E-06	1.0E-02	mg/m ³	2.0E-03	mg/m ³	Developmental, Cardiovascular, Immunological	5.0E+00
				TRICHLOROETHYLENE	8.6E+01	µg/L	1.1E+00	μg/m ³	3.1E-06	(µg/m ³) ⁻¹	3.6E-06		mg/m ³		mg/m ³		NA

TABLE 7.3-CTE Resident CALCULATION OF CHEMICAL CANCER RISKS AND NON-CANCER HAZARDS CENTRAL TENDENCY EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident Receptor Age: Adult

	_	xposure		EPC Cancer Risk Calculations							Non-Cancer Hazard Calculations						
Medium	Exposure Medium	Exposure Point	Exposure Route	Chemical of Potential Concern	Value	Value	Lipite	Intake/Exposur	e/Exposure Concentration CSF/Unit Risk		Cancer Risk	Intake/Exposu	re Concentration	RfD/RfC		Critical Effect	Hazard Quotient
					value	Value Units		Units	Value	Units	Cancer Risk	Value	Units	Value	Units	Chucar Enect	Hazard Quotient
	Exposure Route Total									2.6E-04						8.1E+00	
		Exposure Point	Total								4.6E-04						
	Exposure Mediu	m Total									4.6E-04						1.6E+01
Medium Total fo	Total for Child										4.6E-04						1.6E+01
								Total	of Receptor Risks	Across All Media	4.6E-04	Total of Receptor Hazards Across All Me				Total of Receptor Hazards Across All Media	1.6E+01

Notes:

CNS = Central Nervous System

CSF = Cancer Slope Factor

EPC = Exposure Point Concentration

HI = Hazard Index

NA = Not Applicable or Not Available

RfD/RfC = Reference Dose/Reference Concentration

Trichloroethylene was evaluated for both mutagenic risk to the kidney and non-mutagenic risk to the liver. The total risk for trichloroethylene is summed in Table 9.3-CTE

Age-weighted average (AWA) age-dependent adjustment factors (ADAFs) were applied to cancer CSF for constituents acting via a mutagenic mode of action (MMOA).

6.6.E+00
8.8.E-04
9.2.E-04
9.3.E+00
1.4.E-02

Total Development, Immune & Cardiovascular HI Across All Media =

Total Hematologic & Immune HI Across All Media =

Total Kidney, Liver & Ocular HI Across All Media =

Total Liver HI Across All Media =

TABLE 9.1-RME Worker SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs REASONABLE MAXIMUM EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future

Exposure Point: Core of the Plume

Receptor Population: Worker

Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern			Carcinogenic Risk	ζ.		Non-Carcinogenic Hazard Quotient						
	moulum			Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total		
			1,1,2-TRICHLOROETHANE	1.9E-07				1.9E-07	Hematologic, Immune	2.4E-03			2.4E-03		
			1,2-DICHLOROETHANE	9.6E-07				9.6E-07	NA	NA			NA		
			CARBON TETRACHLORIDE	1.3E-03				1.3E-03	Liver	1.3E+01			1.3E+01		
		Core of the	CHLOROFORM	4.2E-05				4.2E-05	Liver	3.8E-01			3.8E-01		
Groundwater	Tap Water	Plume	CIS-1,2-DICHLOROETHYLENE	NA				NA	Urinary, Whole Body	3.5E-02			3.5E-02		
Groundwater			METHYL TERT-BUTYL ETHER	3.2E-07				3.2E-07	NA	NA			NA		
			TRICHLOROETHYLENE	3.0E-05				3.0E-05	Developmental, Cardiovascular, Immunological	3.7E+00			3.7E+00		
			Chemical Total	1.4E-03	NA	NA		1.4E-03		1.7E+01	NA	NA	1.7E+01		
		Exposure Point T	otal					1.4E-03					1.7E+01		
	Exposure Mediu	um Total						1.4E-03					1.7E+01		
Medium Total								1.4E-03					1.7E+01		
						Re	ceptor Risk Total	1.4E-03			F	Receptor HI Total	1.7E+01		

Total Develo

elopment, Immune & Cardiovascular HI Across All Media =	3.7.E+00
Total Hematologic & Immune HI Across All Media =	2.4.E-03
Total Liver HI Across All Media =	1.4.E+01
Total Urinary & Whole Body HI Across All Media =	3.5.E-02

TABLE 9.1-CTE Worker SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs CENTRAL TENDENCY EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future

Exposure Point: Core of the Plume

Receptor Population: Worker

Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern			Carcinogenic Risk	:		Non-Carcinogenic Hazard Quotient					
	Wealdin			Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
			1,1,2-TRICHLOROETHANE	1.2E-08				1.2E-08	Hematologic, Immune	5.8E-04			5.8E-04	
			1,2-DICHLOROETHANE	6.2E-08				6.2E-08	NA	NA			NA	
			CARBON TETRACHLORIDE	8.5E-05				8.5E-05	Liver	3.2E+00			3.2E+00	
		Core of the	CHLOROFORM	2.7E-06				2.7E-06	Liver	9.4E-02			9.4E-02	
Groundwater	Tap Water	Plume	CIS-1,2-DICHLOROETHYLENE	NA				NA	Urinary, Whole Body	8.5E-03			8.5E-03	
Giounuwalei			METHYL TERT-BUTYL ETHER	2.1E-08				2.1E-08	NA	NA			NA	
			TRICHLOROETHYLENE	2.0E-06				2.0E-06	Developmental, Cardiovascular, Immunological	9.1E-01			9.1E-01	
			Chemical Total	9.0E-05	NA	NA		9.0E-05		4.2E+00	NA	NA	4.2E+00	
		Exposure Point T	otal					9.0E-05					4.2E+00	
	Exposure Mediu	um Total						9.0E-05					4.2E+00	
Medium Total								9.0E-05					4.2E+00	
						Re	ceptor Risk Total	9.0E-05			R	eceptor HI Total	4.2E+00	

Total Develo

elopment, Immune & Cardiovascular HI Across All Media =	9.1.E-01
Total Hematologic & Immune HI Across All Media =	5.8.E-04
Total Liver HI Across All Media =	3.3.E+00
Total Urinary & Whole Body HI Across All Media =	8.5.E-03

TABLE 9.2-RME Resident SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs REASONABLE MAXIMUM EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume

Receptor Population: Resident

Receptor Age: Young Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern			Carcinogenic Risł	(Non-Carcinogenic Hazard Quotient						
	moulum			Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total		
			1,1,2-TRICHLOROETHANE	1.1E-07	8.9E-08	6.9E-09		2.0E-07	Hematologic, Immune	5.5E-03	NA	3.5E-04	5.8E-03		
			1,2-DICHLOROETHANE	5.4E-07	4.5E-07	2.3E-08		1.0E-06	NA	NA	2.9E-02	NA	2.9E-02		
			CARBON TETRACHLORIDE	7.4E-04	1.9E-04	1.7E-04		1.1E-03	Liver	3.1E+01	3.6E+00	7.3E+00	4.2E+01		
		Core of the	CHLOROFORM	2.4E-05	5.2E-05	1.9E-06		7.7E-05	Liver	8.9E-01	2.7E-01	7.0E-02	1.2E+00		
Groundwater	Tap Water	Plume	CIS-1,2-DICHLOROETHYLENE	NA	NA	NA		NA	Urinary, Whole Body	8.1E-02	NA	8.9E-03	9.0E-02		
Groundwater			METHYL TERT-BUTYL ETHER	1.8E-07	7.7E-08	3.6E-09		2.6E-07	NA	NA	1.2E-03	NA	1.2E-03		
			TRICHLOROETHYLENE	3.2E-05	9.2E-06	4.6E-06		4.6E-05	Developmental, Cardiovascular, Immunological	8.6E+00	6.3E+00	1.3E+00	1.6E+01		
			Chemical Total	7.9E-04	2.5E-04	1.8E-04		1.2E-03		4.0E+01	1.0E+01	8.6E+00	5.9E+01		
		Exposure Point T	otal					1.2E-03					5.9E+01		
	Exposure Mediu	um Total						1.2E-03					5.9E+01		
Medium Total								1.2E-03					5.9E+01		
						Re	ceptor Risk Total	1.2E-03			R	Receptor HI Total	5.9E+01		

Total Develop

II Across All Media =	1.6.E+01
II Across All Media =	5.8.E-03
II Across All Media =	4.3.E+01
II Across All Media =	9.0.E-02

1	opment, Immune & Cardiovascular HI Across All Media =
5	Total Hematologic & Immune HI Across All Media =
4	Total Liver HI Across All Media =
	Total Urinary & Whale Dady UI Aaroos All Madia

TABLE 9.2-CTE Resident SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs CENTRAL TENDENCY EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume

Receptor Population: Resident

Receptor Age: Young Child

Medium	edium Exposure Exposur		Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
	moulum			Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
			1,1,2-TRICHLOROETHANE	1.7E-08	3.0E-08	1.8E-09		4.8E-08	Hematologic, Immune	1.3E-03	NA	1.4E-04	1.4E-03
			1,2-DICHLOROETHANE	8.4E-08	1.5E-07	6.0E-09		2.4E-07	NA	NA	1.5E-02	NA	1.5E-02
			CARBON TETRACHLORIDE	1.1E-04	6.2E-05	4.5E-05		2.2E-04	Liver	7.2E+00	1.8E+00	2.8E+00	1.2E+01
		Core of the	CHLOROFORM	3.7E-06	1.7E-05	4.9E-07		2.1E-05	Liver	2.1E-01	1.3E-01	2.8E-02	3.7E-01
Groundwater	Tap Water	p Water Plume	CIS-1,2-DICHLOROETHYLENE	NA	NA	NA		NA	Urinary, Whole Body	1.9E-02	NA	3.5E-03	2.2E-02
Groundwater			METHYL TERT-BUTYL ETHER	2.8E-08	2.6E-08	9.5E-10		5.5E-08	NA	NA	5.8E-04	NA	5.8E-04
			TRICHLOROETHYLENE	5.0E-06	3.1E-06	1.2E-06		9.2E-06	Developmental, Cardiovascular, Immunological	2.0E+00	3.2E+00	4.9E-01	5.7E+00
			Chemical Total	1.2E-04	8.3E-05	4.7E-05		2.5E-04		9.4E+00	5.1E+00	3.4E+00	1.8E+01
	Exposure Point Total							2.5E-04					1.8E+01
	Exposure Medium Total						2.5E-04					1.8E+01	
Medium Total	Medium Total						2.5E-04					1.8E+01	
						Re	eceptor Risk Total	2.5E-04			R	Receptor HI Total	1.8E+01

Total Develop

=	5.7.E+00
=	1.4.E-03
=	1.2.E+01
=	2.2.E-02

pment, Immune & Cardiovascular HI Across All Media =
Total Hematologic & Immune HI Across All Media =
Total Liver HI Across All Media =
Total Urinany & Mhala Pady HI Aaroon All Madia

TABLE 9.3-RME Resident SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs REASONABLE MAXIMUM EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident

Receptor Age: Adult

Medium	Exposure Medium		ure Point Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient					
	moulum			Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Hematologic, Immune 3.3E-03 NA 2.5E-04 NA NA 5.2E-02 NA Liver 1.8E+01 6.5E+00 5.1E+00 Liver 5.3E-01 4.8E-01 5.0E-02		Dermal	Exposure Routes Total		
			1,1,2-TRICHLOROETHANE	2.1E-07	5.3E-07	1.6E-08		7.6E-07	Hematologic, Immune	3.3E-03	NA	2.5E-04	3.5E-03	
			1,2-DICHLOROETHANE	1.1E-06	2.7E-06	5.4E-08		3.8E-06	NA	NA	5.2E-02	NA	5.2E-02	
			CARBON TETRACHLORIDE	1.5E-03	1.1E-03	4.1E-04		3.0E-03	Liver	1.8E+01	6.5E+00	5.1E+00	3.0E+01	
		Core of the	CHLOROFORM	4.7E-05	3.1E-04	4.4E-06		3.6E-04	Liver	5.3E-01	4.8E-01	5.0E-02	1.1E+00	
Groundwater	Tap Water	Water Plume	CIS-1,2-DICHLOROETHYLENE	NA	NA	NA		NA	Urinary, Whole Body	4.9E-02	NA	6.3E-03	5.5E-02	
Groundwater			METHYL TERT-BUTYL ETHER	3.6E-07	4.6E-07	8.5E-09		8.3E-07	NA	NA	2.1E-03	NA	2.1E-03	
			TRICHLOROETHYLENE	3.4E-05	2.7E-05	5.8E-06		6.7E-05	Developmental, Cardiovascular, Immunological	5.2E+00	1.1E+01	8.8E-01	1.7E+01	
			Chemical Total	1.6E-03	1.5E-03	4.2E-04		3.4E-03		2.4E+01	1.8E+01	6.1E+00	4.9E+01	
	Exposure Point Total							3.4E-03					4.9E+01	
	Exposure Medium Total						3.4E-03					4.9E+01		
Medium Total								3.4E-03					4.9E+01	
	Receptor Risk Total					3.4E-03			R	Receptor HI Total	4.9E+01			

Total Develop

=	1.7.E+01
=	3.5.E-03
=	3.1.E+01
=	5.5.E-02

ppment, Immune & Cardiovascular HI Across All Media =
Total Hematologic & Immune HI Across All Media =
Total Liver HI Across All Media =
Tatal Ulainana () Mihala Dasha I II Asusan All Madia

TABLE 9.3-CTE Resident SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs CENTRAL TENDENCY EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident

Receptor Age: Adult

Medium	Exposure Medium		Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
	Wouldm			Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
			1,1,2-TRICHLOROETHANE	2.1E-08	9.4E-08	1.9E-09		1.2E-07	Hematologic, Immune	8.1E-04	NA	7.4E-05	8.8E-04
			1,2-DICHLOROETHANE	1.1E-07	4.8E-07	6.4E-09		5.9E-07	NA	NA	2.3E-02	NA	2.3E-02
			CARBON TETRACHLORIDE	1.4E-04	2.0E-04	4.9E-05		3.9E-04	Liver	4.5E+00	2.9E+00	1.5E+00	8.9E+00
		Core of the Water Plume	CHLOROFORM	4.6E-06	5.5E-05	5.2E-07		6.0E-05	Liver	1.3E-01	2.1E-01	1.5E-02	3.6E-01
Groundwater	Tap Water		CIS-1,2-DICHLOROETHYLENE	NA	NA	NA		NA	Urinary, Whole Body	1.2E-02	NA	1.9E-03	1.4E-02
Groundwater			METHYL TERT-BUTYL ETHER	3.6E-08	8.2E-08	1.0E-09		1.2E-07	NA	NA	9.2E-04	NA	9.2E-04
			TRICHLOROETHYLENE	3.3E-06	4.7E-06	6.9E-07		8.8E-06	Developmental, Cardiovascular, Immunological	1.3E+00	5.0E+00	2.6E-01	6.6E+00
			Chemical Total	1.5E-04	2.6E-04	5.0E-05		4.6E-04		5.9E+00	8.1E+00	1.8E+00	1.6E+01
	Exposure Point Total							4.6E-04					1.6E+01
	Exposure Medium Total						4.6E-04					1.6E+01	
Medium Total	Medium Total						4.6E-04					1.6E+01	
						Re	ceptor Risk Total	4.6E-04			F	Receptor HI Total	1.6E+01

Total Develop

ia =	6.6.E+00
ia =	8.8.E-04
ia =	9.3.E+00
ia =	1.4.E-02

6	pment, Immune & Cardiovascular HI Across All Media =
	Total Hematologic & Immune HI Across All Media =
Ċ,	Total Liver HI Across All Media =
	Total Urinary & Whole Body HI Across All Media =

TABLE 10.1-RME Worker SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs REASONABLE MAXIMUM EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Worker Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern			Carcinogenic Risk	< c		Non-Carcinogenic Hazard Quotient					
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
	Tap Water	Core of the Plume	CARBON TETRACHLORIDE TRICHLOROETHYLENE	1.3E-03 3.0E-05				1.3E-03 3.0E-05	Liver Developmental, Cardiovascular, Immunological	1.3E+01 3.7E+00			1.3E+01 3.7E+00	
Groundwater	Tap water	. iaine	Chemical Total	1.3E-03	NA	NA		1.3E-03		1.7E+01	NA	NA	1.7E+01	
		Exposure Point T	otal					1.3E-03					1.7E+01	
	Exposure Mediu	ım Total						1.3E-03					1.7E+01	
Medium Total								1.3E-03					1.7E+01	
Receptor Risk Total							1.3E-03			R	Receptor HI Total	1.7E+01		

3.7.E+00	
1.3.E+01	

TABLE 10.1-CTE Worker SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs CENTRAL TENDENCY EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Worker

Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern			Carcinogenic Risk	< c		Non-Carcinogenic Hazard Quotient					
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
	Tap Water	Core of the Plume	CARBON TETRACHLORIDE TRICHLOROETHYLENE	8.5E-05 2.0E-06				8.5E-05 2.0E-06	Liver Developmental, Cardiovascular, Immunological	3.2E+00 9.1E-01			3.2E+00 9.1E-01	
Groundwater	rap water		Chemical Total	8.7E-05	NA	NA		8.7E-05		4.1E+00	NA	NA	4.1E+00	
		Exposure Point T	otal					8.7E-05					4.1E+00	
	Exposure Mediu	um Total						8.7E-05					4.1E+00	
Medium Total	Medium Total												4.1E+00	
						Re	ceptor Risk Total	8.7E-05			R	eceptor HI Total	4.1E+00	

9.1.E-01	
3.2.E+00	

TABLE 10.2-RME Resident SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs REASONABLE MAXIMUM EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident

Receptor Age: Young Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient					
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
			CARBON TETRACHLORIDE	7.4E-04	1.9E-04	1.7E-04		1.1E-03	Liver	3.1E+01	3.6E+00	7.3E+00	4.2E+01	
		Core of the	CHLOROFORM	2.4E-05	5.2E-05	1.9E-06		7.7E-05	Liver	8.9E-01	2.7E-01	7.0E-02	1.2E+00	
Groundwater	Tap Water	Plume	TRICHLOROETHYLENE	3.2E-05	9.2E-06	4.6E-06		4.6E-05	Developmental, Cardiovascular, Immunological	8.6E+00	6.3E+00	1.3E+00	1.6E+01	
			Chemical Total	7.9E-04	2.5E-04	1.8E-04		1.2E-03		4.0E+01	1.0E+01	8.6E+00	5.9E+01	
		Exposure Point T	otal					1.2E-03					5.9E+01	
	Exposure Mediu	ım Total						1.2E-03					5.9E+01	
Medium Total	Medium Total												5.9E+01	
						1.2E-03			R	eceptor HI Total	5.9E+01			

1.6.E+01	
0.0.E+00	
4.3.E+01	
0.0.E+00	

Total Development, Immune & Cardiovascular HI Across All Media =

Total Hematologic & Immune HI Across All Media = Total Liver HI Across All Media =

Total Urinary & Whole Body HI Across All Media =

TABLE 10.2-CTE Resident SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs CENTRAL TENDENCY EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident

Receptor Age: Young Child

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
			CARBON TETRACHLORIDE	1.1E-04	6.2E-05	4.5E-05		2.2E-04	Liver	7.2E+00	1.8E+00	2.8E+00	1.2E+01
		Core of the Plume	CHLOROFORM	3.7E-06	1.7E-05	4.9E-07		2.1E-05	Liver	2.1E-01	1.3E-01	2.8E-02	3.7E-01
Groundwater	Tap Water		TRICHLOROETHYLENE	5.0E-06	3.1E-06	1.2E-06		9.2E-06	Developmental, Cardiovascular, Immunological	2.0E+00	3.2E+00	4.9E-01	5.7E+00
Croundwater			Chemical Total	1.2E-04	8.3E-05	4.7E-05		2.5E-04		9.4E+00	5.1E+00	3.4E+00	1.8E+01
		Exposure Point T	otal					2.5E-04					1.8E+01
	Exposure Mediu	ım Total						2.5E-04					1.8E+01
Medium Total	Medium Total							2.5E-04					1.8E+01
						2.5E-04			R	eceptor HI Total	1.8E+01		

5.7.E+00	
1.2.E+01	

TABLE 10.3-RME Resident SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs REASONABLE MAXIMUM EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern	Carcinogenic Risk					Non-Carcinogenic Hazard Quotient					
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total	
	Tap Water	Core of the Plume	CARBON TETRACHLORIDE	1.5E-03	1.1E-03	4.1E-04		3.0E-03	Liver	1.8E+01	6.5E+00	5.1E+00	3.0E+01	
			CHLOROFORM	4.7E-05	3.1E-04	4.4E-06		3.6E-04	Liver	5.3E-01	4.8E-01	5.0E-02	1.1E+00	
Groundwater			TRICHLOROETHYLENE	3.4E-05	2.7E-05	5.8E-06		6.7E-05	Developmental, Cardiovascular, Immunological	5.2E+00	1.1E+01	8.8E-01	1.7E+01	
Groundwater			Chemical Total	1.6E-03	1.4E-03	4.2E-04		3.4E-03		2.4E+01	1.8E+01	6.0E+00	4.8E+01	
		Exposure Point T	otal					3.4E-03					4.8E+01	
	Exposure Mediu	um Total						3.4E-03					4.8E+01	
Medium Total	Medium Total												4.8E+01	
						3.4E-03			R	Receptor HI Total	4.8E+01			

1.7.E+01
3.1.E+01

TABLE 10.3-CTE Resident SUMMARY OF RECEPTOR RISKS AND HAZARDS FOR COPCs CENTRAL TENDENCY EXPOSURE Middlesex Sampling Plant (MSP) FUSRAP Site, Middlesex County, New Jersey

Scenario Timeframe: Hypothetical Future Exposure Point: Core of the Plume Receptor Population: Resident Receptor Age: Adult

Medium	Exposure Medium	Exposure Point	Chemical of Potential Concern			Carcinogenic Risk	ζ.		Non-Carcinogenic Hazard Quotient				
				Ingestion	Inhalation	Dermal	External (Radiation)	Exposure Routes Total	Primary Target Organ(s)	Ingestion	Inhalation	Dermal	Exposure Routes Total
		Core of the Water Plume	CARBON TETRACHLORIDE	1.4E-04	2.0E-04	4.9E-05		3.9E-04	Liver	4.5E+00	2.9E+00	1.5E+00	8.9E+00
	Tap Water		CHLOROFORM	4.6E-06	5.5E-05	5.2E-07		6.0E-05	Liver	1.3E-01	2.1E-01	1.5E-02	3.6E-01
Groundwater			TRICHLOROETHYLENE	3.3E-06	4.7E-06	6.9E-07		8.8E-06	Developmental, Cardiovascular, Immunological	1.3E+00	5.0E+00	2.6E-01	6.6E+00
Groundwater			Chemical Total	1.5E-04	2.6E-04	5.0E-05		4.6E-04		5.9E+00	8.1E+00	1.8E+00	1.6E+01
		Exposure Point T	otal					4.6E-04					1.6E+01
	Exposure Medium Total												1.6E+01
Medium Total	Medium Total												1.6E+01
				4.6E-04			R	Receptor HI Total	1.6E+01				

6.6.E+00
9.3.E+00

C SUPPORTING DATA

ProUCL Output

	А	В	С	D	Е	F	G	Н		J	K		L
1					UCL Statis	tics for Data	Sets with N	on-Detects					
2													
3			cted Options										
4	Dat	te/Time of Co		ProUCL 5.16/		::46:43 PM							
5			From File	ProUCL Input	_a.xls								
6			I Precision	OFF									
7		Confidence		95%									
8	Number o	of Bootstrap (Operations	2000									
9													
10	1,1,2-TRIC	HLOROETH	ANE										
11						-	-						
12	L						Statistics						
13			Total	Number of Ob		10			Number		Observations	4	
14	L				of Detects	1					Non-Detects	9	
15	L		N	umber of Distir	nct Detects	1			Numbe	r of Distinct	Non-Detects	3	3
16													
17		-	-	ct data value v				-					
18	It is sugge	ested to use	alternative s	site specific va	lues deterr	nined by the	Project Tea	m to estima	te environme	ental parame	eters (e.g., EF	νС, В	3TV).
19													
20				The data set f	or variable	1,1,2-TRIC	HLOROETH	ANE was no	ot processed				
21	L												
22	L												
23	1,2-DICHLO	DROETHAN	E										
24	ļ												
25	ļ						Statistics						
26	ļ		Total	Number of Ob		10			Number		Observations	6	
27	ļ				of Detects	3					Non-Detects	7	
28	ļ		N	umber of Distir		3			Numbe		Non-Detects	3	
29	ļ				um Detect	0.37					Non-Detect).3
30	ļ				um Detect	2.74					Non-Detect	15	
31					ce Detects	1.424				Percent	Non-Detects		0%
32	ļ				an Detects	1.637		SD Detects		1.193			
33	ļ				an Detects	1.8					CV Detects).729
34	ļ				ss Detects	-0.604					tosis Detects	N/.	
35				Mean of Logg	ed Detects	0.2				SD of Log	ged Detects	1	1.056
36					Mana 1			4 a al \ 7 - 1:					
37					•		only 3 Detec		and cation - 1				
38				his is not enou	ign to comp	bute meanin	giul or reliad	Ie statistics		es.			
39													
40					N			Out					
41				· · · · · · · · · · · · · · · · · · ·			t on Detects	Only					
42				hapiro Wilk Te		0.986			=				
43	ļ		5% S	hapiro Wilk Cri		0.767	De	elected Data		-	gnificance Lev	/el	
44				Lilliefors Te		0.221							
45			5	% Lilliefors Cri		0.425				nai at 5% Sig	gnificance Lev	/el	
46	ļ			Dete	cted Data a	appear Norn	nal at 5% Sig	Initicance Le	evei				
47			14	Mala, 400 C	- 41 - 41								
48			Kaplan-	Meier (KM) St		-	ritical Value	s and other	-		T		
49	 				KM Mean	0.746			KN		Fror of Mean).345
50					KM SD	0.845				95% KN	I (BCA) UCL	N/.	/A

	A B C D E	F	G H I J K	1
51	95% KM (t) UCL	1.378	95% KM (Percentile Bootstrap) UCL	N/A
52	95% KM (z) UCL	1.313	95% KM Bootstrap t UCL	N/A
53	90% KM Chebyshev UCL	1.78	95% KM Chebyshev UCL	2.249
54	97.5% KM Chebyshev UCL	2.899	99% KM Chebyshev UCL	4.177
55				
56	Gamma GOF	Tests on De	etected Observations Only	
57	Not End	ough Data to	Perform GOF Test	
58		-		
	Gamma	Statistics or	Detected Data Only	
59	k hat (MLE)	1.861	k star (bias corrected MLE)	N/A
60	Theta hat (MLE)	0.88	Theta star (bias corrected MLE)	N/A
61	nu hat (MLE)	11.16	nu star (bias corrected)	N/A
62	Mean (detects)	1.637		
63				
64	Gamma BOS	Statistics us	sing Imputed Non-Detects	
65			b NDs with many tied observations at multiple DLs	
66	-		s <1.0, especially when the sample size is small (e.g., <15-20) $s < 1.0$	
67			yield incorrect values of UCLs and BTVs	
68				
69		-	n the sample size is small.	
70	-		y be computed using gamma distribution on KM estimates	
71	Minimum	0.01	Mean	0.498
72	Maximum	2.74	Median	0.01
73	SD	0.966	CV	1.941
74	k hat (MLE)	0.282	k star (bias corrected MLE)	0.264
75	Theta hat (MLE)	1.764	Theta star (bias corrected MLE)	1.884
76	nu hat (MLE)	5.647	nu star (bias corrected)	5.286
77	Adjusted Level of Significance (β)	0.0267		
78	Approximate Chi Square Value (5.29, α)	1.287	Adjusted Chi Square Value (5.29, β)	0.979
79	95% Gamma Approximate UCL (use when n>=50)	2.046	95% Gamma Adjusted UCL (use when n<50)	N/A
80				
81	Estimates of Ga	amma Parai	meters using KM Estimates	
82	Mean (KM)	0.746	SD (KM)	0.845
83	Variance (KM)	0.714	SE of Mean (KM)	0.345
84	k hat (KM)	0.779	k star (KM)	0.612
85	nu hat (KM)	15.58	nu star (KM)	12.24
86	theta hat (KM)	0.957	theta star (KM)	1.218
87	80% gamma percentile (KM)	1.229	90% gamma percentile (KM)	1.93
88	95% gamma percentile (KM)	2.664	99% gamma percentile (KM)	4.434
89				
90	Gamma	a Kaplan-M	eier (KM) Statistics	
90 91	Approximate Chi Square Value (12.24, α)	5.385	Adjusted Chi Square Value (12.24, β)	4.62
	95% Gamma Approximate KM-UCL (use when n>=50)	1.695	95% Gamma Adjusted KM-UCL (use when n<50)	1.975
92				
93	Lognormal GO	F Test on D	etected Observations Only	
94	Shapiro Wilk Test Statistic	0.899	Shapiro Wilk GOF Test	
95	5% Shapiro Wilk Critical Value	0.767	Detected Data appear Lognormal at 5% Significance Le	evel
96	Lilliefors Test Statistic	0.31	Lilliefors GOF Test	
97	5% Lilliefors Critical Value	0.425	Detected Data appear Lognormal at 5% Significance Le	vel
98			rmal at 5% Significance Level	
99	Delected Data ap	pour Logno		
100				

	А	В		С			E	F	G		4		-	J		К		
101								S Statistics	-			3						
102					Mea	n in Origin	nal Scale	0.521						Me	an in L	_og S	cale	-2.468
103					SI	D in Origin	nal Scale	0.954						5	SD in L	_og S	cale	2.142
104		95% 1	t UCL (assume	es norm	nality of RC	OS data)	1.074	95% Percentile Bootstrap UCL							1.047		
105					95% B(CA Bootst	rap UCL	1.192						95% E	Bootsti	rap t l	UCL	4.464
105					95%	H-UCL (Lo	og ROS)	50.74										
107																		
107				Stati	istics us	sing KM e	stimates	on Logged	Data and As	suming	Lognor	mal Dis	tributi	on				
108					I	KM Mean	(logged)	-0.736							KM G	Geo M	lean	0.479
110						KM SD	(logged)	0.828				95%	% Criti	cal H V	Value	(KM-I	Log)	2.763
111			KM	Standa	ard Erro	r of Mean	(logged)	0.338					9	5% H-	UCL ((KM -	Log)	1.448
							(logged)	0.828				95%	% Criti	cal H \	Value	(KM-I	Log)	2.763
112			KM	Standa	ard Erro	r of Mean		0.338										
113							(-33)											
114								DL/2 S	tatistics									
115				DL/2	Normal	1					C	L/2 Log	ı-Tran	sform	ed			
116						n in Origin	al Scale	1.343					,		an in L	00.5	cale	-0.804
117						D in Origin									SD in L	-		1.45
118				95% t l		ssumes no		2.699							5% H-	-		9.235
119					•		• •	ethod, provi	ded for com	narieon	e and hi	etorical	roaco		57011-			9.200
120								eulou, provi		panson	s anu m	Storical	Teasu	115				
121						No	nnorom	etric Distribu	tion Eroo LIC		intion							
122							-											
123					Dei		ta appea	r Normal Di	stributed at a	5% Sigi	nificance	e Level						
124								Ourrented										
125						050/ 1/1			UCL to Use)								
126						95% KN	1 (t) UCL	1.378										
127					<u> </u>		(050				<u> </u>				<u> </u>	050/		
128	N	lote: Sugg	jestions	_	-			6 UCL are pr						appro	priate	95%	UCL	
129								sed upon dat	-									
130								Its of the sin								•		
131	Hov	wever, sin	nulation	is result	its will n	iot cover a	ill Real V	/orld data se	ts; for additio	onal ins	ight the	user ma	ay war	it to co	nsult	a stat	listicia	3n.
132																		
₁₃₃ C	IS-1,2-DIC	HLOROE	THYLE	ENE														
134																		
135									Statistics									
136				Total		er of Obse		10				Numl			ct Obs			10
137						Number of		8							of Nor			2
138				N	lumber	of Distinct		8				Num			nct Nor			2
139							n Detect	0.45							ium No			0.3
140						Maximur		4.87							ium No			15
141						Variance	Detects	3.761						Perce	ent Nor	n-Det	ects	20%
142						Mean	Detects	2.269							SI	D Det	ects	1.939
143						Median	Detects	1.485							C,	V Det	ects	0.855
144					ç	Skewness	Detects	0.502						k	Curtosi	s Det	ects	-1.938
145					Mean	of Logged	Detects	0.414					ŝ	SD of I	Logge	d Det	ects	1.008
146								1	1									
147							Norn	nal GOF Tes	t on Detects	s Only								
148				S	Shapiro	Wilk Test	Statistic	0.813			S	hapiro '	Wilk G	OF T	est			
149				5% S	Shapiro	Wilk Critic	al Value	0.818		Detecte	d Data	Not Nor	mal at	5% S	ignific	ance	Leve	I
150					Lillie	efors Test	Statistic	0.28				Lilliefo	rs GO	F Tes	t			
150								1	1									

	A B C D E	F	G H I J K	L
151	5% Lilliefors Critical Value	0.283	Detected Data appear Normal at 5% Significance Leve	el
152	Detected Data appear	Approximat	e Normal at 5% Significance Level	
153				
154	Kaplan-Meier (KM) Statistics usin	ng Normal C	ritical Values and other Nonparametric UCLs	
155	KM Mean	2.05	KM Standard Error of Mean	0.648
156	KM SD	1.819	95% KM (BCA) UCL	3.17
157	95% KM (t) UCL	3.238	95% KM (Percentile Bootstrap) UCL	3.103
158	95% KM (z) UCL	3.116	95% KM Bootstrap t UCL	3.414
159	90% KM Chebyshev UCL	3.994	95% KM Chebyshev UCL	4.875
160	97.5% KM Chebyshev UCL	6.098	99% KM Chebyshev UCL	8.499
161				
162			etected Observations Only	
163	A-D Test Statistic	0.638	Anderson-Darling GOF Test	
164	5% A-D Critical Value	0.73	Detected data appear Gamma Distributed at 5% Significance	e Level
165	K-S Test Statistic	0.28	Kolmogorov-Smirnov GOF	
166	5% K-S Critical Value	0.3	Detected data appear Gamma Distributed at 5% Significance	e Level
167	Detected data appear	Gamma Dis	stributed at 5% Significance Level	
168		<u> </u>		
169			Detected Data Only	
170	k hat (MLE)	1.376	k star (bias corrected MLE)	0.944
171	Theta hat (MLE)	1.648	Theta star (bias corrected MLE)	2.404
172	nu hat (MLE)	22.02	nu star (bias corrected)	15.1
173	Mean (detects)	2.269		
174	Commo BOS	Statiatica	sing Imputed New Detecto	
175			b NDs with many tied observations at multiple DLs	
176	-		s <1.0, especially when the sample size is small (e.g., <15-20)	
177			yield incorrect values of UCLs and BTVs	
178			in the sample size is small.	
179		-	y be computed using gamma distribution on KM estimates	
180	Minimum	0.01	Mean	1.97
181	Maximum	4.87	Median	1.157
182	SD	1.858	CV	0.943
183	k hat (MLE)	0.779	k star (bias corrected MLE)	0.612
184	Theta hat (MLE)	2.528	Theta star (bias corrected MLE)	3.219
185	nu hat (MLE)	15.59	nu star (bias corrected)	12.24
186	Adjusted Level of Significance (β)	0.0267		
187	Approximate Chi Square Value (12.24, α)	5.388	Adjusted Chi Square Value (12.24, β)	4.623
188 189	95% Gamma Approximate UCL (use when n>=50)	4.478	95% Gamma Adjusted UCL (use when n<50)	5.219
	··· 、 /		· · · · · · · · · · · · · · · · · · ·	
100		amma Darai	meters using KM Estimates	
190 101	Estimates of Ga	amma raiai	-	
191	Estimates of Ga Mean (KM)	2.05	SD (KM)	1.819
191 192			SD (KM) SE of Mean (KM)	1.819 0.648
191 192 193	Mean (KM)	2.05		
191 192 193 194	Mean (KM) Variance (KM)	2.05 3.308	SE of Mean (KM)	0.648
191 192 193 194 195	Mean (KM) Variance (KM) k hat (KM)	2.05 3.308 1.27	SE of Mean (KM) k star (KM)	0.648 0.956
191 192 193 194 195 196	Mean (KM) Variance (KM) k hat (KM) nu hat (KM)	2.05 3.308 1.27 25.41	SE of Mean (KM) k star (KM) nu star (KM)	0.648 0.956 19.12
191 192 193 194 195 196 197	Mean (KM) Variance (KM) k hat (KM) nu hat (KM) theta hat (KM)	2.05 3.308 1.27 25.41 1.614	SE of Mean (KM) k star (KM) nu star (KM) theta star (KM)	0.648 0.956 19.12 2.144
191 192 193 194 195 196	Mean (KM) Variance (KM) k hat (KM) nu hat (KM) theta hat (KM) 80% gamma percentile (KM)	2.05 3.308 1.27 25.41 1.614 3.311	SE of Mean (KM) k star (KM) nu star (KM) theta star (KM) 90% gamma percentile (KM)	0.648 0.956 19.12 2.144 4.773

	А	В	С	D	E	F	G	Н	1	J	K	L
201	A		-	i Square Valu		10.2	G		Adjusted Ch	i Square Value		9.093
202	95%	Gamma Ap	proximate KM	I-UCL (use w	hen n>=50)	3.841		95% Gam	ma Adjusted k	M-UCL (use w	/hen n<50)	4.31
203						I	<u> </u>				I	
204				Lo	gnormal GC	F Test on D	etected Ob	servations (Only			
205			S	hapiro Wilk T	est Statistic	0.851			Shapiro W	lk GOF Test		
206			5% SI	hapiro Wilk C	ritical Value	0.818	De	tected Data		ormal at 5% Sig	gnificance Le	evel
207				Lilliefors T	est Statistic	0.249				GOF Test		
208			5	% Lilliefors C		0.283				ormal at 5% Sig	gnificance Le	evel
209				Detec	cted Data ap	opear Logno	rmal at 5%	Significance	e Level			
210												
211						S Statistics	Using Impu	ted Non-Del	tects			0.140
212	-				iginal Scale						Log Scale	0.148
213		050(iginal Scale				050/		Log Scale	1.169
214		95% t l	-	s normality of	-	3.023			95%	Percentile Boo	•	2.856
215			(95% BCA Boo	•	3.014				95% Boots	strap t UCL	3.406
216				95% H-UCL	. (LOG KOS)	8.833						
217			Otatia	tion weiner 1/1						h		
218			Statis		an (logged)	0.234	Jata and As	suming Log	normal Distri		Geo Mean	1.264
219					SD (logged)	1.024			05%	Critical H Value		3.152
220			KM Standa	rd Error of Me		0.365			90 /6	95% H-UCL		6.259
221					SD (logged)	1.024			95%	Critical H Value		3.152
222			KM Standar	rd Error of Me		0.365			3370		= (IXIVI-LOG)	5.152
223					an (logged)	0.505						
224						DI /2 S	tatistics					
225			DI /2 I	Normal		0020			DI /2 og-1	ransformed		
226			0021		iginal Scale	2.58			<i>DD1</i> 109		Log Scale	0.343
227					iginal Scale						Log Scale	1.289
228			95% t L	JCL (Assume	-	4.042					I-Stat UCL	16.05
229				-			ded for com	parisons an	d historical re			
230 231								·				
232					Nonparame	etric Distribu	tion Free U	CL Statistic	S			
233			Det	tected Data a	ppear Appr	oximate Nor	mal Distribu	ited at 5% S	ignificance L	evel		
234												
235						Suggested	UCL to Use)				
236				95%	KM (t) UCL	3.238						
237											·	
238			When a d	lata set follow	s an approx	imate (e.g., r	normal) dist	ribution pase	sing one of the	e GOF test		
239		When app	olicable, it is s	uggested to u	use a UCL b	ased upon a	distribution	(e.g., gamm	a) passing bo	th GOF tests in	n ProUCL	
240												
241		Note: Sugge	•	•		•		•		nost appropriat	e 95% UCL.	
242									and skewnes			
243										Maichle, and I	. ,	
244	Но	owever, simu	llations result	s will not cove	er all Real W	/orld data se	ts; for additi	onal insight	the user may	want to consul	t a statisticia	an.
245												
246	TERT-BUT	YL METHYL	ETHER									
247						<u> </u>	01-11					
248			- - · ·	No.	h		Statistics					
249			Total	Number of O					Numbe	r of Distinct Ob		5
250				Numbe	r of Detects	4				Number of N	on-Detects	6

A	A B C D E	F	G H I J K	
251	Number of Distinct Detects	3	Number of Distinct Non-Detects	2
252	Minimum Detect	0.37	Minimum Non-Detect	0.29
253	Maximum Detect	23.5	Maximum Non-Detect	0.3
254	Variance Detects	133.4	Percent Non-Detects	60%
255	Mean Detects	6.175	SD Detects	11.55
256	Median Detects	0.415	CV Detects	1.87
257	Skewness Detects	2	Kurtosis Detects	4
258	Mean of Logged Detects	0.098	SD of Logged Detects	2.042
259				
260	Norm	al GOF Tes	t on Detects Only	
261	Shapiro Wilk Test Statistic	0.632	Shapiro Wilk GOF Test	
262	5% Shapiro Wilk Critical Value	0.748	Detected Data Not Normal at 5% Significance Level	
263	Lilliefors Test Statistic	0.44	Lilliefors GOF Test	
264	5% Lilliefors Critical Value	0.375	Detected Data Not Normal at 5% Significance Level	
265	Detected Data	a Not Norma	I at 5% Significance Level	
266				
267	Kaplan-Meier (KM) Statistics usir	ng Normal C	ritical Values and other Nonparametric UCLs	
268	KM Mean	2.644	KM Standard Error of Mean	2.539
269	KM SD	6.952	95% KM (BCA) UCL	N/A
270	95% KM (t) UCL	7.298	95% KM (Percentile Bootstrap) UCL	N/A
271	95% KM (z) UCL	6.82	95% KM Bootstrap t UCL	N/A
272	90% KM Chebyshev UCL	10.26	95% KM Chebyshev UCL	13.71
272	97.5% KM Chebyshev UCL	18.5	99% KM Chebyshev UCL	27.9
274				
275	Gamma GOF	Tests on De	tected Observations Only	
276	A-D Test Statistic	0.881	Anderson-Darling GOF Test	
277	5% A-D Critical Value	0.694	Detected Data Not Gamma Distributed at 5% Significance	Level
278	K-S Test Statistic	0.465	Kolmogorov-Smirnov GOF	
279	5% K-S Critical Value	0.415	Detected Data Not Gamma Distributed at 5% Significance	Level
280			disuted at E0/ Olanificanae Laural	
	Detected Data Not C	Gamma Disti	ributed at 5% Significance Level	
	Detected Data Not C	Gamma Disti		
281			Detected Data Only	
281 282			-	0.263
281 282 283	Gamma	Statistics on	Detected Data Only	0.263
281 282 283 284	Gamma k hat (MLE)	Statistics on 0.384	b Detected Data Only k star (bias corrected MLE)	
281 282 283 284 285	Gamma k hat (MLE) Theta hat (MLE)	Statistics on 0.384 16.06	Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE)	23.5
281 282 283 284	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE)	Statistics on 0.384 16.06 3.076	Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE)	23.5
281 282 283 284 285 286	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects)	Statistics on 0.384 16.06 3.076 6.175	Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE)	23.5
281 282 283 284 285 286 287	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects) Gamma ROS	Statistics on 0.384 16.06 3.076 6.175 Statistics us	Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE) nu star (bias corrected)	23.5
281 282 283 284 285 286 287 288	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects) GROS may not be used when data se	Statistics on 0.384 16.06 3.076 6.175 Statistics us et has > 50%	Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE) nu star (bias corrected MLE) sing Imputed Non-Detects	23.5
281 282 283 284 285 286 287 288 289	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects) GROS may not be used when data se GROS may not be used when data se	Statistics on 0.384 16.06 3.076 6.175 Statistics us et has > 50% small such as	Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE) nu star (bias corrected MLE) nu star (bias corrected)	23.5
281 282 283 284 285 286 287 288 289 290 291	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects) GROS may not be used when data se GROS may not be used when data se GROS may not be used when kstar of detects is s	Statistics on 0.384 16.06 3.076 6.175 Statistics us et has > 50% small such as nethod may	Detected Data Only	23.5
281 282 283 284 285 286 287 287 288 289 290	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects) Gamma ROS GROS may not be used when data se GROS may not be used when kstar of detects is s For such situations, GROS r	Statistics on 0.384 16.06 3.076 6.175 Statistics us et has > 50% small such as nethod may ally true whe	Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE) nu star (bias corrected MLE) nu star (bias corrected) sing Imputed Non-Detects NDs with many tied observations at multiple DLs s <1.0, especially when the sample size is small (e.g., <15-20) yield incorrect values of UCLs and BTVs	23.5
281 282 283 284 285 286 287 287 288 289 290 291 291 292	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects) Gamma ROS GROS may not be used when data se GROS may not be used when kstar of detects is s For such situations, GROS r	Statistics on 0.384 16.06 3.076 6.175 Statistics us et has > 50% small such as nethod may ally true whe	A Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE) nu star (bias corrected MLE) nu star (bias corrected) sing Imputed Non-Detects NDs with many tied observations at multiple DLs s <1.0, especially when the sample size is small (e.g., <15-20) yield incorrect values of UCLs and BTVs n the sample size is small.	23.5
281 282 283 284 285 286 287 288 289 290 291 291 292 293	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects) GROS may not be used when data se GROS may not be used when data se GROS may not be used when kstar of detects is s For such situations, GROS r This is especia For gamma distributed detected data, BTVs a	Statistics on 0.384 16.06 3.076 6.175 Statistics us at has > 50% small such as nethod may ally true whe nd UCLs ma	Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE) nu star (bias corrected MLE) sing Imputed Non-Detects NDs with many tied observations at multiple DLs s <1.0, especially when the sample size is small (e.g., <15-20)	23.5 2.102
281 282 283 284 285 286 287 288 289 290 291 292 293 293 294 295	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects) Gamma ROS GROS may not be used when data se GROS may not be used when data se GROS may not be used when kstar of detects is se For such situations, GROS r This is especia For gamma distributed detected data, BTVs a Minimum	Statistics on 0.384 16.06 3.076 6.175 Statistics us et has > 50% small such as method may ally true whe 0.01	A Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE) nu star (bias corrected MLE) nu star (bias corrected) sing Imputed Non-Detects NDs with many tied observations at multiple DLs s <1.0, especially when the sample size is small (e.g., <15-20) yield incorrect values of UCLs and BTVs n the sample size is small. y be computed using gamma distribution on KM estimates Mean	23.5 2.102
281 282 283 284 285 286 287 288 289 290 290 291 292 293 293 294 295 296	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects) GROS may not be used when data se GROS may not be used when kstar of detects is s For such situations, GROS r This is especia For gamma distributed detected data, BTVs a Minimum Maximum	Statistics on 0.384 16.06 3.076 6.175 Statistics us et has > 50% small such as nethod may ally true whe nd UCLs ma 0.01 23.5	Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE) nu star (bias corrected MLE) sing Imputed Non-Detects NDs with many tied observations at multiple DLs s <1.0, especially when the sample size is small (e.g., <15-20)	23.5 2.102 2.476 0.01
281 282 283 284 285 286 287 288 289 290 291 292 293 293 294 295	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects) Gamma ROS GROS may not be used when data se GROS may not be used when kstar of detects is se GROS may not be used when kstar of detects is se For such situations, GROS r This is especia For gamma distributed detected data, BTVs a Minimum Maximum	Statistics on 0.384 16.06 3.076 6.175 Statistics us et has > 50% small such as nethod may ally true whe nd UCLs ma 0.01 23.5 7.389	Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE) nu star (bias corrected MLE) nu star (bias corrected MLE) sing Imputed Non-Detects NDs with many tied observations at multiple DLs s <1.0, especially when the sample size is small (e.g., <15-20) yield incorrect values of UCLs and BTVs n the sample size is small. y be computed using gamma distribution on KM estimates Mean Median 	23.5 2.102 2.476 0.01 2.984
281 282 283 284 285 286 287 288 289 290 291 292 293 292 293 294 295 295 296 297	Gamma k hat (MLE) Theta hat (MLE) nu hat (MLE) Mean (detects) Gamma ROS GROS may not be used when data se GROS may not be used when kstar of detects is s For such situations, GROS r This is especia For gamma distributed detected data, BTVs a Minimum Maximum SD k hat (MLE)	Statistics on 0.384 16.06 3.076 6.175 Statistics us et has > 50% small such as nethod may ally true whe nd UCLs ma 0.01 23.5 7.389 0.202	Detected Data Only k star (bias corrected MLE) Theta star (bias corrected MLE) nu star (bias corrected MLE) sing Imputed Non-Detects NDs with many tied observations at multiple DLs s <1.0, especially when the sample size is small (e.g., <15-20)	23.5 2.102 2.476 0.01 2.984 0.208

307 k hat (KM) 0.145 k 308 nu hat (KM) 2.893 nu 309 theta hat (KM) 18.28 theta 310 80% gamma percentile (KM) 3.134 90% gamma percentile (KM) 311 95% gamma percentile (KM) 14.21 99% gamma percentile (KM) 312 313 Gamma Kaplan-Meier (KM) Statistics 314 Approximate Chi Square Value (3.36, α) 0.486 Adjusted Chi Square Value 315 95% Gamma Approximate KM-UCL (use when n>=50) 18.27 95% Gamma Adjusted KM-UCL (use when n>=50) 316 11 Lognormal GOF Test on Detected Observations Only 318 318 Shapiro Wilk Test Statistic 0.667 Shapiro Wilk GOF Test 319 5% Shapiro Wilk Critical Value 0.748 Detected Data Not Lognormal at 5% Significance Level 321 5% Lilliefors Test Statistic 0.416 Lilliefors GOF Test 322 Detected Data Not Lognormal at 5% Significance Level 322 Detected Data Not Lognormal at 5% Significance Level 322 Detected Data Not Lognormal at 5% Significance Level 323 Lasaamad DOC Statistica Laian Instact M	hen n<50) SD (KM) Mean (KM) a star (KM) a star (KM) entile (KM) entile (KM) entile (KM) hen n<50) ficance Leve	L 0.571 N/A 6.952 2.539 0.168 3.358 15.75 7.938 32.03 0.338 26.28
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302 1	SD (KM) Mean (KM) a star (KM) a star (KM) entile (KM) entile (KM) entile (KM) hen n<50) ficance Lev	2.539 0.168 3.358 15.75 7.938 32.03 0.338 26.28
304 Estimates of Gamma Parameters using KM Estimates 305 Mean (KM) 2.644 306 Variance (KM) 48.33 SE of M 307 k hat (KM) 0.145 H 308 nu hat (KM) 2.893 nu 309 theta hat (KM) 18.28 theta 310 80% gamma percentile (KM) 3.134 90% gamma percentile (KM) 311 95% gamma percentile (KM) 14.21 99% gamma percentile (KM) 312 313 Gamma Kaplan-Meier (KM) Statistics 314 Approximate Chi Square Value (3.36, q) 0.486 Adjusted Chi Square Value value (3.36, q) 315 95% Gamma Approximate KM-UCL (use when n>=50) 18.27 95% Gamma Adjusted KM-UCL (use when n>=50) 316 18.27 95% Gamma Adjusted KM-UCL (use when n>=50) 18.27 95% Gamma Adjusted KM-UCL (use when n>=50) 318 Shapiro Wilk Test Statistic 0.667 Shapiro Wilk GOF Test 319 5% Shapiro Wilk Critical Value 0.748 Detected Data Not Lognormal at 5% Significance 321 5% Lilliefors Critical Value 0.375 Detected Data Not Lognormal at 5% Significance <	Mean (KM) a star (KM) a star (KM) a star (KM) entile (KM) entile (KM) entile (KM) hen n<50) ficance Leve	2.539 0.168 3.358 15.75 7.938 32.03 0.338 26.28
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305 Variance (KM) 48.33 SE of M 306 K hat (KM) 0.145 K 308 nu hat (KM) 2.893 nu 309 theta hat (KM) 18.28 theta 310 80% gamma percentile (KM) 3.134 90% gamma percentile (KM) 311 95% gamma percentile (KM) 14.21 99% gamma percentile (KM) 312 Gamma Kaplan-Meier (KM) Statistics 313 314 Approximate Chi Square Value (3.36, α) 0.486 Adjusted Chi Square Value (3.36, α) 315 95% Gamma Approximate KM-UCL (use when n>=50) 18.27 95% Gamma Adjusted KM-UCL (use w 316 317 Lognormal GOF Test on Detected Observations Only 318 319 Shapiro Wilk Test Statistic 0.667 Shapiro Wilk GOF Test 319 5% Shapiro Wilk Critical Value 0.748 Detected Data Not Lognormal at 5% Signi 320 Lilliefors Test Statistic 0.416 Lilliefors GOF Test 321 5% Lilliefors Critical Value 0.375 Detected Data Not Lognormal at 5% Signi 322 Detected Data Not Lognormal at 5% Significance Level 323	Mean (KM) a star (KM) a star (KM) a star (KM) entile (KM) entile (KM) entile (KM) hen n<50) ficance Leve	2.539 0.168 3.358 15.75 7.938 32.03 0.338 26.28
300 k hat (KM) 0.145 k 307 nu hat (KM) 2.893 nu 309 theta hat (KM) 18.28 theta 310 80% gamma percentile (KM) 3.134 90% gamma percentile (KM) 311 95% gamma percentile (KM) 14.21 99% gamma percentile (KM) 312 313 Gamma Kaplan-Meier (KM) Statistics 314 Approximate Chi Square Value (3.36, α) 0.486 Adjusted Chi Square Valu 315 95% Gamma Approximate KM-UCL (use when n>=50) 18.27 95% Gamma Adjusted KM-UCL (use w 316	star (KM) a star (KM) a star (KM) entile (KM) entile (KM) entile (KM) hen n<50)	0.168 3.358 15.75 7.938 32.03 0.338 26.28
307 nu hat (KM) 2.893 nu 309 theta hat (KM) 18.28 theta 310 80% gamma percentile (KM) 3.134 90% gamma percentile (KM) 311 95% gamma percentile (KM) 14.21 99% gamma percentile (KM) 312 313 Gamma Kaplan-Meier (KM) Statistics 314 Approximate Chi Square Value (3.36, q) 0.486 Adjusted Chi Square Value (3.36, q) 315 95% Gamma Approximate KM-UCL (use when n>=50) 18.27 95% Gamma Adjusted KM-UCL (use w 316 18.27 95% Gamma Adjusted KM-UCL (use w 318 Shapiro Wilk Test Statistic 0.667 Shapiro Wilk GOF Test 319 5% Shapiro Wilk Critical Value 0.748 Detected Data Not Lognormal at 5% Signi 320 Lilliefors Test Statistic 0.416 Lilliefors GOF Test 321 5% Lilliefors Critical Value 0.375 Detected Data Not Lognormal at 5% Signi 322 Detected Data Not Lognormal at 5% Significance Level 323	a star (KM) a star (KM) entile (KM) entile (KM) e (3.36, β) hen n<50) ficance Lev	3.358 15.75 7.938 32.03 0.338 26.28
309 theta hat (KM) 18.28 theta 310 80% gamma percentile (KM) 3.134 90% gamma percentile (KM) 311 95% gamma percentile (KM) 14.21 99% gamma percentile (KM) 312 313 Gamma Kaplan-Meier (KM) Statistics 314 Approximate Chi Square Value (3.36, a) 0.486 Adjusted Chi Square Value (3.36, a) 315 95% Gamma Approximate KM-UCL (use when n>=50) 18.27 95% Gamma Adjusted KM-UCL (use w 316 Lognormal GOF Test on Detected Observations Only 318 Shapiro Wilk Test Statistic 0.667 Shapiro Wilk GOF Test 319 5% Shapiro Wilk Critical Value 0.748 Detected Data Not Lognormal at 5% Signi 320 Lilliefors Test Statistic 0.416 Lilliefors GOF Test 321 5% Lilliefors Critical Value 0.375 Detected Data Not Lognormal at 5% Signi 322 Detected Data Not Lognormal at 5% Signi Significance Level 323 Lagnormal DOC Statistic Linical Using Linguidad Neg Data to the	a star (KM) entile (KM) entile (KM) e (3.36, β) hen n<50) ficance Lev	15.75 7.938 32.03 0.338 26.28
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311 95% gamma percentile (KM) 14.21 99% gamma percentile 312 313 Gamma Kaplan-Meier (KM) Statistics 314 Approximate Chi Square Value (3.36, a) 0.486 Adjusted Chi Square Value 315 95% Gamma Approximate KM-UCL (use when n>=50) 18.27 95% Gamma Adjusted KM-UCL (use w 316 317 Lognormal GOF Test on Detected Observations Only 318 Shapiro Wilk Test Statistic 0.667 Shapiro Wilk GOF Test 319 5% Shapiro Wilk Critical Value 0.748 Detected Data Not Lognormal at 5% Significance Level 321 5% Lilliefors Critical Value 0.375 Detected Data Not Lognormal at 5% Significance Level 322 Detected Data Not Lognormal at 5% Significance Level 323	entile (KM) e (3.36, β) hen n<50) ficance Lev	32.03 0.338 26.28
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320 5% Lilliefors Critical Value 0.375 Detected Data Not Lognormal at 5% Significance 322 Detected Data Not Lognormal at 5% Significance Level 323 Lognormal DOS Statistics Using Imputed Non Detected	ficance Lev	ei
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323		ei
Legnermel DOC Statistics Lising Imputed New Detects		
Los di Lonnormai RUS Statistics Usino imputen Non-Detects		
524		-3.741
525	Log Scale	3.754
320	Log Scale	
327 95% t UCL (assumes normality of ROS data) 6.757 95% Percentile Boot 95% BCA Bootstrap UCL 9.442 95% Boots		7.136
328		117.5
329 95% H-UCL (Log ROS) 5501579		
330 221 Statistics using KM estimates on Logged Data and Assuming Lognormal Distribution		
		0.405
332	Geo Mean	0.495
333	(0,	3.741
334 KM Standard Error of Mean (logged) 0.473 95% H-UCL	(B)	5.765
335 KM SD (logged) 1.296 95% Critical H Value	(KIVI-LOG)	3.741
336 KM Standard Error of Mean (logged) 0.473		
337 DI /2 Statiatica		
338 DL/2 Statistics 230 DL/2 Normal DL/2 Log-Transformed		
333		1 100
	Log Scale	-1.109
	Log Scale	1.571
342	I-Stat UCL	11.2
343 DL/2 is not a recommended method, provided for comparisons and historical reasons		
344		
345 Nonparametric Distribution Free UCL Statistics		
346 Data do not follow a Discernible Distribution at 5% Significance Level		
347		
348 Suggested UCL to Use		
349 KM Bootstrap t UCL N/A		
350		

	A B C D E F G H I J K L													
351														
352	Recommendations are based upon data size, data distribution, and skewness.													
353	These recommendations are based upon the results of the simulation studies summarized in Singh, Maichle, and Lee (2006).													
354	However, simulations require will not sever all Pool World date sets: for additional insight the user may want to consult a statistician													
355														

Middlesex Sampling Plant Draft Final Supplemental Risk Assessment

Risk Calculator Output

Site-specific Worker Equation Inputs for Tap Water (RME)

Variable	Value
THQ (target hazard quotient) unitless	1
TR (target risk) unitless	0.000001
LT (lifetime) years	70
K (volatilization factor of Andelman) L/m ³	0.5
I_{sc} (apparent thickness of stratum corneum) cm	0.001
ED _{res} (exposure duration - resident) years	25
ED _{res-c} (exposure duration - child) years	0
ED _{res-a} (exposure duration - adult) years	25
ED ₀₋₂ (mutagenic exposure duration first phase) years	0
ED ₂₋₆ (mutagenic exposure duration second phase) years	0
ED ₆₋₁₆ (mutagenic exposure duration third phase) years	0
ED ₁₆₋₂₆ (mutagenic exposure duration fourth phase) years	25
EF _{res} (exposure frequency) days/year	250
EF _{res-c} (exposure frequency - child) days/year	0
EF _{res-a} (exposure frequency - adult) days/year	250
EF ₀₋₂ (mutagenic exposure frequency first phase) days/year	0
EF ₂₋₆ (mutagenic exposure frequency second phase) days/year	0
EF ₆₋₁₆ (mutagenic exposure frequency third phase) days/year	0
EF ₁₆₋₂₆ (mutagenic exposure frequency fourth phase) days/year	250
ET _{event res-adj} (age-adjusted exposure time) hours/event	0.71
ET _{res-madj} (mutagenic age-adjusted exposure time) hours/event	0.71
ET _{res} (exposure time) hours/day	24
ET _{res-c} (dermal exposure time - child) hours/event	0
ET _{res-a} (dermal exposure time - adult) hours/event	0.71

ET _{res-c} (inhalation exposure time - child) hours/day	0
ET _{res-a} (inhalation exposure time - adult) hours/day	24
ET ₀₋₂ (mutagenic inhalation exposure time first phase) hours/day	0
ET ₂₋₆ (mutagenic inhalation exposure time second phase) hours/day	0
ET ₆₋₁₆ (mutagenic inhalation exposure time third phase) hours/day	0
ET ₁₆₋₂₆ (mutagenic inhalation exposure time fourth phase) hours/day	24
ET ₀₋₂ (mutagenic dermal exposure time first phase) hours/event	0
ET ₂₋₆ (mutagenic dermal exposure time second phase) hours/event	0
ET ₆₋₁₆ (mutagenic dermal exposure time third phase) hours/event	0
ET ₁₆₋₂₆ (mutagenic dermal exposure time fourth phase) hours/event	0.71
BW _{res-a} (body weight - adult) kg	80
BW _{res-c} (body weight - child) kg	0
BW ₀₋₂ (mutagenic body weight) kg	0
BW ₂₋₆ (mutagenic body weight) kg	0
BW ₆₋₁₆ (mutagenic body weight) kg	0
BW ₁₆₋₂₆ (mutagenic body weight) kg	80
IFW _{res-adj} (adjusted intake factor) L/kg	195.313
IFW _{res-adj} (adjusted intake factor) L/kg	195.313
IFWM _{res-adj} (mutagenic adjusted intake factor) L/kg	195.313
IFWM _{res-adj} (mutagenic adjusted intake factor) L/kg	195.313
IRW _{res-c} (water intake rate - child) L/day	0
IRW _{res-a} (water intake rate - adult) L/day	2.5
IRW ₀₋₂ (mutagenic water intake rate) L/day	0
IRW ₂₋₆ (mutagenic water intake rate) L/day	0
IRW ₆₋₁₆ (mutagenic water intake rate) L/day	0
IRW ₁₆₋₂₆ (mutagenic water intake rate) L/day	2.5
EV _{res-a} (events - adult) per day	1
EV _{res-c} (events - child) per day	0
EV ₀₋₂ (mutagenic events) per day	0

EV ₂₋₆ (mutagenic events) per day	0
EV ₆₋₁₆ (mutagenic events) per day	0
EV ₁₆₋₂₆ (mutagenic events) per day	1
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	1632812.5
DFWM _{res-adj} (mutagenic age-adjusted dermal factor) cm ² -event/kg	1632812.5
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	1632812.5
DFWM _{res-adj} (mutagenic age-adjusted dermal factor) cm ² -event/kg	1632812.5
SA _{res-c} (skin surface area - child) cm ²	0
SA _{res-a} (skin surface area - adult) cm ²	20900
SA ₀₋₂ (mutagenic skin surface area) cm ²	0
SA ₂₋₆ (mutagenic skin surface area) cm ²	0
SA ₆₋₁₆ (mutagenic skin surface area) cm ²	0
SA ₁₆₋₂₆ (mutagenic skin surface area) cm ²	20900

Output generated 18JUL2017:13:08:19

Site-specific Resident Risk for Tap Water

Chemical	Chemical Type	Ingestion SF (mg/kg-day) ⁻¹	SFO Ref	Inhalation Unit Risk (ug/m ³) ⁻¹	IUR Ref	Chronic RfD (mg/kg-day)	Chronic RfD Ref	Chronic RfC (mg/m ³)	Chronic RfC Ref	K _p (cm/hr)	MW	B (unitless)
Carbon Tetrachloride	Organics	0.07	I	0.00006	I	0.004	IR	0.1	IR	0.0163	153.82	0.0777536
Chloroform	Organics	0.031	С	0.000023	I	0.01	IR	0.0977	AT	0.00683	119.38	0.0287021
Dichloroethane, 1,2-	Organics	0.091	I	0.000026	I	0.006	SC	0.007	PP	0.0042	98.96	0.0160696
Dichloroethylene, 1,2-cis-	Organics	-		-		0.002	IR	-		0.011	96.944	0.0416562
Methyl tert-Butyl Ether (MTBE)	Organics	0.0018	С	0.00000026	С	-		3	IR	0.00211	88.151	0.0076194
Trichloroethane, 1,1,2-	Organics	0.057	I	0.000016	I	0.004	IR	0.0002	SC	0.00504	133.41	0.0223899
Trichloroethylene	Organics	0.046	I	0.0000041	I	0.0005	IR	0.002	IR	0.0116	131.39	0.0511406
*Total Risk/HI		-		-		-		-		-	-	-

Output generated 18JUL2017:13:08:19

t (hr)	T _{event} (hr/event)	FA (unitless)	In EPD?	MCL (ug/L)	Concentration (ug/L)	Ingestion Risk	Dermal Risk	Inhalation Risk	Carcinogenic Risk	Ingestion Child HQ	Dermal Child HQ
1.8342224	0.7642593	1	Yes	5	2460	0.00132	0.000365	0.00181	0.00349	-	-
1.1764893	0.4902039	1	Yes	80	178	0.0000422	0.00000393	0.000501	0.000547	-	-
0.9041406	0.3767253	1	Yes	5	1.38	0.0000096	4.82E-08	0.00000439	0.0000054	-	-
0.8809401	0.3670584	1	Yes	70	3.24	-	-	-	-	-	-
0.7865124	0.3277135	1	Yes	-	23.5	0.00000323	7.6E-09	0.000000747	0.00000108	-	-
1.4097951	0.5874146	1	Yes	5	0.44	0.000000192	1.44E-08	0.00000861	0.00000107	-	-
1.3735485	0.5723119	1	Yes	5	86.1	0.0000305	0.0000052	0.0000432	0.0000788	-	-
-	-	-		-	-	0.00139	0.000374	0.00236	0.00412	-	-

Inhalation Child HQ	Noncarcinogenic Child HI	Ingestion Adult HQ	Dermal Adult HQ	Inhalation Adult HQ	Noncarcinogenic Adult HI
-	-	13.2	3.65	8.42	25.2
-	-	0.381	0.0355	0.624	1.04
-	-	0.00492	0.000247	0.0675	0.0727
-	-	0.0347	0.0045	-	0.0392
-	-	-	-	0.00268	0.00268
-	-	0.00235	0.000177	0.753	0.756
-	-	3.69	0.63	14.7	19.1
-	-	17.3	4.32	24.6	46.2

Site-specific Worker Equation Inputs for Tap Water (CTE)

Variable	Value
THQ (target hazard quotient) unitless	1
TR (target risk) unitless	0.000001
LT (lifetime) years	70
K (volatilization factor of Andelman) L/m ³	0.5
I_{sc} (apparent thickness of stratum corneum) cm	0.001
ED _{res} (exposure duration - resident) years	6.6
ED _{res-c} (exposure duration - child) years	0
ED _{res-a} (exposure duration - adult) years	6.6
ED ₀₋₂ (mutagenic exposure duration first phase) years	0
ED ₂₋₆ (mutagenic exposure duration second phase) years	0
ED_{6-16} (mutagenic exposure duration third phase) years	0
ED ₁₆₋₂₆ (mutagenic exposure duration fourth phase) years	6.6
EF _{res} (exposure frequency) days/year	125
EF _{res-c} (exposure frequency - child) days/year	0
EF _{res-a} (exposure frequency - adult) days/year	125
EF ₀₋₂ (mutagenic exposure frequency first phase) days/year	0
EF ₂₋₆ (mutagenic exposure frequency second phase) days/year	0
EF ₆₋₁₆ (mutagenic exposure frequency third phase) days/year	0
EF ₁₆₋₂₆ (mutagenic exposure frequency fourth phase) days/year	125
ET _{event res-adj} (age-adjusted exposure time) hours/event	0.71
ET _{res-madj} (mutagenic age-adjusted exposure time) hours/event	0.71
ET _{res} (exposure time) hours/day	24
ET _{res-c} (dermal exposure time - child) hours/event	0
ET _{res-a} (dermal exposure time - adult) hours/event	0.71

ET _{res-c} (inhalation exposure time - child) hours/day	0
ET _{res-a} (inhalation exposure time - adult) hours/day	24
ET ₀₋₂ (mutagenic inhalation exposure time first phase) hours/day	0
ET ₂₋₆ (mutagenic inhalation exposure time second phase) hours/day	0
ET ₆₋₁₆ (mutagenic inhalation exposure time third phase) hours/day	0
ET ₁₆₋₂₆ (mutagenic inhalation exposure time fourth phase) hours/day	24
ET ₀₋₂ (mutagenic dermal exposure time first phase) hours/event	0
ET ₂₋₆ (mutagenic dermal exposure time second phase) hours/event	0
ET ₆₋₁₆ (mutagenic dermal exposure time third phase) hours/event	0
ET ₁₆₋₂₆ (mutagenic dermal exposure time fourth phase) hours/event	0.71
BW _{res-a} (body weight - adult) kg	80
BW _{res-c} (body weight - child) kg	0
BW ₀₋₂ (mutagenic body weight) kg	0
BW ₂₋₆ (mutagenic body weight) kg	0
BW ₆₋₁₆ (mutagenic body weight) kg	0
BW ₁₆₋₂₆ (mutagenic body weight) kg	80
IFW _{res-adi} (adjusted intake factor) L/kg	12.684
IFW _{res-adj} (adjusted intake factor) L/kg	12.684
IFWM _{res-adi} (mutagenic adjusted intake factor) L/kg	12.684
IFWM _{res-adi} (mutagenic adjusted intake factor) L/kg	12.684
IRW _{res-c} (water intake rate - child) L/day	0
IRW _{res-a} (water intake rate - adult) L/day	1.23
IRW ₀₋₂ (mutagenic water intake rate) L/day	0
IRW ₂₋₆ (mutagenic water intake rate) L/day	0
IRW ₆₋₁₆ (mutagenic water intake rate) L/day	0
IRW ₁₆₋₂₆ (mutagenic water intake rate) L/day	1.23
EV _{res-a} (events - adult) per day	1
EV _{res-c} (events - child) per day	0
EV ₀₋₂ (mutagenic events) per day	0

EV ₂₋₆ (mutagenic events) per day	0
EV ₆₋₁₆ (mutagenic events) per day	0
EV ₁₆₋₂₆ (mutagenic events) per day	1
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	215531.25
DFWM _{res-adj} (mutagenic age-adjusted dermal factor) cm ² -event/kg	215531.25
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	215531.25
DFWM _{res-adj} (mutagenic age-adjusted dermal factor) cm ² -event/kg	215531.25
SA _{res-c} (skin surface area - child) cm ²	0
SA _{res-a} (skin surface area - adult) cm ²	20900
SA ₀₋₂ (mutagenic skin surface area) cm ²	0
SA ₂₋₆ (mutagenic skin surface area) cm ²	0
SA ₆₋₁₆ (mutagenic skin surface area) cm ²	0
SA ₁₆₋₂₆ (mutagenic skin surface area) cm ²	20900

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Site-specific Worker Equation Inputs for Tap Water (CTE)

Chemical	Chemical Type	Ingestion SF (mg/kg-day) ⁻¹	SFO Ref	Inhalation Unit Risk (ug/m ³) ⁻¹	IUR Ref	Chronic RfD (mg/kg-day)	Chronic RfD Ref	Chronic RfC (mg/m ³)	Chronic RfC Ref	K _p (cm/hr)
Carbon Tetrachloride	Organics	0.07	I	0.00006	I	0.004	IR	0.1	IR	0.0163
Chloroform	Organics	0.031	С	0.000023	I	0.01	IR	0.0977	AT	0.00683
Dichloroethane, 1,2-	Organics	0.091	I	0.000026	I	0.006	SC	0.007	PP	0.0042
Dichloroethylene, 1,2-cis-	Organics	-		-		0.002	IR	-		0.011
Methyl tert-Butyl Ether (MTBE)	Organics	0.0018	С	0.00000026	С	-		3	IR	0.00211
Trichloroethane, 1,1,2-	Organics	0.057	I	0.000016	I	0.004	IR	0.0002	SC	0.00504
Trichloroethylene	Organics	0.046	I	0.0000041	I	0.0005	IR	0.002	IR	0.0116
*Total Risk/HI		-		-		-		-		-

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MW	B (unitless)	t (hr)	T _{event} (hr/event)	FA (unitless)	In EPD?	MCL (ug/L)	Concentration (ug/L)	Ingestion Risk	Dermal Risk	Inhalation Risk
153.82	0.0777536	1.8342224	0.7642593	1	Yes	5	2460	0.0000855	0.0000482	0.000238
119.38	0.0287021	1.1764893	0.4902039	1	Yes	80	178	0.00000274	0.000000518	0.0000661
98.96	0.0160696	0.9041406	0.3767253	1	Yes	5	1.38	6.23E-08	6.36E-09	0.00000579
96.944	0.0416562	0.8809401	0.3670584	1	Yes	70	3.24	-	-	-
88.151	0.0076194	0.7865124	0.3277135	1	Yes	-	23.5	0.00000021	0.000000001	9.86E-08
133.41	0.0223899	1.4097951	0.5874146	1	Yes	5	0.44	1.25E-08	1.9E-09	0.000000114
131.39	0.0511406	1.3735485	0.5723119	1	Yes	5	86.1	0.00000198	0.00000687	0.000057
-	-	-	-	-		-	-	0.0000903	0.0000494	0.000311

Carcinogenic Risk	Ingestion Child HQ	Dermal Child HQ	Inhalation Child HQ	Noncarcinogenic Child HI	Ingestion Adult HQ	Dermal Adult HQ	Inhalation Adult HQ	Noncarcinogenic Adult HI
0.000372	-	-	-	-	3.24	1.83	4.21	9.28
0.0000694	-	-	-	-	0.0937	0.0177	0.312	0.424
0.00000648	-	-	-	-	0.00121	0.000124	0.0338	0.0351
-	-	-	-	-	0.00853	0.00225	-	0.0108
0.00000121	-	-	-	-	-	-	0.00134	0.00134
0.00000128	-	-	-	-	0.000579	0.0000885	0.377	0.377
0.0000836	-	-	-	-	0.907	0.315	7.37	8.59
0.000451	-	-	-	-	4.25	2.16	12.3	18.7

Site-specific Young Child Resident Risk for Tap Water (RME)

Variable	Value
THQ (target hazard quotient) unitless	1
TR (target risk) unitless	0.000001
LT (lifetime) year	70
K (volatilization factor of Andelman) L/m ³	0.5
I _{sc} (apparent thickness of stratum corneum) cm	0.001
ED _{res} (exposure duration - resident) year	6
ED _{res-c} (exposure duration - child) year	6
ED _{res-a} (exposure duration - adult) year	0
ED ₀₋₂ (mutagenic exposure duration first phase) year	2
ED ₂₋₆ (mutagenic exposure duration second phase) year	4
ED ₆₋₁₆ (mutagenic exposure duration third phase) year	0
ED ₁₆₋₂₆ (mutagenic exposure duration fourth phase) year	0
EF _{res} (exposure frequency) day/year	350
EF _{res-c} (exposure frequency - child) day/year	350
EF _{res-a} (exposure frequency - adult) day/year	0
EF ₀₋₂ (mutagenic exposure frequency first phase) day/year	350
EF ₂₋₆ (mutagenic exposure frequency second phase) day/year	350
EF ₆₋₁₆ (mutagenic exposure frequency third phase) day/year	0
EF ₁₆₋₂₆ (mutagenic exposure frequency fourth phase) day/year	0
ET _{res-adj} (age-adjusted exposure time) hour/event	0.54
ET _{res-madj} (mutagenic age-adjusted exposure time) hour/event	0.54
ET _{res} (exposure time) hour/day	24
ET _{res-c} (dermal exposure time - child) hour/event	0.54
ET _{res-a} (dermal exposure time - adult) hour/event	0
ET _{res-c} (inhalation exposure time - child) hour/day	24
ET _{res-a} (inhalation exposure time - adult) hour/day	0
ET ₀₋₂ (mutagenic inhalation exposure time first phase) hour/day	24
ET ₂₋₆ (mutagenic inhalation exposure time second phase) hour/day	24
ET ₆₋₁₆ (mutagenic inhalation exposure time third phase) hour/day	0
ET ₁₆₋₂₆ (mutagenic inhalation exposure time fourth phase) hour/day	0
ET ₀₋₂ (mutagenic dermal exposure time first phase) hour/event	0.54
ET ₂₋₆ (mutagenic dermal exposure time second phase) hour/event	0.54
ET ₆₋₁₆ (mutagenic dermal exposure time third phase) hour/event	0
ET ₁₆₋₂₆ (mutagenic dermal exposure time fourth phase) hour/event	0
BW _{res-a} (body weight - adult) kg	0
BW _{res-c} (body weight - child) kg	15
BW ₀₋₂ (mutagenic body weight) kg	15
BW ₂₋₆ (mutagenic body weight) kg	15
BW ₆₋₁₆ (mutagenic body weight) kg	0

BW ₁₆₋₂₆ (mutagenic body weight) kg	0
IFW _{res-adj} (adjusted intake factor) L/kg	109.2
IFW _{res-adj} (adjusted intake factor) L/kg	109.2
IFWM _{res-adj} (mutagenic adjusted intake factor) L/kg	582.4
IFWM _{res-adj} (mutagenic adjusted intake factor) L/kg	582.4
IRW _{res-c} (water intake rate - child) L/day	0.78
IRW _{res-a} (water intake rate - adult) L/day	0
IRW ₀₋₂ (mutagenic water intake rate) L/day	0.78
IRW ₂₋₆ (mutagenic water intake rate) L/day	0.78
IRW ₆₋₁₆ (mutagenic water intake rate) L/day	0
IRW ₁₆₋₂₆ (mutagenic water intake rate) L/day	0
EV _{res-a} (events - adult) per day	0
EV _{res-c} (events - child) per day	1
EV ₀₋₂ (mutagenic events) per day	1
EV ₂₋₆ (mutagenic events) per day	1
EV ₆₋₁₆ (mutagenic events) per day	0
EV ₁₆₋₂₆ (mutagenic events) per day	0
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	892920
DFWM _{res-adj} (mutagenic age-adjusted dermal factor) cm ² -event/kg	4762240
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	892920
DFWM _{res-adj} (mutagenic age-adjusted dermal factor) cm ² -event/kg	4762240
SA _{res-c} (skin surface area - child) cm ²	6378
SA _{res-a} (skin surface area - adult) cm ²	0
SA ₀₋₂ (mutagenic skin surface area) cm ²	6378
SA ₂₋₆ (mutagenic skin surface area) cm ²	6378
SA ₆₋₁₆ (mutagenic skin surface area) cm ²	0
SA ₁₆₋₂₆ (mutagenic skin surface area) cm ²	0

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Site-specific Young Child Resident Risk for Tap Water (RME)

		Ingestion SF	SFO	Inhalation Unit Risk	IUR	Chronic RfD	Chronic RfD	Chronic RfC	RfC	Kp	
Chemical	Chemical Type	(mg/kg-day) ⁻¹	Ref	(ug/m ³) ⁻¹	Ref	(mg/kg-day)	Ref	(mg/m ³)	Ref	(cm/hr)	MW
Carbon Tetrachloride	Organics	0.07	U	0.00006	U	0.004	U	0.1	U	0.0163	153.82
Chloroform	Organics	0.031	U	0.000023	U	0.01	U	0.0977	U	0.00683	119.38
Dichloroethane, 1,2-	Organics	0.091	U	0.000026	U	0.006	U	0.007	U	0.0042	98.96
Dichloroethylene, 1,1-	Organics	-		-		0.05	U	0.2	U	0.0117	96.944
Dichloroethylene, 1,2-cis-	Organics	-		-		0.002	U	-		0.011	96.944
Methyl tert-Butyl Ether (MTBE)	Organics	0.0018	U	0.0000026	U	-		3	U	0.00211	88.151
Trichloroethane, 1,1,2-	Organics	0.057	U	0.000016	U	0.004	U	0.0002	U	0.00504	133.41
Trichloroethylene	Organics	0.046	U	0.0000041	U	0.0005	U	0.002	U	0.0116	131.39
*Total Risk/HI		-		-		-		-		-	-

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B (unitless)	t (hr)	T _{event} (hr/event)	FA (unitless)	In EPD?	MCL ug/L	Concentration (ug/L)	Ingestion Risk	Dermal Risk	Inhalation Risk	Carcinogenic Risk	Ingestion Child HQ
0.0777536	1.8342224	0.7642593	1	Yes	5	2460	0.000736	0.000174	0.000607	0.00152	30.7
0.0287021	1.1764893	0.4902039	1	Yes	80	178	0.0000236	0.00000187	0.000168	0.000194	0.888
0.0160696	0.9041406	0.3767253	1	Yes	5	1.38	0.00000537	0.00000023	0.00000147	0.0000203	0.0115
0.0443071	0.8809401	0.3670584	1	Yes	7	12.1	-	-	-	-	0.012
0.0416562	0.8809401	0.3670584	1	Yes	70	3.24	-	-	-	-	0.0808
0.0076194	0.7865124	0.3277135	1	Yes	-	23.5	0.000000181	3.63E-09	0.000000251	0.00000436	-
0.0223899	1.4097951	0.5874146	1	Yes	5	0.44	0.000000107	6.88E-09	0.00000289	0.00000403	0.00548
0.0511406	1.3735485	0.5723119	1	Yes	5	86.1	0.0000318	0.00000464	0.0000298	0.0000663	8.58
-	-	-	-		-	-	0.000792	0.000181	0.000807	0.00178	40.2

Dermal Child HQ	Inhalation Child HQ	Noncarcinogenic Child HI	Ingestion Adult HQ	Dermal Adult HQ	Inhalation Adult HQ	Noncarcinogenic Adult HI
7.26	11.8	49.7	-	-	-	-
0.0705	0.874	1.83	-	-	-	-
0.000491	0.0945	0.106	-	-	-	-
0.00142	0.0289	0.0424	-	-	-	-
0.00894	-	0.0897	-	-	-	-
-	0.00376	0.00376	-	-	-	-
0.000352	1.05	1.06	-	-	-	-
1.25	20.6	30.5	-	-	-	-
8.59	34.5	83.3	-	-	-	-

Site-specific Young Child Resident Risk for Tap Water (CTE)

Variable	Value		
THQ (target hazard quotient) unitless	1		
TR (target risk) unitless LT (lifetime) year K (volatilization factor of Andelman) L/m ³			
LT (lifetime) year	70		
K (volatilization factor of Andelman) L/m ³	0.5		
I _{sc} (apparent thickness of stratum corneum) cm	0.001		
ED _{res} (exposure duration - resident) year	4		
ED _{res-c} (exposure duration - child) year	4		
ED _{res-a} (exposure duration - adult) year	0		
ED ₀₋₂ (mutagenic exposure duration first phase) year	0		
ED ₂₋₆ (mutagenic exposure duration second phase) year	4		
ED ₆₋₁₆ (mutagenic exposure duration third phase) year	0		
ED ₁₆₋₂₆ (mutagenic exposure duration fourth phase) year	0		
EF _{res} (exposure frequency) day/year	175		
EF _{res-c} (exposure frequency - child) day/year	175		
EF _{res-a} (exposure frequency - adult) day/year	0		
EF ₀₋₂ (mutagenic exposure frequency first phase) day/year	175		
EF ₂₋₆ (mutagenic exposure frequency second phase) day/year	175		
EF ₆₋₁₆ (mutagenic exposure frequency third phase) day/year	0		
EF ₁₆₋₂₆ (mutagenic exposure frequency fourth phase) day/year	0		
ET _{res-adj} (age-adjusted exposure time) hour/event	0.33		
ET _{res-madj} (mutagenic age-adjusted exposure time) hour/event	0.33		
ET _{res} (exposure time) hour/day	24		
ET _{res-c} (dermal exposure time - child) hour/event	0.33		
ET _{res-a} (dermal exposure time - adult) hour/event	0		
ET _{res-c} (inhalation exposure time - child) hour/day	24		
ET _{res-a} (inhalation exposure time - adult) hour/day	0		
ET ₀₋₂ (mutagenic inhalation exposure time first phase) hour/day	24		
ET ₂₋₆ (mutagenic inhalation exposure time second phase) hour/day	24		
ET ₆₋₁₆ (mutagenic inhalation exposure time third phase) hour/day	0		
ET ₁₆₋₂₆ (mutagenic inhalation exposure time fourth phase) hour/day	0		
ET ₀₋₂ (mutagenic dermal exposure time first phase) hour/event	0.33		
ET ₂₋₆ (mutagenic dermal exposure time second phase) hour/event	0.33		
ET ₆₋₁₆ (mutagenic dermal exposure time third phase) hour/event	0		
ET ₁₆₋₂₆ (mutagenic dermal exposure time fourth phase) hour/event	0		
BW _{res-a} (body weight - adult) kg	0		
BW _{res-c} (body weight - child) kg	15		
BW ₀₋₂ (mutagenic body weight) kg	15		
BW ₂₋₆ (mutagenic body weight) kg	15		
BW ₆₋₁₆ (mutagenic body weight) kg	0		

BW ₁₆₋₂₆ (mutagenic body weight) kg	0
IFW _{res-adj} (adjusted intake factor) L/kg	17.033
IFW _{res-adj} (adjusted intake factor) L/kg	17.033
IFWM _{res-adj} (mutagenic adjusted intake factor) L/kg	51.1
IFWM _{res-adj} (mutagenic adjusted intake factor) L/kg	51.1
IRW _{res-c} (water intake rate - child) L/day	0.365
IRW _{res-a} (water intake rate - adult) L/day	0
IRW ₀₋₂ (mutagenic water intake rate) L/day	0.365
IRW ₂₋₆ (mutagenic water intake rate) L/day	0.365
IRW ₆₋₁₆ (mutagenic water intake rate) L/day	0
IRW ₁₆₋₂₆ (mutagenic water intake rate) L/day	0
EV _{res-a} (events - adult) per day	0
EV _{res-c} (events - child) per day	1
EV ₀₋₂ (mutagenic events) per day	1
EV ₂₋₆ (mutagenic events) per day	1
EV ₆₋₁₆ (mutagenic events) per day	0
EV ₁₆₋₂₆ (mutagenic events) per day	0
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	297640
DFWM _{res-adj} (mutagenic age-adjusted dermal factor) cm ² -event/kg	892920
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	297640
DFWM _{res-adj} (mutagenic age-adjusted dermal factor) cm ² -event/kg	892920
SA _{res-c} (skin surface area - child) cm ²	6378
SA _{res-a} (skin surface area - adult) cm ²	0
SA ₀₋₂ (mutagenic skin surface area) cm ²	6378
SA ₂₋₆ (mutagenic skin surface area) cm ²	6378
SA ₆₋₁₆ (mutagenic skin surface area) cm ²	0
SA ₁₆₋₂₆ (mutagenic skin surface area) cm ²	0

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Site-specific Young Child Resident Risk for Tap Water (CTE)

		Ingestion SF	SFO	Inhalation Unit Risk	IUR	Chronic RfD	Chronic RfD	RfC	Chronic RfC	K _p
Chemical	Chemical Type	(mg/kg-day) ⁻¹	Ref	(ug/m ³) ⁻¹	Ref	(mg/kg-day)	Ref	(mg/m ³)	Ref	(cm/hr)
Carbon Tetrachloride	Organics	0.07	U	0.00006	U	0.004	U	0.1	U	0.0163
Chloroform	Organics	0.031	U	0.000023	U	0.01	U	0.0977	U	0.00683
Dichloroethane, 1,2-	Organics	0.091	U	0.000026	U	0.006	U	0.007	U	0.0042
Dichloroethylene, 1,1-	Organics	-		-		0.05	U	0.2	U	0.0117
Dichloroethylene, 1,2-cis-	Organics	-		-		0.002	U	-		0.011
Methyl tert-Butyl Ether (MTBE)	Organics	0.0018	U	0.0000026	U	-		3	U	0.00211
Trichloroethane, 1,1,2-	Organics	0.057	U	0.000016	U	0.004	U	0.0002	U	0.00504
Trichloroethylene	Organics	0.046	U	0.0000041	U	0.0005	U	0.002	U	0.0116
*Total Risk/HI		-		-		-		-		-

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MW	B (unitless)	t (hr)	T _{event} (hr/event)	FA (unitless)	In EPD?	MCL ug/L	Concentration (ug/L)	Ingestion Risk	Dermal Risk	Inhalation Risk	Carcinogenic Risk
153.82	0.0777536	1.8342224	0.7642593	1	Yes	5	2460	0.000115	0.0000454	0.000202	0.000362
119.38	0.0287021	1.1764893	0.4902039	1	Yes	80	178	0.00000368	0.000000488	0.0000561	0.0000602
98.96	0.0160696	0.9041406	0.3767253	1	Yes	5	1.38	8.37E-08	5.99E-09	0.000000492	0.00000581
96.944	0.0443071	0.8809401	0.3670584	1	Yes	7	12.1	-	-	-	-
96.944	0.0416562	0.8809401	0.3670584	1	Yes	70	3.24	-	-	-	-
88.151	0.0076194	0.7865124	0.3277135	1	Yes	-	23.5	2.82E-08	9.45E-10	8.37E-08	0.000000113
133.41	0.0223899	1.4097951	0.5874146	1	Yes	5	0.44	1.67E-08	1.79E-09	9.64E-08	0.000000115
131.39	0.0511406	1.3735485	0.5723119	1	Yes	5	86.1	0.00000372	0.000000906	0.00000719	0.0000118
-	-	-	-	-		-	-	0.000122	0.0000468	0.000266	0.000435

Ingestion Child HQ	Dermal Child HQ	Inhalation Child HQ	Noncarcinogenic Child HI	Ingestion Adult HQ	Dermal Adult HQ	Inhalation Adult HQ	Noncarcinogenic Adult HI
7.18	2.84	5.9	15.9	-	-	-	-
0.208	0.0276	0.437	0.672	-	-	-	-
0.00268	0.000192	0.0473	0.0501	-	-	-	-
0.00281	0.000553	0.0145	0.0178	-	-	-	-
0.0189	0.00349	-	0.0224	-	-	-	-
-	-	0.00188	0.00188	-	-	-	-
0.00128	0.000138	0.527	0.529	-	-	-	-
2.01	0.489	10.3	12.8	-	-	-	-
9.42	3.36	17.2	30	-	-	-	-

Site-specific Adult Resident Risk for Tap Water (RME)

Variable	Value
THQ (target hazard quotient) unitless	1
TR (target risk) unitless	0.000001
LT (lifetime) year	70
K (volatilization factor of Andelman) L/m ³	0.5
I _{sc} (apparent thickness of stratum corneum) cm	0.001
ED _{res} (exposure duration - resident) year	20
ED _{res-c} (exposure duration - child) year	0
ED _{res-a} (exposure duration - adult) year	20
ED ₀₋₂ (mutagenic exposure duration first phase) year	0
year	0
year	0
year	20
EF _{res} (exposure frequency) day/year	350
EF _{res-c} (exposure frequency - child) day/year	0
EF _{res-a} (exposure frequency - adult) day/year	350
day/year	0
day/year	0
day/year	0
day/year	350
ET _{res-adj} (age-adjusted exposure time) hour/event	0.71
hour/event	0.71
ET _{res} (exposure time) hour/day	0.54
ET _{res-c} (dermal exposure time - child) hour/event	0
ET _{res-a} (dermal exposure time - adult) hour/event	0.71
ET _{res-c} (inhalation exposure time - child) hour/day	0
ET _{res-a} (inhalation exposure time - adult) hour/day	0.54
hour/day	0
phase) hour/day	0
phase) hour/day	0
phase) hour/day	0.54
hour/event	0
phase) hour/event	0
hour/event	0
phase) hour/event	0.71
BW _{res-a} (body weight - adult) kg	80
BW _{res-c} (body weight - child) kg	0
BW ₀₋₂ (mutagenic body weight) kg	0
BW ₂₋₆ (mutagenic body weight) kg	0
BW ₆₋₁₆ (mutagenic body weight) kg	0

BW ₁₆₋₂₆ (mutagenic body weight) kg	80
IFW _{res-adj} (adjusted intake factor) L/kg	218.75
IFW _{res-adj} (adjusted intake factor) L/kg	218.75
IFWM _{res-adj} (mutagenic adjusted intake factor) L/kg	218.75
IFWM _{res-adj} (mutagenic adjusted intake factor) L/kg	218.75
IRW _{res-c} (water intake rate - child) L/day	0
IRW _{res-a} (water intake rate - adult) L/day	2.5
IRW ₀₋₂ (mutagenic water intake rate) L/day	0
IRW ₂₋₆ (mutagenic water intake rate) L/day	0
IRW ₆₋₁₆ (mutagenic water intake rate) L/day	0
IRW ₁₆₋₂₆ (mutagenic water intake rate) L/day	2.5
EV _{res-a} (events - adult) per day	1
EV _{res-c} (events - child) per day	0
EV ₀₋₂ (mutagenic events) per day	0
EV ₂₋₆ (mutagenic events) per day	0
EV ₆₋₁₆ (mutagenic events) per day	0
EV ₁₆₋₂₆ (mutagenic events) per day	1
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	1828750
cm ² -event/kg	1828750
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	1828750
cm ² -event/kg	1828750
SA _{res-c} (skin surface area - child) cm ²	0
SA _{res-a} (skin surface area - adult) cm ²	20900
SA ₀₋₂ (mutagenic skin surface area) cm ²	0
SA ₂₋₆ (mutagenic skin surface area) cm ²	0
SA ₆₋₁₆ (mutagenic skin surface area) cm ²	0
SA ₁₆₋₂₆ (mutagenic skin surface area) cm ²	20900

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Site-specific Adult Resident Risk for Tap Water (RME)

		Ingestion SF	SFO	Inhalation Unit Risk	IUR	Chronic RfD	Chronic RfD	Chronic RfC	Chronic RfC	K _p	
Chemical	Chemical Type	(mg/kg-day) ⁻¹		(ug/m ³) ⁻¹	Ref	(mg/kg-day)	Ref	(mg/m ³)	Ref	(cm/hr)	MW
Carbon Tetrachloride	Organics	0.07	U	0.00006	U	0.004	U	0.1	U	0.0163	153.82
Chloroform	Organics	0.031	U	0.000023	U	0.01	U	0.0977	U	0.00683	119.38
Dichloroethane, 1,2-	Organics	0.091	U	0.000026	U	0.006	U	0.007	U	0.0042	98.96
Dichloroethylene, 1,1-	Organics	-		-		0.05	U	0.2	U	0.0117	96.944
Dichloroethylene, 1,2-cis-	Organics	-		-		0.002	U	-		0.011	96.944
Methyl tert-Butyl Ether (MTBE)	Organics	0.0018	U	0.00000026	U	-		3	U	0.00211	88.151
Trichloroethane, 1,1,2-	Organics	0.057	U	0.000016	U	0.004	U	0.0002	U	0.00504	133.41
Trichloroethylene	Organics	0.046	U	0.0000041	U	0.0005	U	0.002	U	0.0116	131.39
*Total Risk/HI		-		-		-		-		-	-

Output generated 13SEP2016:14:42:57

B (unitless)	t (hr)	T _{event} (hr/event)	FA (unitless)	In EPD?	MCL ug/L	Concentration (ug/L)	Ingestion Risk	Dermal Risk	Inhalation Risk	Carcinogenic Risk	Ingestion Child HQ
0.0777536	1.8342224	0.7642593	1	Yes	5	2460	0.00147	0.000409	0.0000455	0.00193	-
0.0287021	1.1764893	0.4902039	1	Yes	80	178	0.0000472	0.0000044	0.0000126	0.0000643	-
0.0160696	0.9041406	0.3767253	1	Yes	5	1.38	0.00000108	0.00000054	0.000000111	0.00000124	-
0.0443071	0.8809401	0.3670584	1	Yes	7	12.1	-	-	-	-	-
0.0416562	0.8809401	0.3670584	1	Yes	70	3.24	-	-	-	-	-
0.0076194	0.7865124	0.3277135	1	Yes	-	23.5	0.00000362	8.52E-09	1.88E-08	0.0000039	-
0.0223899	1.4097951	0.5874146	1	Yes	5	0.44	0.000000215	1.61E-08	2.17E-08	0.00000253	-
0.0511406	1.3735485	0.5723119	1	Yes	5	86.1	0.0000341	0.00000583	0.00000109	0.000041	-
-	-	-	-		-	-	0.00156	0.000419	0.0000594	0.00204	-

Dermal Child HQ	Inhalation Child HQ	Noncarcinogenic Child HI	Ingestion Adult HQ	Dermal Adult HQ	Inhalation Adult HQ	Noncarcinogenic Adult HI
-	-	-	18.4	5.11	0.265	23.8
-	-	-	0.533	0.0497	0.0197	0.603
-	-	-	0.00689	0.000346	0.00213	0.00936
-	-	-	0.00723	0.000998	0.00065	0.00888
-	-	-	0.0485	0.0063	-	0.0548
-	-	-	-	-	0.0000845	0.0000845
-	-	-	0.0033	0.000248	0.0237	0.0273
-	-	-	5.16	0.881	0.464	6.5
-	-	-	24.2	6.05	0.776	31

Site-specific Adult Resident Risk for Tap Water (CTE)

Variable	Value
THQ (target hazard quotient) unitless	1
TR (target risk) unitless	0.000001
LT (lifetime) year	70
K (volatilization factor of Andelman) L/m ³	0.5
I _{sc} (apparent thickness of stratum corneum) cm	0.001
ED _{res} (exposure duration - resident) year	8
ED _{res-c} (exposure duration - child) year	0
ED _{res-a} (exposure duration - adult) year	8
ED ₀₋₂ (mutagenic exposure duration first phase) year	0
ED ₂₋₆ (mutagenic exposure duration second phase) year	0
ED ₆₋₁₆ (mutagenic exposure duration third phase) year	0
ED ₁₆₋₂₆ (mutagenic exposure duration fourth phase) year	8
EF _{res} (exposure frequency) day/year	175
EF _{res-c} (exposure frequency - child) day/year	0
EF _{res-a} (exposure frequency - adult) day/year	175
EF ₀₋₂ (mutagenic exposure frequency first phase) day/year	0
EF ₂₋₆ (mutagenic exposure frequency second phase) day/year	0
EF ₆₋₁₆ (mutagenic exposure frequency third phase) day/year	0
EF ₁₆₋₂₆ (mutagenic exposure frequency fourth phase) day/year	175
ET _{res-adj} (age-adjusted exposure time) hour/event	0.25
ET _{res-madj} (mutagenic age-adjusted exposure time) hour/event	0.25
ET _{res} (exposure time) hour/day	0.25
ET _{res-c} (dermal exposure time - child) hour/event	0
ET _{res-a} (dermal exposure time - adult) hour/event	0.25
ET _{res-c} (inhalation exposure time - child) hour/day	0
ET _{res-a} (inhalation exposure time - adult) hour/day	0.25
ET ₀₋₂ (mutagenic inhalation exposure time first phase) hour/day	0
ET ₂₋₆ (mutagenic inhalation exposure time second phase) hour/day	0
ET ₆₋₁₆ (mutagenic inhalation exposure time third phase) hour/day	0
ET ₁₆₋₂₆ (mutagenic inhalation exposure time fourth phase) hour/day	0.25
ET ₀₋₂ (mutagenic dermal exposure time first phase) hour/event	0
ET ₂₋₆ (mutagenic dermal exposure time second phase) hour/event	0
ET ₆₋₁₆ (mutagenic dermal exposure time third phase) hour/event	0
ET ₁₆₋₂₆ (mutagenic dermal exposure time fourth phase) hour/event	0.25
BW _{res-a} (body weight - adult) kg	80
BW _{res-c} (body weight - child) kg	0
BW ₀₋₂ (mutagenic body weight) kg	0
BW ₂₋₆ (mutagenic body weight) kg	0
BW ₆₋₁₆ (mutagenic body weight) kg	0

BW ₁₆₋₂₆ (mutagenic body weight) kg	80
IFW _{res-adj} (adjusted intake factor) L/kg	21.473
IFW _{res-adj} (adjusted intake factor) L/kg	21.473
IFWM _{res-adj} (mutagenic adjusted intake factor) L/kg	21.473
IFWM _{res-adj} (mutagenic adjusted intake factor) L/kg	21.473
IRW _{res-c} (water intake rate - child) L/day	0
IRW _{res-a} (water intake rate - adult) L/day	1.227
IRW ₀₋₂ (mutagenic water intake rate) L/day	0
IRW ₂₋₆ (mutagenic water intake rate) L/day	0
IRW ₆₋₁₆ (mutagenic water intake rate) L/day	0
IRW ₁₆₋₂₆ (mutagenic water intake rate) L/day	1.227
EV _{res-a} (events - adult) per day	1
EV _{res-c} (events - child) per day	0
EV ₀₋₂ (mutagenic events) per day	0
EV ₂₋₆ (mutagenic events) per day	0
EV ₆₋₁₆ (mutagenic events) per day	0
EV ₁₆₋₂₆ (mutagenic events) per day	1
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	365750
DFWM _{res-adj} (mutagenic age-adjusted dermal factor) cm ² -event/kg	365750
DFW _{res-adj} (age-adjusted dermal factor) cm ² -event/kg	365750
DFWM _{res-adj} (mutagenic age-adjusted dermal factor) cm ² -event/kg	365750
SA _{res-c} (skin surface area - child) cm ²	0
SA _{res-a} (skin surface area - adult) cm ²	20900
SA ₀₋₂ (mutagenic skin surface area) cm ²	0
SA ₂₋₆ (mutagenic skin surface area) cm ²	0
SA ₆₋₁₆ (mutagenic skin surface area) cm ²	0
SA ₁₆₋₂₆ (mutagenic skin surface area) cm ²	20900

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Site-specific Adult Resident Risk for Tap Water (CTE)

Chemical	Chemical Type	Ingestion SF (mg/kg-day) ⁻¹	SFO Ref	Inhalation Unit Risk (ug/m ³) ⁻¹	IUR Ref	Chronic RfD (mg/kg-day)	Chronic RfD Ref	Chronic RfC (mg/m ³)	RfC	K _p (cm/hr)	MW
Carbon Tetrachloride	Organics	0.07	U	0.00006	U	0.004	U	0.1	U	0.0163	153.82
Chloroform	Organics	0.031	U	0.000023	U	0.01	U	0.0977	U	0.00683	119.38
Dichloroethane, 1,2-	Organics	0.091	U	0.000026	U	0.006	U	0.007	U	0.0042	98.96
Dichloroethylene, 1,1-	Organics	-		-		0.05	U	0.2	U	0.0117	96.944
Dichloroethylene, 1,2-cis-	Organics	-		-		0.002	U	-		0.011	96.944
Methyl tert-Butyl Ether (MTBE)	Organics	0.0018	U	0.00000026	U	-		3	U	0.00211	88.151
Trichloroethane, 1,1,2-	Organics	0.057	U	0.000016	U	0.004	U	0.0002	U	0.00504	133.41
Trichloroethylene	Organics	0.046	U	0.0000041	U	0.0005	U	0.002	U	0.0116	131.39
*Total Risk/HI		-		-		-		-		-	-

Output generated 13SEP2016:14:45:24

B (unitless)	t (hr)	T _{event} (hr/event)	FA (unitless)	In EPD?	MCL ug/L	Concentration (ug/L)	Ingestion Risk	Dermal Risk	Inhalation Risk	Carcinogenic Risk	Ingestion Child HQ
0.0777536	1.8342224	0.7642593	1	Yes	5	2460	0.000145	0.0000485	0.00000421	0.000197	-
0.0287021	1.1764893	0.4902039	1	Yes	80	178	0.00000464	0.000000522	0.00000117	0.0000633	-
0.0160696	0.9041406	0.3767253	1	Yes	5	1.38	0.000000106	6.4E-09	1.02E-08	0.000000122	-
0.0443071	0.8809401	0.3670584	1	Yes	7	12.1	-	-	-	-	-
0.0416562	0.8809401	0.3670584	1	Yes	70	3.24	-	-	-	-	-
0.0076194	0.7865124	0.3277135	1	Yes	-	23.5	3.56E-08	1.01E-09	1.74E-09	3.83E-08	-
0.0223899	1.4097951	0.5874146	1	Yes	5	0.44	2.11E-08	1.92E-09	2.01E-09	0.00000025	-
0.0511406	1.3735485	0.5723119	1	Yes	5	86.1	0.00000335	0.00000691	0.000000101	0.00000414	-
-	-	-	-		-	-	0.000153	0.0000498	0.0000055	0.000208	-

Dermal Child HQ	Inhalation Child HQ	Noncarcinogenic Child HI	Ingestion Adult HQ	Dermal Adult HQ	Inhalation Adult HQ	Noncarcinogenic Adult HI
-	-	-	4.52	1.52	0.0614	6.1
-	-	-	0.131	0.0147	0.00455	0.15
-	-	-	0.00169	0.000103	0.000492	0.00229
-	-	-	0.00177	0.000296	0.000151	0.00222
-	-	-	0.0119	0.00187	-	0.0138
-	-	-	-	-	0.0000196	0.0000196
-	-	-	0.000809	0.0000736	0.00549	0.00638
-	-	-	1.27	0.261	0.107	1.63
-	-	-	5.94	1.8	0.18	7.91

ProUCL Outlier Assessment

	A	В	С	D	E	F	G	н	I	J	K	L
1	Outlier Tests for Selected Variables excluding nondetects											
2		User Selected Options										
3	Dat	Date/Time of Computation ProUCL 5.17/7/2016 3:22:09 PM										
4		From File ProUCL Input_a.xls										
5		Full Precision OFF										
6												
7												
8	Dixon's	Outlier Test	t for CARBO	N TETRACH	ILORIDE							
9												
10	Total N = 10											
11	Number ND:											
12	Number Det											
13	10% critical		9									
14	5% critical value: 0.477											
15												
16	Note: NDs excluded from Outlier Test											
17	1. Data Value 2460 is a Potential Outlier (Upper Tail)?											
18				utiler (Oppe	r rail)?							
19	Test Statistic	a: 0.041										
20		0.041										
21	For 10% sig	nificance lev	vel, 2460 is n	ot an outlier								
22	-		el, 2460 is no									
23	-		el, 2460 is no									
24												
25	2. Data Valu	.e 7.7 is a P	Potential Outl	ier (Lower T	ail)?							
20												
27 28												
28 29												
30	For 10% sig	nificance lev	vel, 7.7 is not	an outlier.								
31	For 5% signi	ificance leve	el, 7.7 is not a	an outlier.								
32	For 1% signi	ificance leve	el, 7.7 is not a	an outlier.								
33												
55										1	1	1

	А	В	С	D	E	F	G	н	I	J	К	L
1		Outlier Tests for Selected Variables excluding nondetects										-
2		User Selected Options										
3	Dat	Date/Time of Computation ProUCL 5.17/7/2016 3:23:27 PM										
4				From File	ProUCL Inp	ut_a.xls						
5			Ful	I Precision	OFF							
6												
7												
8	D	ixon's Outlie	er Test for Cl	HLOROFOR	M							
9	T : 111 40											
10	Total N = 10											
11	Number ND:											
12	Number Det 10% critical		<u></u>									
13			9									
14 5% critical value: 0.477 15 1% critical value: 0.597												
15 1% crucal value: 0.597												
16												
17 18 1. Data Value 222 is a Potential Outlier (Upper Tail)?												
18												
19	Test Statistic	c: 0.279										
20												
21 22	For 10% sig	nificance lev	vel, 222 is no	t an outlier.								
22	-		el, 222 is not									
23			el, 222 is not									
25												
26	2. Data Value 2.9 is a Potential Outlier (Lower Tail)?											
27												
28	Test Statistic	c: 0.001										
29												
30	Fax 10% significance level 2.0 is not on sutting											
31	-		el, 2.9 is not a									
32	For 1% sign	ificance leve	el, 2.9 is not a	an outlier.								
33												

	A	В	С	D	E	F	G	н	I	J	K	L
1	Outlier Tests for Selected Variables excluding nondetects										-	
2		User Selected Options										
3	Date	Date/Time of Computation ProUCL 5.17/7/2016 3:24:09 PM										
4	From File ProUCL Input_a.xls											
5		Full Precision OFF										
6												
7												
8	Dixon's Out	ier Test for	TRICHLOR	DETHYLEN	E (TCE)							
9	T . IN 40											
10	Total N = 10 Number NDs	- 0										
11	Number NDs											
12	10% critical		<u>а</u>									
13	5% critical va		,									
14	1% critical value: 0 507											
15	Note: NDs excluded from Outlier Test											
16												
17 18	1. Data Val	ue 121 is a	Potential Ou	tlier (Upper	Tail)?							
10					,							
20	Test Statistic	: 0.496										
21												
	For 10% sig	nificance lev	vel, 121 is an	outlier.								
23	For 5% signi	ficance leve	el, 121 is an c	outlier.								
24	For 1% signi	ficance leve	el, 121 is not a	an outlier.								
25												
26	2. Data Value 0.61 is a Potential Outlier (Lower Tail)?											
27												
28	Test Statistic	: 0.024										
29												
30	30 For 10% significance level, 0.61 is not an outlier. 21 For 5% significance level, 0.61 is not an outlier.											
31	_											
32	⊢or 1% signi	ficance leve	el, 0.61 is not	an outlier.								
33												

APPENDIX B

TECHNICAL MEMORANDUM

Bedrock Hydrogeology Assessment and Recommended Additional Testing Program Middlesex Sampling Plant

Memo

To: Dave Miller, ECC

From: Andrew Michalski, Michalski & Associates

CC: Helen Edge, USACE-NYD; James Moore, USACE-NYD; Josephine Newton-lund, USACE-KCD; Bradley Brink, USACE-KCD

Date: March 8, 2010

Re: Middlesex Sampling Plant – Bedrock Hydrogeology Assessment and Recommended Additional Testing Program

Purpose and Scope of This Memo

This Memo discusses existing hydrogeologic and contaminant data for fractured bedrock at the abovereferenced site, re-assesses the bedrock as a leaky multi-unit aquifer, and provides recommendations for additional investigations for adequate bedrock characterization and delineation of groundwater contaminated by carbon tetrachloride (CTC) and trichloroethene (TCE). Included at the end of this Memo are descriptions of testing procedures for certain tests recommended as vital tools of bedrock characterization efforts at this site.

Strike and Dip of Bedrock Bedding

The beds of the Passaic Formation have a northeast-southwest strike that is nearly parallel with the railroad tracks at the northern boundary of the site. My best estimate of the strike is N56°E, based on the nearest dip and strike measurements, strike of geologic contacts and topographic ridges on available regional geologic maps¹, as well as observation of bedrock outcrops in the railroad cut. The best estimate for dip angle is 11° to NW, from averaging the nearest three dip measurements shown on the regional geologic maps. The dip direction is nearly parallel with Mountain Avenue, and the attached site cross-section plane follows this dip direction (Figures 1 and 2).

This current estimate of the strike direction is likely to be within less than 5° from true strike direction, and the dip angle within 2° from true dip angle. Site-specific values for dip and strike will be determined from borehole geophysics data to be obtained from temporary test holes discussed later in this Memo.

¹ Parker, R.A., 1993. Stratigraphic relations of the sedimentary rocks below the Lower Jurassic Orange Mountain Basalt, Northern Newark Basin, New Jersey. USGS.

Drake, A. et al, 1996. Bedrock geologic map of Northern New Jersey. USGS Misc. Inv. Map I-2540-A. Stanford, S.D., 2009. Surficial geology of the Plainfield quadrangle, NJGS OFM 77.

Hydraulic Performance of Existing Monitoring Wells

Hydraulic conductivity (K) or transmissivity (T) values for open-hole (or screened) intervals of bedrock wells, when available, provide information on whether a given well is completed within an aquifer or an aquitard unit. A low K value (10^{-6} cm/s to 10^{-5} cm/s) indicates that no major water-transmitting fracture is intersected within the monitored interval. Such "slow" wells can only intercept minor transmissive fractures within an aquitard (or semi-confining) unit. On the other hand, open-hole intervals of wells with K > 10^{-4} cm/s are considered "fast" wells intersecting major transmissive fractures that can be considered as discrete aquifer units.

URS (May 2005) slug-tested five "deep" bedrock wells installed in shallow bedrock (MW-1D, 2D, 3D, 9D and 11D) and 13 overburden wells. A page with URS-calculated K values for these wells is attached. The lowest K values (10^{-6} cm/s) were for wells MW-2D and MW-3D, followed by MW-1D. These low K values indicate that open intervals of these three wells, installed in the northern portion of the site, do not intersect any major transmissive fractures. These wells are all completed within an aquitard, or semi-confining unit of the dipping bedrock. Of the five bedrock wells tested, MW-11D is the only well showing K value of 10^{-4} cm/s. This value indicates that open-hole section in MW-11D intersects a significant/major transmissive fracture, or fractures, which - in the interpretation shown of Figure 1 – follow the dipping bedding-plane fracture(s) below the aquitard unit penetrated by the "slow" wells MW-1D, 2D and 3D.

The higher K average values obtained for overburden wells than for the bedrock wells provide hydraulic justification for the presence of water-saturated zone in the overburden.

As only five of some ten bedrock wells currently installed at the site were slug-tested by URS, I've estimated hydraulic conductivity of the untested bedrock wells based on their hydraulic performance during low-flow sampling events. A "fast" well shows no or little drawdown during the low-flow purging, while no drawdown stabilization during the purging is typical of a "slow" well. Applying this criterion, MW-5D is a "fast" well, while MW-24D is a "slow" well. Well MW-22D belongs to an intermediate category.

Vertical Gradients and Flows

Groundwater elevations measured in bedrock wells MW-1D, 2D, 3D, 21D, 22D, 23D, and 24D are approximately 10 ft to 15 ft lower than groundwater elevations measured in adjacent overburden wells. Given the vertical distance from the top of bedrock to middle of open-hole intervals of these bedrock wells is approximately 25 ft, the calculated vertical hydraulic gradient is approximately 0.4 to 0.6. The occurrence of such strong downward gradient values is typical of low-permeability (aquitard) units, such as one in which the listed "slow" bedrock wells are completed.

As open-hole sections of these wells, typically 25 ft long, run across the aquitard subject to the strong downward hydraulic gradient, vertical cross-flows are likely to develop in water columns of these wells. In this hydraulic set-up, water inflow would generally be from fractures within the upper portion of the open hole, while outflow/exit through fracture(s) in the lower portion. Although the amount of such downward flow is quite small², it can overwhelm the hydraulics and water quality of some wells. Consequently, samples collected from impacted bedrock monitoring wells reflect the quality of groundwater in inflows derived from the upper portion of the open-hole intervals. These samples are not representative of native water quality in the water exits/outflow zones. Native (regional) water quality in exit fracture(s) may be so impacted by the injection via exit fracture(s) that even extensive purging cannot remove the prior injection impact. Salient assumption that low-flow samples collected from the "slow" bedrock wells represent native water quality in fractures at the pump intake depth is thus incorrect for such wells.

Assuming that water exits via a fracture located at the bottom of the open-hole section and inflows are from fractures within the reminder of the open-hole section, a capture (contaminant contribution) zone to a "slow"

² Estimated between 0.01 gpm to 0.1 gpm for the site-specific transmissivity and head difference values in the "slow" wells. Such small vertical flows can only be measured via tracing techniques.

bedrock well is estimated to extent maximum of 150 ft in the up-dip direction and somewhat more into the upgradient side of the strike direction. For VOC-contaminated wells MW-2D and MW-24D, locations of VOC sources/inflows could be refined further through collecting of several unpurged, depth-discrete groundwater samples along the open-hole segments and then considering contaminant concentrations in such samples and measured cross-flows.

Specific Electrical Conductance (EC) and Temperature Logging

On February 19, 2010, EC and temperature logs were obtained for water columns of eight bedrock wells, including MW-1D, 2D, 5D, 11D, 21D, 22D, 23D and 24D (see attached EC-T logs). The logging was conducted using a hand-held downhole probe (Solinst TLC Meter). Well MW-11D was logged only to a depth of 42.4 ft from the top of casing (TOC) where a suspected pump centralizer blocked probe advance. Well MW-24D was probed to be 7 ft deeper than reported on its completion log.

The logging was conducted to identify likely locations of minor transmissive fractures within the logged water columns. Locations of hydraulically active inflow fractures are manifested by inflections of the logs at inflow locations, as mineral content and temperature of inflowing water differs from the water present in the water column. A sharp inflection, such as one logged at 34 ft in MW-5D, is typical of a single-fracture inflow. More "stretched" inflections, such as those seen in MW-1D and MW-21D, tend to be associated with inflows from several minor fractures, or small fracture zones. On the other hand, straight vertical portions of the logs are indicative of tight bedrock portions in the water columns where vertical flows dominate.

The locations of transmissive fractures interpreted from the EC-T logs of individual bedrock wells are shown on the hydrogeologic cross-section (Figure 1). They are assumed to be associated with bedding-plane fractures. The interpretation shown on Figure 1 is tentative, as it is based on the EC-T logs and general hydraulic well performance data. It needs to be verified by additional testing, including vertical flow tracing tests. These tests should be conducted at least in existing bedrock wells impacted by VOC contamination.

Sources of the VOCs

VOCs of concern in bedrock groundwater include CTC, TCE and MTBE. The latter contaminant is unrelated to former site operations.

TCE detections in on-site soils suggest that some of the TCE found in shallow bedrock wells may originate from on-site source(s). TCE and cis-1,2 dichloroethene (TCE breakdown compound) were detected in a soil sample underlying Pipe Chases (URS, 2005, page 2-11). TCE was also detected in the 2002 sediment samples from the settling basin and septic tank, as well as in soil samples from the settling basin area (URS, 2005, Vol. II, Appendix A, Tables A-1 and A-2). The highest TCE concentrations in groundwater (<100 ppb) were detected in MW-2D and MW-24D. TCE was also detected at concentrations of 3.8 ppb and 3.9 ppb in shallow groundwater in HP-4 and HP-5 installed by URS in 2004 along Mountain Avenue (URS Memo of Feb 5, 2005). HP-4 and HP-5 were located hydraulically downgradient with respect to overburden groundwater flow in the northern portion of the site.

The highest concentration of CTC (several hundred ppb) has been detected in well MW-24D. Lower concentrations have been found in MW-22D and MW23D (URS, Memo of Feb 5, page 8, indicates that CTC was detected in MW23D). CTC was also detected (at 89 ppb) in shallow piezometer URSPT-4 located approximately 110 ft N-NE of MW-2D. These detections suggest a source of CTC located to the northeast of MW-2D (Figures 1 and 2). A domestic well, shown to be located approximately 120 ft north of MW24D, may have played some role in spreading CTC into the bedrock toward MW-24D. The source of CTC appears to be local, either onsite or offsite adjacent to Mountain Avenue.

Synthesis of Site Hydrogeologic Data into Preliminary Site Model

On Figure 1, existing bedrock wells are projected onto a vertical cross-section plane passing through MW-2D located near the middle of the northern half of the site. This projection allows one to depict the position of individual bedrock monitoring wells in relation to hydrostratigraphic units of the dipping bedrock beds.

In its simplest version, the site hydrostratigraphic model consists of the saturated overburden unit and a dipping aquifer below associated with more transmissive bedding fractures. These two units are separated by a wedge-like semi-confining, or aquitard unit. Nearly all bedrock wells of the northern portion of the site are completed within this aquitard (Figure 1). The "fast" bedrock wells, MW-5D, and 11D, located in the southern portion of the site, are open to the aquifer near its subcrop area.

A more realistic version of the site model should accounts for internal structure of the aquitard and aquifer units, as well as for other units below the current exploration depth of merely 50-60 ft. The aquitard unit includes minor transmissive fractures that provide contaminant migration pathways within the aquitard and also into deeper units. Some of such likely minor fractures were mapped by the recent EC and temperature surveys. The strong downward gradient across the aquitard promotes down-dip flow (and contaminant migration) along such minor bedding fractures. It is noted that downward migration along sub-vertical joints may be hindered by termination of the majority of joint fractures at bed boundaries. With increasing depth, the down-dip flow within the minor bedding fracture turns horizontal under prevailing horizontal gradient in along-strike direction. The migration pathway of CTC in the aquitard at this site includes down-dip migration from the shallow zone toward MW-24D, followed by along-strike migration of CTC toward well MW-23D. It fits the generic flow pattern³.

Objectives of Additional Bedrock Investigation

Extending the depth of bedrock exploration, characterization and monitoring into an aquifer unit below the aquitard is a major objective of additional bedrock investigations and means of completing vertical delineation of the VOC contaminants. This aquifer unit provides a potentially fast pathway for lateral migration of contaminants derived from the overlying aquitard. But it also has large potential for dispersive dilution of the contaminants. For small contaminant fluxes from the overlying aquitard, concentrations of VOCs of concern in the aquifer may fall below the governing standards. If not, the exploration and monitoring needs to be extended to the next bedrock aquifer unit below. Technical approach to this investigation is outlined below.

Additional goals include better characterization of the VOC-impacted aquitard unit, specifically the distribution of minor transmissive fractures, vertical flows inside the aquitard wells, and better resolution of potential sources of the VOCs. These goals can be achieved through conducting specialized tests, including in-well flow tracing using salt as a tracer. These tests should be followed by collection of depth-discrete well water samples.

Technical Approach

Location and Depth of Test Holes

Three deep temporary tests holes (TTHs), ultimately converted to deep bedrock monitoring wells, are proposed to be installed at the following locations (Figure 2):

³ Groundwater flow directions indicated on Figure 2 are apparent and should not be used to determine contaminant migration pathways because 1) the map (Figure 2) considers the bedrock as a single-aquifer by combining potentiometric levels from wells completed in different aquifer units, such as 2D and 21D (Figure 1), and 2) Potentiometric heads in aquitard wells are impacted by vertical gradients; they represent transmissivity-averaged heads in inflow and exit zones penetrated.

A – Along-strike and upgradient of MW-24D - to explore potential offsite sources of TCE and CTC and determine upgradient/background water quality in the aquifer below the main aquitard (Figure 1);

B - Along strike and downgradient of the site - to determine site impacts on water quality in the aquifer;

C – Structurally down-dip of the possible source area identified north-east of MW-2D – to determine extent of the contamination in down-dip reaches of the aquifer and install the third well necessary for determining groundwater flow direction.

Each of these TTHs would start as a 10-inch hole drilled approximately 10 ft into the bedrock to set a 6-inch casing. Once grout in the annulus has cured, 6-inch hole will be advanced via air rotary/hammer to a total depth of at least 150 ft for THHs A and B, and 170 ft for C.

The THHs would remain open for a period of up to 2 weeks to complete the testing program outlined below, and then converted to deep monitoring wells targeting a specific aquifer unit identified through the testing. If results of early testing (in-well flow tracing and depth-discrete vertical flow sampling) indicate contaminant migration along a long open hole may be of significant concern, a temporary packer would be set in the hole to stop the migration until the hole is converted to a monitoring well.

Recommended Testing Program

The following testing program is recommended for each of the TTHs:

- <u>Borehole geophysics</u>, including optical televiewer, gamma, caliper, fluid conductivity, SP and electric resistivity logs. Optical televiewer survey should also be conducted in existing wells MW-2D, 23D and 24D. Conducting gamma log also in existing well MW-22D will make easier for dip and strike determination based on correlation of gamma logs.
- 2) Sufficient number of <u>in-well vertical flow tracing tests</u> using saline tracer should be conducted in each TTH to identify locations of inflow and exit fractures and measure associated vertical flow within the entire openhole segments. Tracing tests should also be conducted in existing wells MW-1D, 2D, 22D, 23D and 24D. For testing of existing wells, pumps and associated piping need to be removed first. This can be done following the next scheduled sampling round.
- 3) The in-well flow tracing tests should then be followed by <u>depth-discrete sampling of vertical flow</u> for VOCs in each TTH, with a 24-hour lab turnout requested for analytical results. A maximum of 4 to 5 samples would be collected from each TTH. Depth-discrete sampling should also be conducted in existing wells MW-2D, 23D and 24D, but with a standard lab turnout time.
- 4) Finally, <u>packer tests</u> should be conducted in selected transmissive zones identified through analysis of testing results obtained from stages 1 to 3. In addition to routine packer sampling, the packer testing will incorporate measurements of hydraulic heads and transmissivities of packer-isolated zones.

The scope and interpretation of results of the recommended testing program are discussed in the attached paper⁴. Two of the recommended tests (in-well vertical flow tracing and depth-discrete sampling of vertical flow) have not been adequately publicized as tools for bedrock characterization. Therefore, I have included detailed description of procedures for these two tests at the end of this Memo.

Anticipated Need for Additional Delineation Wells

The recommended testing program is expected to result in adequate characterization of site bedrock as a leaky multi-unit aquifer system and delineating of the vertical extent of the VOC contamination. However,

⁴ Michalski A., 2009, *Hydrogeologic characterization of contaminated sites in the Newark basin: Selecting conceptual flow model and characterization tools.* In: Herman, G.C. and Serfes, M.E., eds., Contribution to the geology and hydrogeology of the Newark basin: N.J. Geological Survey Bulletin 77, Trenton, N.J., Chapter d, p. D1-D12.

additional monitoring wells will likely be needed to complete horizontal delineation within VOC- impacted bedrock units, including:

- Two deep bedrock wells to complete horizontal delineation of VOCs in the aquifer unit; and
- Two shallow bedrock monitoring wells to complete delineation of VOCs in the aquitard in the downdip and downgradient directions.

IN-WELL FLOW TRACING USING SALT TRACER

The in-well flow tracing procedure described below is aimed at locating transmissive fractures and measurement of small vertical flows (cross-flows) within long open-hole bedrock test holes/wells.

Equipment: Downhole EC-T probe (Solinst TLC meter, or similar hand-operated downhole EC probe, as standard borehole geophysics probes are too bulky for this application); Sampling tubing with a plunger and funnel; Common salt (NaCl); Fresh (spring or distilled) water; Logging forms.

Testing Procedure:

- Obtain baseline logs of specific electrical conductance (EC) and temperature along the water column of the tested hole/well. Use the same small-diameter downhole EC-T probe that will subsequently be used to track salt tracer slug migration. Based on the baseline logs, and any prior geologic and geophysical logs, select a target release depth for the salt tracer.
- 2) Cut the required length of a small diameter PVC sampling tubing (3/8" ID), attach a plunger to the lower end of the tubing (leaving a gap for tracer release sideways) and an appropriately-sized funnel to the upper end that will rest on the casing rim. Lower the tubing to the target release depth. Prepare salt tracer solution, typically 20 to 60 grams of NaCl dissolved in no more than 0.5 gal of water. Pre-measure the volume of freshwater chaser required to displace the tracer from the tubing. For the 3/8"ID tubing, 0.22 liters of chaser is needed per every 10 ft of the tracer in the tubing. The suggested amount of salt will produce initial EC values of 5 to 10 times above the baseline EC at the release depth.
- 3) Pour the tracer solution into the tubing, followed by the pre-measured volume of the chaser to displace the tracer in the tubing. Then slowly withdraw the tubing from the well.
- 4) Lower the downhole EC probe to a depth of 5 to 10 ft above the tracer injection depth and continue downward logging at one-foot interval till baseline EC values are read again. On a logging form, record the EC values logged versus depth, together with the clock time at the start and the end of the logging, and at peak EC value. The recorded EC values provide the first image of the injected tracer slug, and a reference for determining its subsequent movement and dispersion pattern.
- 5) Repeat the EC logging of the segment of the water column with tracer-elevated EC values to obtain a series of tracer images over time. Use prior logging runs to select the frequency of the logging. Maintain the same logging direction. The tracing test may run from hours to several days, depending on site-specific conditions. More than one tracer injection may be required to test the entire open-hole segment of deep test-holes/wells.

Data Interpretation:

To interpret in-well flow tracing test data, transfer the depth-EC readings (including the baseline EC) into a spreadsheet, and plot EC values from individual logging runs. Location of water inflow and exit zones, and the type of inflow or exit flow (discrete versus diffuse) can be interpreted from changes in the shape and the size of the sequence of images.

The size of the tracer images is determined by an area between a current log run and the baseline run. This area is proportional to the mass of the salt tracer remaining in the hole, and can be quantified by incorporating the Simpson integration rule into the spreadsheet. A flow-exit-zone/fracture is recognized by a decreasing size and disappearance of the tracer image at the exit zone (the loss of tracer mass from the hole), and/or by slower tracer velocity beyond the exit location.

Local tracer velocity value is calculated from the vertical distance traveled by a selected marker point on two tracer images and the elapsed time difference. Vertical flow is then calculated as a product of the local velocity and the cross-sectional area of the hole. It is important to determine the vertical flows from data collected in-between two nearest inflow fractures, as the velocity marker selected marker should not cross an inflow fracture. The signature of an inflow fracture observed on the graphs may include persisting disturbance of the sequential tracer images at the inflow location (an indication of a discrete inflow), and a faster tracer migration (steeper slope of the EC) downstream of the inflow location.

DEPTH-DISCRETE SAMPLING OF VERTICAL FLOW

The depth-discrete sampling procedure described below permits a rapid screening-level assessment of concentrations of contaminants of concern in individual inflow fractures/zones identified through in-well flow tracing. Information on vertical contaminant distribution and the position of potential source(s) of the detected contamination can thus be obtained.

Equipment: A low-flow sampling submersible pump; Sampling tubing (preferably ¼' ID); EC meter; Sampling vials.

Sampling Procedure:

1) Select the depths of discrete sample collection. In general, the sampling depths should be selected half-way between identified inflow fractures, in order to avoid mixing zones. Do not sample at inflow fractures where mixing with water moving through the hole may be incomplete. Also, the sampling should be conducted in a way that limits disturbance to the cross-flows.

2) Measure and mark sampling depth locations on the sampling tubing. Attach the submersible pump and lower it to the lowest sampling depth, leaving several feet of excess tubing above the top of casing.

3) Start pumping at a low rate to purge approximately 2 to 3 tubing volumes. Check EC of the discharge; it should be nearly the same as baseline EC logged earlier at this sampling depth. Proceed with collection of analytical samples. Stop the pump when finished.

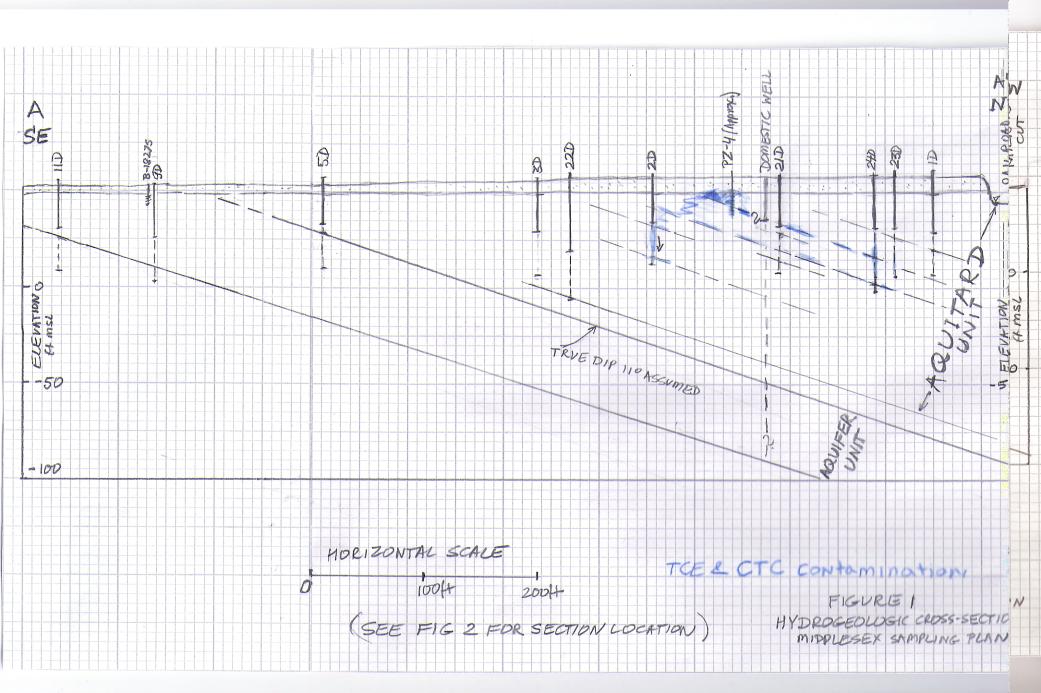
- 4) Move the pump to the next (marked-out) sampling depth. Cut-off excess tubing and go to Step 3.
- 5) Repeat Steps 3 and 4 for the remaining sampling depths.

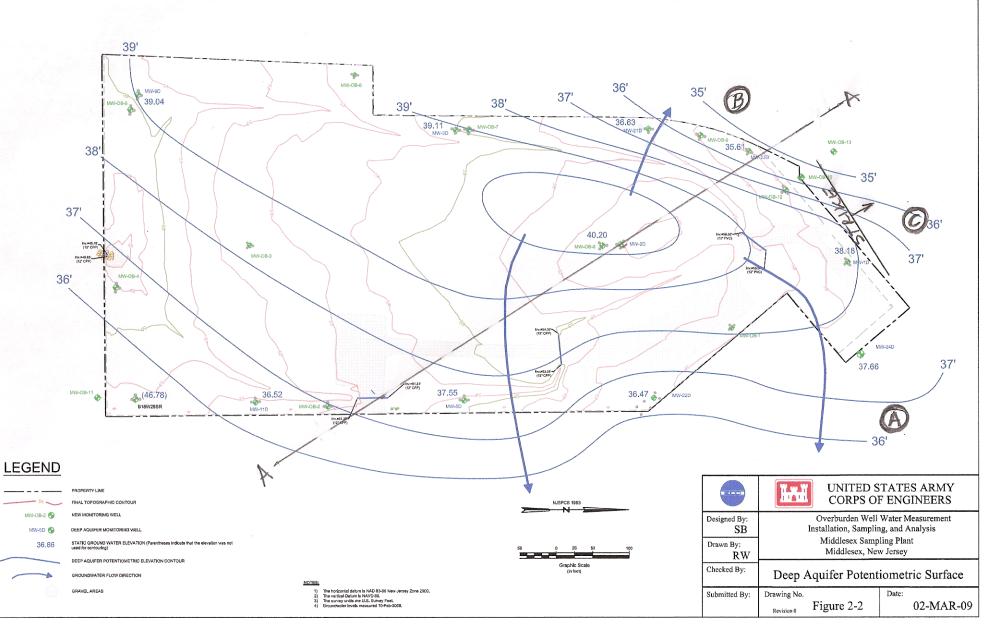
Interpretation of Sampling Results:

The actual concentration of a contaminant of interest in an inflow fracture (C_f) is determined from the previously measured vertical flows above (Q_a) and below (Q_b) the fracture and contaminant concentrations in depth-discrete flow samples collected above (C_a) and below (C_b) the inflow fracture USING the following formula (Michalski, 2009):

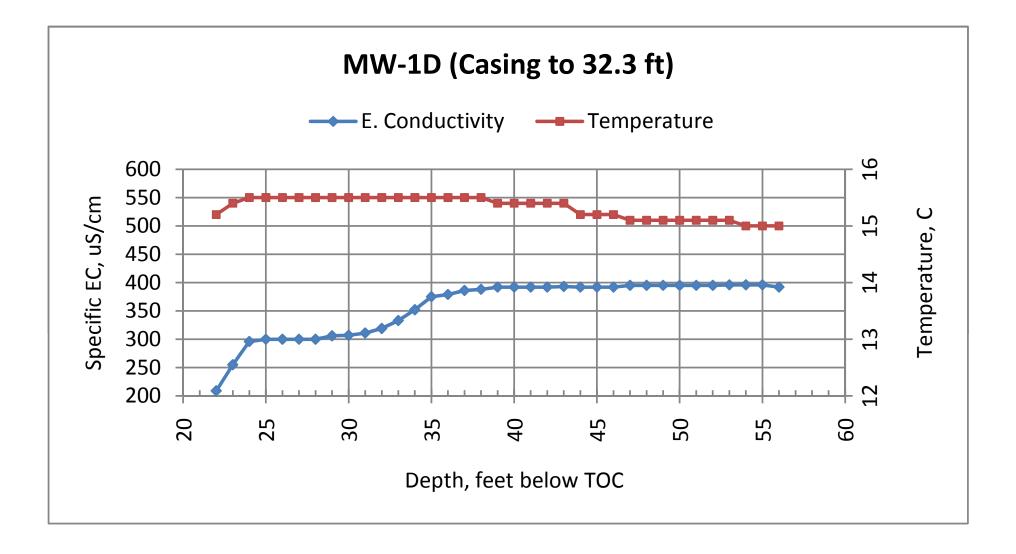
$$C_f = (Q_b C_b - Q_a C_a)/(Q_b - Q_a)$$

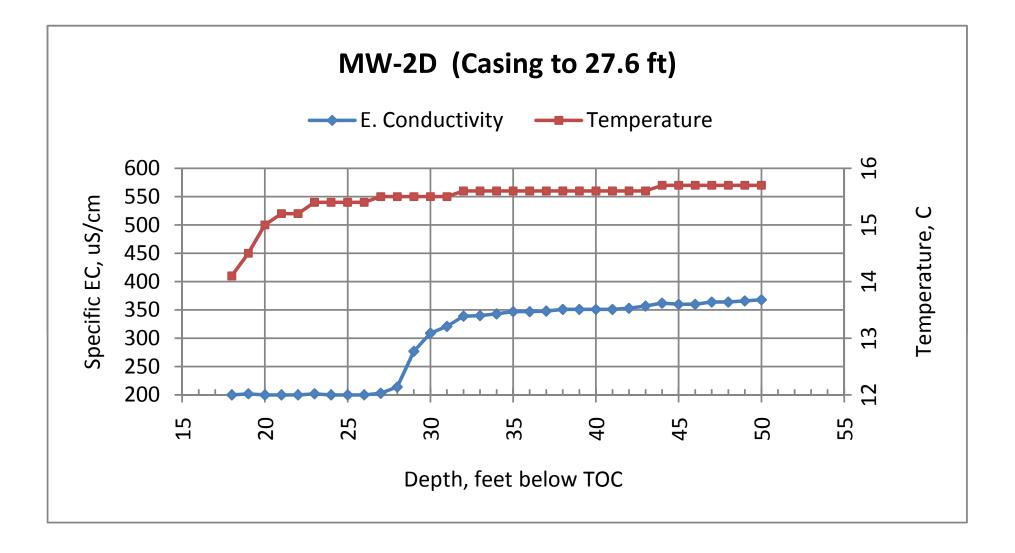
This formula is derived from the principle of contaminant mass preservation upon simple mixing under an assumed steady state vertical flow in the hole. The computational setup is comparable to determining the contaminant concentration in an inaccessible tributary stream based on the measured flows and contaminant concentrations in the main river at sections located upstream and downstream of the confluence.

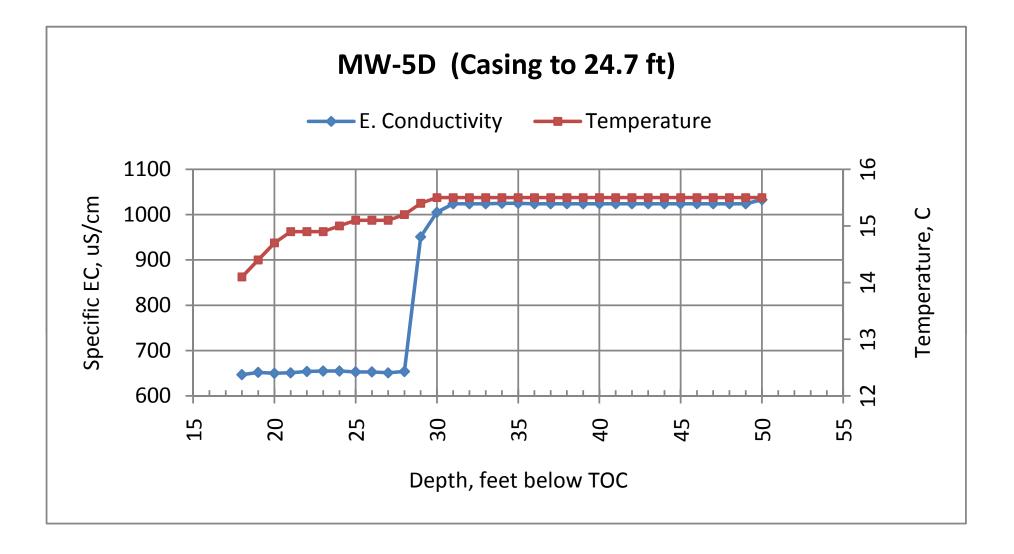


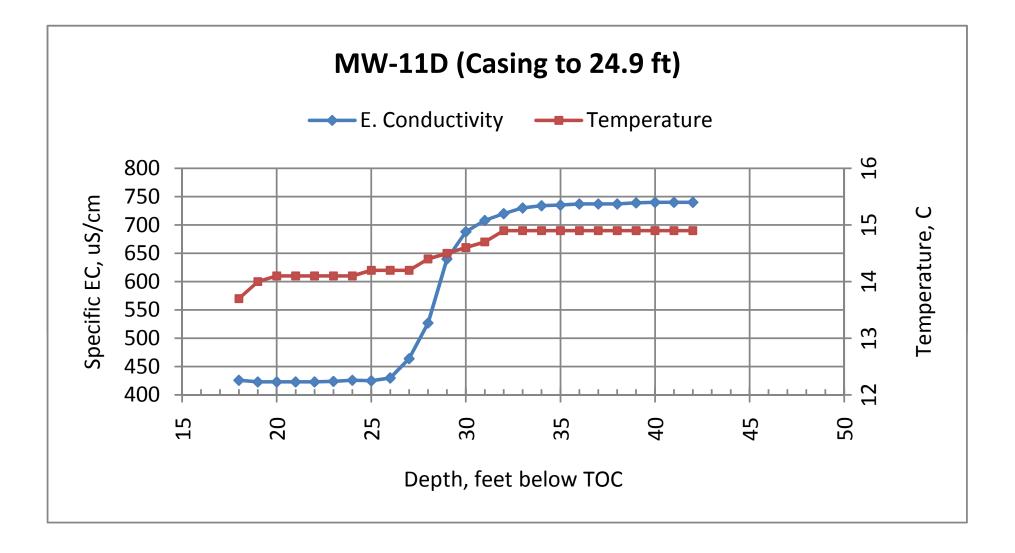


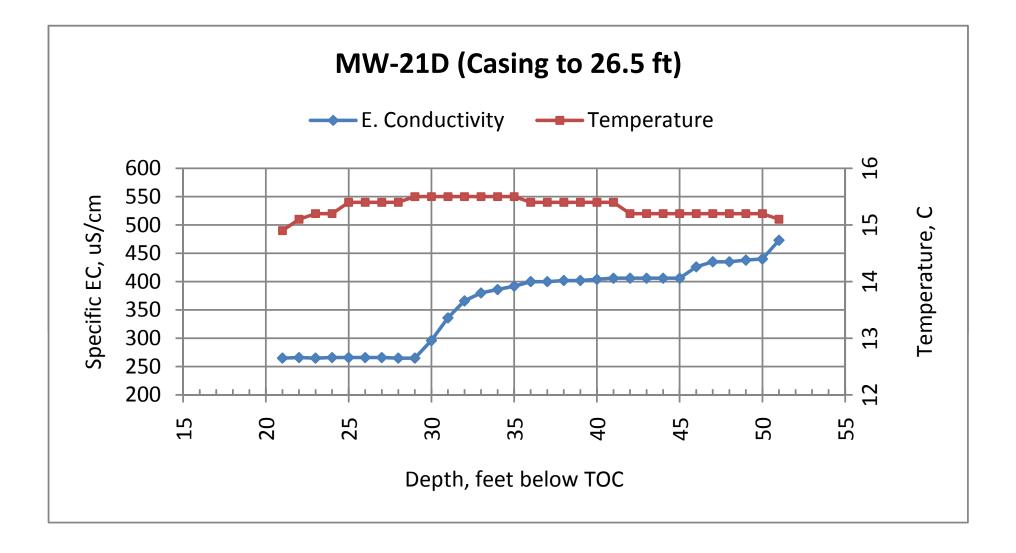
B B O - APPROX. LOCATIONS OF TTH'S FIGURE 2. A - - A' - UNE OF HYDROGELOGIC CROSS-SECTION

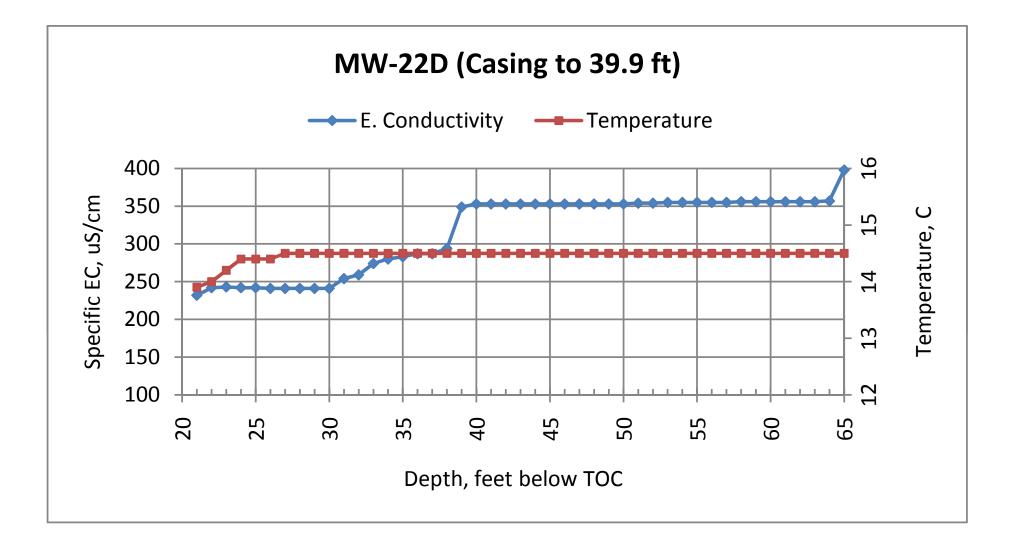


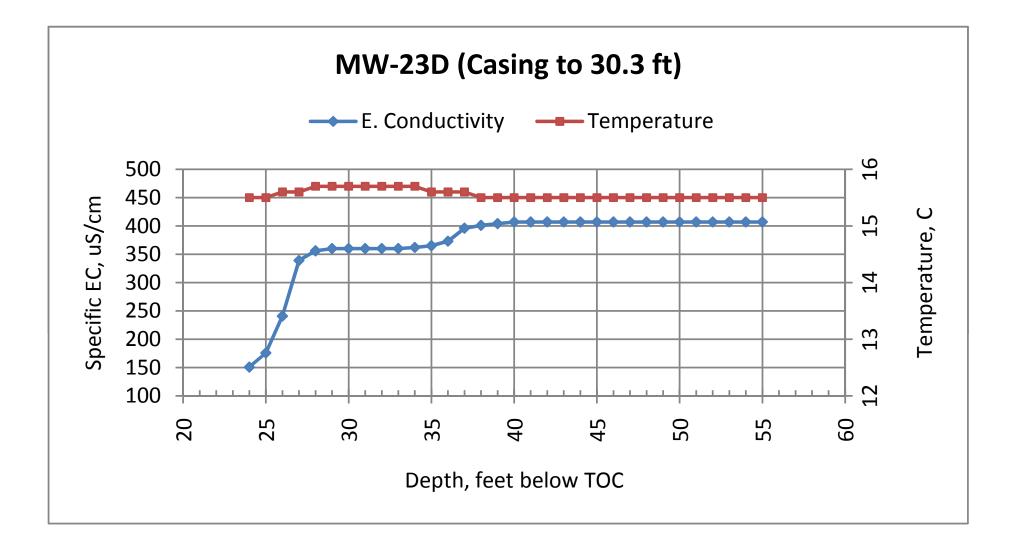


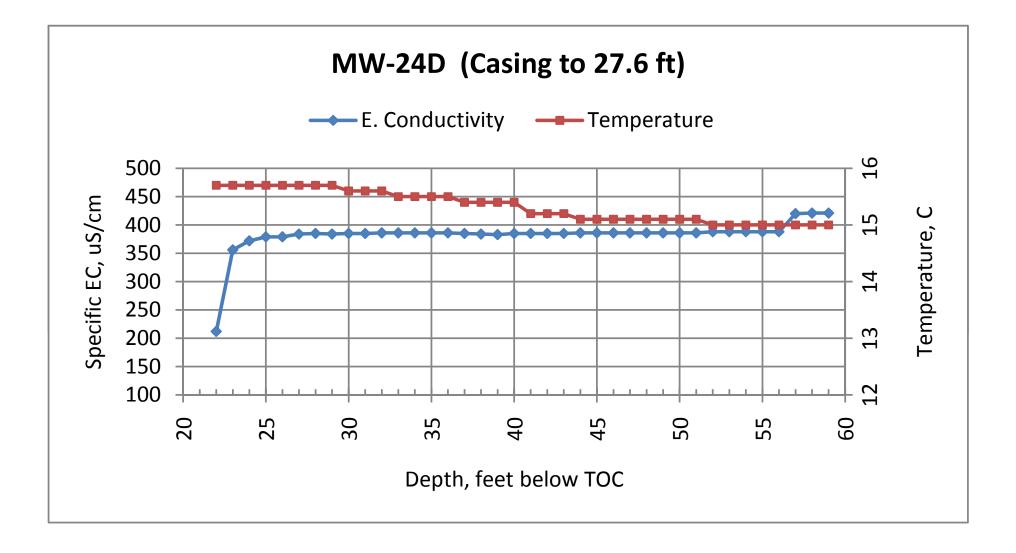












Middlesex Sampling Plant 239 Mountain Avenue Borough of Middlesex, New Jersey Slug Test Analysis

Well	Unit	Lithology	Test	K (ft/day)	K (cm/sec)
URSMW-1S	Overburden	Resid. Soil, Weathered BR	Rising Head	1.0E-01	3.5E-05
URSMW-2S	Overburden	Weathered BR	Falling Head	1.0E-01	3.5E-05
URSMW-2S	Overburden	Weathered BR	Rising Head	3.0E-02	1.1E-05
URSMW-4S	Overburden	Resid. Soil, Weathered BR	Falling Head	2.0E-01	7.1E-05
URSMW-4S	Overburden	Resid. Soil, Weathered BR	Rising Head	2.6E-01	9.2E-05
URSMW-5S	Overburden	Resid. Soil, Weathered BR	Rising Head	2.0E-02	7.1E-06
URSMW10S	Overburden	Resid. Soil, Weathered BR	Falling Head	4.5E-01	1.6E-04
URSMW10S	Overburden	Resid. Soil, Weathered BR	Rising Head	6.5E-01	2.3E-04
URSMW11S	Overburden	Resid. Soil, Weathered BR	Rising Head	1.2E+01	4.2E-03
URSMW-12S	Overburden	Weathered BR	Falling Head	5.0E+00	1.8E-03
URSMW-12S	Overburden	Weathered BR	Rising Head	3.0E+00	1.1E-03
URSMW-14S	Overburden	Resid. Soil, Weathered BR	Falling Head	5.0E-01	1.8E-04
URSMW-14S	Overburden	Resid. Soil, Weathered BR	Rising Head	2.0E+00	7.1E-04
URSMW-15S	Overburden	Weathered BR	Rising Head	7.0E+00	2.5E-03
URSMW-16S	Overburden	Residual Soil	Falling Head	7.0E+00	2.5E-03
URSMW-16S	Overburden	Residual Soil	Rising Head	1.0E+01	3.5E-03
URSMW-17S	Overburden	Resid. Soil, Weathered BR	Falling Head	5.0E-03	1.8E-06
URSMW-17S	Overburden	Resid. Soil, Weathered BR	Rising Head	3.0E-03	1.1E-06
URSMW-18S	Overburden	Residual Soil	Rising Head	3.3E+00	1.2E-03
			Min	3.0E-03	1.1E-06
			Max	1.2E+01	4.2E-03
			Avg	2.7E+00	9.6E-04

Well	Unit	Lithology	Test	K (ft/day)	K (cm/sec)
URSMW-1D	Bedrock	Shallow Bedrock	Falling Head	1.0E-02	3.5E-06
URSMW-1D	Bedrock	Shallow Bedrock	Rising Head	7.0E-02	2.5E-05
URSMW-2D	Bedrock	Shallow Bedrock	Falling Head	1.2E-02	4.2E-06
URSMW-2D	Bedrock	Shallow Bedrock	Rising Head	1.0E-02	3.5E-06
URSMW-3D	Bedrock	Shallow Bedrock	Falling Head	5.0E-03	1.8E-06
URSMW-3D	Bedrock	Shallow Bedrock	Rising Head	1.5E-02	5.3E-06
URSMW-9D	Bedrock	Shallow Bedrock	Rising Head	1.30E-01	4.6E-05
URSMW-9D	Bedrock	Shallow Bedrock	Falling Head	1.10E-01	3.9E-05
URSMW-11D	Bedrock	Shallow Bedrock	Falling Head	6.00E-01	2.1E-04
URSMW-11D	Bedrock	Shallow Bedrock	Rising Head	5.20E-01	1.8E-04
			Min	5.0E-03	1.8E-06
			Max	6.0E-01	2.1E-04
			Avg	1.5E-01	5.2E-05

Well	Unit	Lithology	Test	K (ft/day)	K (cm/sec)
URSMW6S	Overburden	Pipe Chase	Falling Head	3.0E-01	1.1E-04
URSMW6S	Overburden	Pipe Chase	Rising Head	8.0E-01	2.8E-04
			Min	3.0E-01	1.1E-04
			Max	8.0E-01	2.8E-04
			Avg	5.5E-01	1.9E-04

APPENDIX C

BOREHOLE LITHOLOGIC LOGS AND WELL CONSTRUCTION SUMMARIES

APPENDIX D

BOREHOLE GEOPHYSICAL LOGS

Fluid Temperature Conductivity Acoustic Televiewer Natural Gamma Caliper Spontaneous Potential Resistivity

APPENDIX E

ELECTRICAL CONDUCTANCE AND TEMPERATURE LOGS SALT TRACER TEST PLOTS

APPENDIX F

ANALYTICAL LABORATORY REPORTS FOR DEPTH DESCRETE SAMPLES

APPENDIX G

PACKER TEST DATA

APPENDIX H

QUALITY CONTROL SUMMARY REPORT FOR SE 15 AND SE 16