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Kansas City, Missouri 64106-2896

Contract No. W912DQ-11-D-3011

Task Order No. 0002

**BASIS OF DESIGN (100%)**  
**for**  
**In-Situ Groundwater Treatment**  
**at the**  
**Peninsula Boulevard Groundwater Plume Superfund Site**  
**Operable Unit 1**

Hempstead, New York

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## LIST OF ACRONYMS

APP	Accident Prevention Plan
ARAR	Applicable or Relevant and Appropriate Requirement
ARD	Anaerobic Reductive Dechlorination
ATSDR	Agency for Toxic Substances and Disease Registry
BDR	Basis of Design Report
bgs	Below Ground Surface
°C	Degrees Celsius
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
cis-1,2-DCE	cis-1,2-Dichloroethene
COC	Contaminant of Concern
CVOC	Chlorinated Volatile Organic Compound
DCE	Dichloroethene
Delta Well	Delta Well & Pump Company, Inc.
DER	Data Evaluation Report
DNAPL	Dense Non-Aqueous Phase Liquid
DO	Dissolved Oxygen
DOT	Department of Transportation
DPT	Direct Push Technology
DPW	Department of Public Works
E&S	Erosion and Sediment
Eh	Specific Conductivity
EISB	Enhanced In-Situ Bioremediation
EPA	United States Environmental Protection Agency
EVO	Emulsified Vegetable Oil
°F	Degrees Fahrenheit
fpd	Feet per Day
FS	Feasibility Study
ft	Foot or Feet
ft <sup>2</sup> /d	Square Feet per Day
g/L	Gram per Liter
gpm	Gallons Per Minute
HDR	Henningson, Durham & Richardson Architecture and Engineering, P.C.
HI	Hazard Index
HSA	Hollow Stem Auger
HTRW	Hazardous, Toxic, and Radioactive Wastes
ID	Inside Diameter
ISCR	In-Situ Chemical Reduction
ITR	Independent Technical Review
IW	Injection Well
JM	Jameco Aquifer
K	Hydraulic Conductivity
lbs	Pounds
L/kg	Liter per Kilogram
LQL	Lower Quantifiable Limit
MCL	Maximum Contaminant Level
MCLG	Maximum Contaminant Level Goal
mg/kg	Milligrams Per Kilogram
mg/L	Milligrams Per Liter
msl	Mean Sea Level
mV	Milli Volt
MW	Monitoring Well
NCDH	Nassau County Department of Health



## LIST OF ACRONYMS (Cont'd)

NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List
NYAW	New York American Water
NYCRR	New York Code, Rules, and Regulations
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
O&M	Operation and Maintenance
OD	Outside Diameter
ORP	Oxidation Reduction Potential
OSHA	Occupational Safety and Health Administration
OSWER	Office of Solid Waste and Emergency Response
OU-1	Operable Unit 1
OW	Observation Well
PCB	Polychlorinated Biphenyl
PCE	Tetrachloroethene or Perchloroethene
PDI	Pre-Design Investigation
PIM	Post-Injection Monitoring
POTW	Publicly-Owned Treatment Works
ppb	Parts Per Billion
ppm	Parts Per Million
PQL	Practical Quantification Limit
PRG	Preliminary Remedial Goal
psi	Pounds Per Square Inch
PVC	Polyvinyl Chloride
PW	Pumping Well
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
qPCR	Quantitative Polymerase Chain Reaction
RA	Remedial Action
RAO	Remedial Action Objective
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SDWA	Safe Drinking Water Act
SSHP	Site Safety and Health Plan
Site	Peninsula Boulevard Groundwater Plume Superfund Site
SMCL	Secondary Maximum Contaminant Level
SOP	Standard Operating Procedure
SPDES	State Pollution Discharge Elimination System
SU	Standard Units (for pH)
SVOC	Semi-Volatile Organic Compound
Sy	Specific Yield
TBC	To Be Considered
TCE	Trichloroethene
TCL	Target Compound List
TCLP	Toxic Characteristic Leaching Procedure
Tetra Tech	Tetra Tech, Inc. or Tetra Tech Engineering and Surveying PC
TOC	Total Organic Carbon
TOGS	Division of Water Technical and Operational Guidance Series
TSCA	Toxic Substances Control Act





### LIST OF ACRONYMS (Cont'd)

TSDf	Treatment, Storage, or Disposal Facility
TW	Temporary Well
UGA	Upper Glacial Aquifer
µg/L	Micrograms per liter
USACE	U.S. Army Corps of Engineers
U.S.C.	United States Code
USDW	Underground Source of Drinking Water
USGS	United States Geological Survey
VFA	Volatile Fatty Acid
VOC	Volatile Organic Compound
Zebra	Zebra Environmental Corporation
ZVI	Zero Valent Iron



## 1.0 INTRODUCTION

### 1.1 PURPOSE

This remedial design project is being performed under Indefinite Delivery Contracts (IDC) for Architect-Engineer (A-E) Services within EPA Region 2 and the Northwestern Division (MEGA Phase A) Contract Number W912DQ-11-D-3011. This document focuses on implementing the selected remedy for in-situ treatment as presented in the Record of Decision (ROD) (EPA Region 2, 2011). Tetra Tech Engineering and Surveying PC (Tetra Tech) has prepared this Basis of Design Report (BDR) for Operable Unit 1 (OU-1) at the Peninsula Boulevard Groundwater Plume Superfund Site (Site), located in Hempstead, New York, for the U.S. Army Corps of Engineers (USACE) Kansas City District. Location and topography of the Site are presented in Figure 1-1.

The intent of the document is to facilitate the acquisition of services of a remedial action (RA) contractor to complete construction of the in-situ groundwater treatment remedy that meets or supports RA objectives and attainment of clean-up standards. The BDR provides RA requirements, and the RA contractor will implement methods to achieve these requirements.

This report presents the remedial design (RD) for the in-situ treatment remedy that includes a set of documents: basis of design narrative, criteria and rationale for the selection of system components, drawings, specifications, schedule, operation and maintenance (O&M), and cost estimates. These documents provide guidance for construction of the remedy that meet RA objectives and performance standards as stated in the ROD. Specifically, the BDR is organized as follows:

- Section 1.0 presents the purpose and overview of the groundwater remedy.
- Section 2.0 provides the site background including site location, site geology and hydrogeology, and historical plume delineation.
- Section 3.0 presents the RA Objectives (RAOs), the Applicable or Relevant and Appropriate Requirements (ARARs), and discusses how the design complies with these ARARs.
- Section 4.0 summarizes the treatability pilot testing and pre-design investigation results.
- Section 5.0 describes the area identified for in-situ treatment.
- Section 6.0 presents the detailed design for the in-situ treatment component.
- Section 7.0 discusses drawings and specifications.
- Section 8.0 provides measures to minimize environmental impacts.
- Section 9.0 discusses project delivery, remediation schedule, and estimated costs.
- Section 10.0 provides ROD variances.
- Section 11.0 identifies easement and access agreements.
- Section 12.0 lists references.

Several appendices are also provided to support the BDR, such as analytical data.

### 1.2 OVERVIEW OF OU-1 REMEDY

The response action described in the ROD represents the first planned remedial phase or OU-1 at the Site to address contaminated groundwater. The source of the groundwater contamination will be addressed as



the second remedial phase or OU-2 and will be the subject of a subsequent decision document. The major components of the OU-1 remedy are as follows:

- Extraction of the groundwater via pumping and ex-situ treatment of the extracted groundwater prior to discharge to the publicly-owned treatment works (POTW) or surface water, or re-injection to the aquifer.
- In-situ chemical treatment of targeted high concentration contaminant areas, as appropriate.
- Monitored natural attenuation for those areas where active remediation is not performed.
- Institutional controls.
- Long-term monitoring to ensure the effectiveness of the remedy.

This BDR addresses the in-situ chemical treatment component only. The general focus of in-situ treatment is to address tetrachloroethene (PCE) and trichloroethene (TCE) levels in groundwater exceeding 10,000 micrograms per liter ( $\mu\text{g/L}$ ). Note that the OU-1 remedy may be performed in multiple stages, with the in-situ groundwater treatment component likely the first stage. Other design components of the OU-1 remedy (e.g., groundwater extraction, treatment, and discharge) will be presented in a separate stand-alone document and are not part of this report.

The in-situ treatment remedy involves enhanced in-situ bioremediation (EISB), which is a form of in-situ chemical reduction (ISCR). ISCR uses reductants such as emulsified vegetable oil (EVO), lactate, and zero-valent iron (ZVI). The reductants typically donate electrons as a source of energy, which act to remove chlorine atoms from chlorinated volatile organic compounds (CVOCs), such as PCE and TCE. As a form of ISCR, EISB also stimulates the growth of bacteria that destroy CVOCs through natural processes by modifying subsurface conditions.

### **1.3 APPLICABLE CRITERIA**

The engineering analysis and RD for the in-situ treatment remedy are based on the following primary applicable studies, criteria, and regulatory requirements:

- Remedial Investigation (RI) Report (HDR, 2011a).
- Feasibility Study (FS) Report (HDR, 2011b).
- Record of Decision, OU-1, Peninsula Boulevard Groundwater Plume Superfund Site (EPA Region 2, 2011).
- Applicable Federal and New York State Department of Environmental Conservation (NYSDEC) guidance, standards, and requirements.



## 2.0 SITE BACKGROUND

Unless otherwise stated, Section 2.0 is based on the RI Report (HDR, 2011a); FS Report (HDR, 2011b); ROD (EPA Region 2, 2011); and Remedial Design Work Plan (Tetra Tech, 2012a).

### 2.1 SITE DESCRIPTION

The Site consists of the area within and around a groundwater plume identified during a series of site investigations and limited interim removal activities at the former Grove Cleaners site conducted between 1991 and 2001. The Site is located in the Village of Hewlett (Town of Hempstead, Nassau County, New York) with Valley Stream and Lynbrook located to the north; East Rockaway and Hewlett Harbor to the east; Woodsburgh and Hewlett Bay Park to the south; and Woodmere to the west. John F. Kennedy International Airport is located about three miles to the west of the Site. A map of the Site Location is provided as Figure 1-1.

The area consists of a mix of commercial and residential properties, with the majority of the commercial properties located along Mill Road, Peninsula Boulevard, Broadway, and West Broadway. Woodmere Middle School is located along the western boundary of the Site. New York American Water (NYAW; formerly the Long Island American Water Company) operates its Plant #5 Well Field on property located approximately 1,000 feet north of the Site. NYAW has been monitoring and treating groundwater pumped from this well field since 1991, and continues to maintain monitoring and treatment activities to address both iron fouling, a common and naturally-occurring problem for Long Island water suppliers, and volatile organic compound (VOC) contamination (Tetra Tech, 2012a). The active wells are reportedly screened in the Jameco Aquifer at depths to approximately 150 feet below ground surface (bgs); no pumping by NYAW is currently occurring in the Upper Glacial Aquifer (UGA). According to NYAW representatives, the practice of pumping in the UGA for water production purposes has not occurred since approximately 1990-1991 (EPA Region 2, 2011).

During previous investigations, several former and existing dry cleaners were identified as potential sources of tetrachloroethene (PCE) contamination at the Site. The source of the groundwater contamination will be addressed as the second remedial phase, or OU-2, and will be the subject of a subsequent decision document.

#### 2.1.1 Site History and Status

The information provided in the following section is generally summarized from EPA Region 2, 2011; HDR, 2011a; HDR, 2011b; and Tetra Tech, 2008:

In March 1991, the Nassau County Department of Health (NCDH) cited Grove Cleaners (located at 1274 Peninsula Boulevard; see Figure 1-2) for discharging hazardous waste into dry wells via a drain located north of the eastern building. PCE was detected in soil and sludge samples collected from these dry wells at concentrations of 2,200 and 110 milligrams per kilogram (mg/kg), respectively.

In 1992, NYSDEC became involved with the Site. Grove Cleaners was classified as a Class 2 Inactive Hazardous Waste Disposal Site in March 1993.

From 1991 through October 2001, a series of field investigations were performed on behalf of either the property owner or NYSDEC. In addition, in April 1994, a removal action was implemented at Grove Cleaners with 13 55-gallon drums of sludge recovered from the drains and dry wells. Between January and February 1999, a second removal action was performed. Approximately 4,000 gallons of groundwater were pumped from a 4-inch recovery well. PCE was detected at 1,100 µg/L at the end of this event.

The results of these activities indicated an extensive plume of contaminated groundwater, primarily impacted by PCE, located north and south of Peninsula Boulevard. The results of the investigative work did not produce enough evidence to determine that Grove Cleaners was solely responsible for the



contamination, and suggested the potential for additional source areas. A “No Further Action” ROD was issued by NYSDEC for Grove Cleaners in March 2003.

The United States Environmental Protection Agency (EPA) assumed responsibility for the larger Peninsula Boulevard Groundwater Plume Site in September 2002. This Site was proposed for placement on the National Priorities List (NPL) in March 2004. The Site was placed final on the NPL in August 2004.

Between August 2006 and November 2007, Tetra Tech conducted initial RI field activities, including environmental sampling and hydrogeological analyses. A resulting Data Evaluation Report (DER) was submitted in October 2008 (Tetra Tech, 2008).

The Agency for Toxic Substances and Disease Registry (ATSDR), in cooperation with the New York State Department of Health (NYSDOH), prepared a Public Health Assessment for the Site in April 2007. Based on the available data, ATSDR concluded there was no present health risk, due to the treatment of water produced from the NYAW Plant #5 wells and engineering controls limiting access to the unnamed tributary (see Figure 1-2). Additional sampling to evaluate vapor intrusion and actions to reduce potential future exposures to groundwater and surface water were recommended.

In March 2008, July 2008, February 2009, and March 2011, EPA performed vapor intrusion sampling at multiple residences near the Site. VOCs were found at concentrations at or above EPA Region 2 screening levels in sub-slab and/or indoor air at two residences. A sub-slab depressurization system was installed at one residence in July 2009 to mitigate the impacts of soil vapor intrusion by reducing or eliminating vapor entry into the building. In addition, EPA performed sampling at the North Woodmere Middle School in 2004. PCE was not detected in the basement, classrooms, or the auditorium. Trace levels of PCE (0.15 to 0.35 parts per billion [ppb]) were observed in the art room and in the drains in a bathroom; these trace levels were determined to not pose any health concerns.

Henningson, Durham & Richardson Architecture and Engineering, P.C. (HDR) conducted supplemental RI work in 2010 and 2011 to address RI data gaps. The focus of this work was further characterization of the contamination in the UGA. The identification of additional potential sources was also a goal, as were completion of human health and ecological risk evaluations. The RI Report (HDR, 2011a) indicated the following:

- Chlorinated compounds were detected in both shallow and deep UGA groundwater. A “20-foot clay” layer (a regional term that refers to the approximate thickness of this silt/clay layer over much of southern Long Island) bisected the UGA across most of the Site area, but pinches out north of Peninsula Boulevard. The “shallow” and “deep” portions of the UGA were identified as being above and below the “20-foot clay” layer, respectively, to facilitate identification and evaluation of remedial alternatives based on the nature and extent of contamination.
- The shallow UGA (0 to 30 feet bgs) was characterized by a 3,500-foot long VOC plume oriented in a north-south direction, with an area of PCE concentrations exceeding 1,000 µg/L extending approximately 2,000 feet from West Broadway to 200 feet north of Peninsula Boulevard. South of Peninsula Boulevard (upgradient), the plume was approximately 1,000 feet wide. North of Peninsula Boulevard (downgradient), the VOC plume was approximately 400 feet wide. The greater width of the plume south of Peninsula Boulevard may be the result of comingling of contaminant plumes from multiple upgradient source area(s), subsurface disturbance due to infrastructure placement, or the relatively flat groundwater surface.
- The deep UGA (40 to 75 feet bgs) was characterized by a 1,100-foot long VOC plume oriented in a northeast-southwest direction. PCE was detected at concentrations greater than 10,000 µg/L at three RI locations, including HW-037, HW-038, and MW-27D (HDR, 2011a).
- Surface water, sediment and, to a lesser degree, soils also had been impacted by the plume-related VOCs, specifically PCE and its breakdown products.



- Screening for the potential for anaerobic biodegradation and natural attenuation of chlorinated solvents in the area of the Site was performed. On a scale from inadequate (score of “0”) to adequate (score of “15”), only one well received a screening score of 15, which was the lower limit of the adequate evidence category for natural attenuation. Specific to biodegradation of PCE, the screening scored “0” in all wells.
- The source area(s) of the plume were not identified during the RI, although the plume characteristics (areal extent and relative concentrations) appeared to indicate a potential source property at the former Chloe’s West Broadway Cleaners (presently Cedarwood Cleaners) at the intersection of Hewlett Parkway and West Broadway.

The human health risk assessment concluded, under current exposure scenarios, that risks to human health and the environment were largely controlled through engineering and institutional controls, i.e., the continued monitoring and treatment of groundwater extracted through the NYAW Plant #5 Well Field; restrictions on the use of private wells in the county; fencing around surface water areas on-site; and EPA’s continuing investigation and mitigation of vapor intrusion impacts in the area of the plume. However, in a future use scenario assuming direct use of impacted groundwater (i.e., assuming that engineering controls are not in place at Plant #5), risks existed from groundwater (ingestion, dermal contact, and inhalation exposure routes) resulting from Site-related VOCs exceeding acceptable levels for carcinogenic and non-carcinogenic effects. The risk assessments indicated that concentrations of plume-related VOCs in other on-site media do not pose unacceptable risks to either human health or ecological resources.

In July 2011, the FS Report was prepared and preliminary RAOs and preliminary remedial goals (PRGs) were developed for the Site (HDR, 2011b). The FS developed, screened, and evaluated potentially applicable remedial alternatives to provide sufficient data to select a feasible and cost-effective remedy that would protect public health and the environment from potential Site-related risks.

In September 2011, EPA published the OU-1 ROD, which documented the selection of a remedy for the groundwater contamination (see Section 1.2). It noted that a second remedial phase or operable unit, including a subsequent decision document, would address any sources of groundwater contamination.

### **2.1.2 Pre-Design Investigation**

In November 2011, Tetra Tech was tasked by USACE, under an interagency agreement with EPA Region 2, to perform the necessary pre-design and RD activities to develop the design components required to perform the RAs and meet RAOs. The objectives of this work were to:

- Address data gaps required for preparation of a complete design package, including identifying the current extent of groundwater affected by constituents at concentrations above applicable criteria through investigation and modeling activities.
- Develop the RD components and basis.
- Perform required testing of RD components.
- Prepare the required design documents to implement the remedies presented in the ROD.

The RD included a pre-design investigation (PDI), that was conducted in accordance with the May 2012 Work Plan, the March 2013 Work Plan Addendum, the December 2012 Quality Assurance Project Plan (QAPP) and addendum, and the May 2012 Accident Prevention Plan (APP). The PDI included the following tasks:

- Utility location services were performed in December 2012 and February 2013, including trenching, to facilitate utility avoidance during well installation and to confirm utility locations for design purposes. A geophysical survey of the roadways was conducted within the Site area by Delta Geophysics, Inc.



- Well locations were adjusted to account for the results of the geophysical survey, and each well location was then cleared to at least 5 feet bgs by Zebra Environmental Corporation (Zebra) using soft-dig methodologies (i.e., hand digging and vacuum excavation). Clearance of well locations was conducted immediately prior to well installation. In addition, Zebra excavated three trenches, using soft-dig methodologies, across roadways to verify the location of utilities as determined by the geophysical survey and information gathered from the Town of Hempstead and Nassau County. These trenches were cleared across the northern end of Hamilton Avenue near Peninsula Boulevard, the northern end of Hewlett Parkway near Webster Street, and the southern end of Hewlett Parkway.
- Shallow and deep UGA monitoring wells were installed for injection, pumping, and observation purposes and completion of the aquifer testing; and injection and monitoring/observation wells were installed for completion of the in-situ treatability study. Well installation was conducted primarily from March through May 2013, with additional well installation activities in January 2014. Twenty wells, temporary and permanent, were installed. Shallow wells were screened in the shallow UGA, (above the “20 foot clay”) and deep wells were screened in the deep UGA between the “20 foot clay” and the Gardiners Clay.
- Well locations (previous and newly installed) are shown on Figure 2-1; Table 2-1 provides well construction details. Permanent wells were installed by Delta Well & Pump Company, Inc. (Delta Well), and temporary wells (denoted as “TW”) were installed by Zebra. All wells were developed after completion. Relevant boring logs, well construction diagrams, and well development records are provided in the Basis of Design for Ex-Situ Groundwater Treatment (Tetra Tech, 2014). The wells were installed as follows:
  - Three pumping wells (PW-01S, PW-02S, and PW-01D) and three observation wells (OW-01S, OW-01D, and TW-09) were installed for completion of the aquifer testing. The pumping and observation wells were installed using hollow stem auger (HSA) drilling methodology, and were completed as flush-mounts.
  - For the in-situ treatability study, two permanent injection wells (IW-01S and IW-01D) were installed for the injection of LactOil™. The injection wells were installed using HSA drilling methodology, and were completed as flush-mounts. Twelve temporary 2-inch polyvinyl chloride (PVC) wells for monitoring/observation purposes were also installed for the in-situ treatability study. The temporary wells were installed using pre-packed wells and direct push methodologies.
- Groundwater sampling was conducted from existing monitoring wells and new wells installed as part of the PDI. A “Current Understanding” groundwater sampling event was completed in July 2012, a pre-injection sampling event for the in-situ treatability study was completed in May 2013, and sampling events subsequent to LactOil injection and ISCR barrier completion, discussed below, were conducted in October and December 2013. In addition, groundwater samples were collected during monitoring well installation in the deep UGA to verify contaminant concentrations directly above the 20-foot clay, during step-testing of the pumping wells for determination of disposal, and during aquifer testing for the bench scale ex-situ treatability study.
- A limited groundwater investigation of the Jameco Aquifer (below the UGA and underlying Gardiners Clay) was conducted in May and August 2013, including installation of three monitoring wells in this formation and groundwater sampling of these wells. The three monitoring wells were installed using roto sonic drilling methodologies by Boart Longyear. Well locations for the Jameco Aquifer investigation are shown in Figure 2-2. The wells were screened within the Jameco Gravel formation, and were completed as flush-mounts. Groundwater samples were collected from these wells for VOC analysis only.





- Aquifer evaluation testing was conducted utilizing existing wells and wells installed as part of the PDI. Step tests were conducted at newly installed wells PW-01S and PW-01D in May 2013, and this information was utilized to complete 24-hour pumping tests in the shallow and deep UGA in August 2013. After completion of the pumping tests, it was determined that additional data were required for the shallow UGA. Therefore, two additional wells, PW-02S and TW-09, were installed, as described above. A step test at PW-02S was completed in January 2014, and a second 24-hour pumping test, utilizing the newly installed wells, was conducted in February 2014.
- A topographic survey was conducted by Borbas Surveying and Mapping LLC in October 2012. The survey was collected at 2-foot contours of the Site in support of the RD, including Site features, boundaries, easements, rights of way, and utilities.
- From May 2013 through December 2013, in-situ treatability testing was conducted to develop the in-situ remedy. In-situ treatability testing included performing a limited ISCR injection program; pre- and post-injection monitoring; and data evaluation. The study involved two major components: (1) installing an ISCR barrier and (2) employing enhanced bioremediation activity using EVO and lactate to degrade groundwater VOCs. Section 4.0 provides a detailed discussion on the in-situ treatability testing study.
- A bench-scale groundwater ex-situ treatment train treatability study was performed to address data gaps associated with the conceptual process design. This bench scale study was conducted by Water Remediation Technologies Inc. from August through December 2013. A detailed discussion of the ex-situ treatability study is presented in the Basis of Design for Ex-Situ Groundwater Treatment (Tetra Tech, 2014).

## **2.2 SITE CHARACTERISTICS**

### **2.2.1 Topography and Surface Drainage**

The Site slopes to the north and west toward Doxey Brook Drain and Motts Creek with surface elevations decreasing from approximately 20 feet above mean sea level (msl) near the southern border of the Site to approximately one foot above msl in the vicinity of Doxey Brook Drain and the nearby NYAW property to the north.

Portions of Motts Creek, Doxey Brook Drain, and an unnamed tributary leading to Motts Creek are located near the Site (see Figure 1-2). The unnamed tributary and Doxey Brook Drain are classified as Class C streams, which are waters supporting fisheries and suitable for non-contact activities. These features merge and eventually drain into Motts Creek (also a Class C stream) at the northern portion of the Site.

### **2.2.2 Geology**

The Site is situated within the Atlantic Coastal Plain Physiographic Province in the southwestern corner of Long Island, New York. The geologic conditions are primarily the result of cycles of advancement and retreat of continental glaciers through approximately 10,000 years before present. Sediments associated with the glacial periods include deposits of till, ice-contact stratified drift, outwash materials, and various other mixtures of sediment and related deposits.

The stratified drift and till deposits are concentrated from the terminal moraines in the center of the island and are present northward to the north shore of the island. Unconsolidated Pleistocene-age strata consisting mostly of outwash deposits are present between the moraine sand and the south shore of the island, where they overlie Cretaceous-age, marine-derived sediments and Pre-Cambrian bedrock. Cretaceous-age deposits range from the late Cretaceous Raritan Formation, composed of an upper clay member (Raritan Clay) and a lower sand member (Lloyd Sand), to the Magothy-Matawan group, which overlies the Raritan Formation. The Magothy is composed of deltaic quartzose sand of continental origin with some interbedded clay and silt. This formation represents one of the important water bearing units that comprise Long Island's water supply aquifers.





Overlying the Magothy-Matawan group in portions of Long Island is the Jameco Gravel formation. The Jameco is the earliest of the Pleistocene deposits in the region, and has only been detected in Kings, southern Queens, and southwestern Nassau County. The thickness of this unit is highly variable owing to its origin as a channel fill deposit within a diversion pathway for the Hudson River. At one time, the course of the river was through what is now the southwestern end of Long Island.

Above the Jameco Gravel is a blue-grey clay layer, the Gardiners Clay, which forms a confining layer over the Jameco and Magothy-Matawan group in areas of the island. The Gardiners Clay was deposited in a marine environment during an interglacial period in the Pleistocene. This unit is the deepest encountered during previous investigations at the Site, with some of the deeper borings completed at the interface between the Gardiners Clay and the overlying unconsolidated Pleistocene deposits. This clay layer is estimated to be approximately 80 feet thick toward the southern extent of the Site boundary, thinning toward the northern Site boundary, where it is approximately 60 feet thick (HDR, 2011a).

During the PDI, soil borings and wells were advanced through the Gardiners Clay and into the Jameco Gravel. Northeast of the Site, at the upgradient JW-01 location (based on assumed flow direction in the Jameco Aquifer from north to south), the Gardiners Clay is only present as lenses interbedded with sand lenses. The depth at which this was seen also correlates with the expected depth of the Gardiners Clay unit. According to information from the NYAW, the Gardiners Clay thins to the north of the Site to about 20 feet in thickness in their well field. At JW-01, the Jameco Gravel was encountered at approximately 156 feet bgs. At JW-02, located within the boundary of the Site (see Figure 2-2), the top of the Gardiners Clay was encountered at 86 feet bgs, and the clay was approximately 60 feet in thickness. The top of the Jameco Gravel was encountered at 145 feet bgs. At JW-03, downgradient of the Site (based on assumed flow direction in the Jameco Aquifer from north to south), the top of the Gardiners Clay was encountered at 90 feet bgs, and was approximately 54 feet in thickness. The Jameco Gravel was encountered at 144 feet bgs at this location.

The sediments above the Gardiners Clay are Pleistocene deposits forming the Upper Glacial Aquifer, the shallowest aquifer on the island. The UGA consists primarily of meltwater-derived coalescing sheets of sand and gravel forming an outwash plain that extends southward from the terminal moraines to the Atlantic shore.

In the vicinity of the Site, the UGA includes a thin layer of marine clay (as indicated by the presence of marine shells and plant remains), locally referred to as the “20-foot clay,” which was deposited during a phase of warmer climate within the Pleistocene glaciations. The “20-foot clay” thickens southward on the Site. Over approximately the southern half of the Site, available data indicate it forms a clay layer thick enough and tight enough to develop several feet of vertical water level difference between the shallow UGA and the deep UGA and result in semi-confined conditions for the deep UGA.

The 2006 through 2013 field investigation activities indicate that the “20-foot clay” is actually a clayey silt, and its competency increases southward across the Site. South of Peninsula Boulevard, it appears to act as a confining unit and is encountered at depths ranging from 20 to 40 feet. The unit thins significantly to about a one-foot thickness in the northern portion of Site, based on analysis of geophysical logging of the re-drilled NYAW wells at Plant #5, located just north of the Site. This unit may completely pinch out in the vicinity of the Plant #5 Well Field. This combination of discontinuity and a significant silt fraction, rather than pure clay, indicates it is not a complete confining layer but is likely a semi-confining unit, with incomplete confinement in the vicinity of the NYAW well field. Based on observations from the PDI, the shallow UGA appears to be very heterogeneous spatially and vertically, whereas the deep UGA is relatively less heterogeneous.

The surficial and shallow subsurface geology of the Site includes a combination of pavement, gravel subgrade, and reworked native soils covering the ground surface. Where present, fill materials typically extend to a depth of approximately one foot below grade. Below the fill layer, there are sporadic layers of peat, organic silts, and fine sands, as noted at several subsurface locations near Peninsula Boulevard. Where present, these layers were encountered at a depth of approximately 4 to 8 feet bgs and exhibited a maximum thickness of approximately 4 feet. These layers of organic material may correlate with a former



creek channel located in the vicinity of the Grove Cleaners site. Overall, the glacial material below the fill is highly heterogeneous across the site, with silts and sands found in varying layers.

### 2.2.3 Hydrogeology

Based on measurements conducted during drilling and testing at the Site, the depth to groundwater ranges from approximately 3 to 15 feet bgs in the shallow UGA and from approximately 6 to 17 feet bgs in the deep UGA. Saturated thickness in the shallow UGA above the "20-foot clay" layer ranges from approximately 10 to 30 feet, and saturated thickness in the deep UGA below the "20-foot clay" ranges from approximately 20 to 50 feet. Monitoring of water levels from on-site wells did not indicate tidal fluctuation of the water table occurs at the Site. No significant change was noted from manually collected water levels over a period encompassing at least one tidal cycle. Pressure transducer readings collected from other on-site wells likewise exhibited no tidal signature over this same period.

Groundwater flow across the Site is generally to the north in both the shallow UGA and deep UGA, with some bend to the northwest in the northern portion of the Site towards Motts Creek and the associated drainage network. Regionally, there appears to be a flow divide located to the south of the Site, with flow south of the divide towards the bay (and associated drainage) and flow north of the divide (including the Site) towards the Motts Creek drainage. Water elevation measurements were used to develop potentiometric surface maps for shallow and deep UGA wells during groundwater monitoring in July 2012 (Figures 2-3 and 2-4) and May 2013 (Figures 2-5 and 2-6).

There is a significant vertical head difference (with potential for downward flow) between the shallow UGA and deep UGA in the southern portion of the Site (e.g., more than five feet near Westervelt Place) due to the low hydraulic conductivity of the "20-foot clay." This vertical head difference declines to the north due to the pinching out of the "20-foot clay" north of Peninsula Boulevard.

In the shallow UGA, water level maps show a substantially steeper horizontal hydraulic gradient in the approximate area between Sturlane Street and Waverly Street, compared to areas south of Sturlane Street and north of Waverly Street. Assuming a similar amount of water flows through these areas in the shallow UGA, this suggests the transmissivity of the shallow UGA is proportionally lower in the area of the steep hydraulic gradient, due to reduced hydraulic conductivity and/or reduced saturated thickness. In the deep UGA, the magnitude of the horizontal hydraulic gradient is very slight relative to the hydraulic gradient observed in the shallow UGA. In the southern part of the Site, there was essentially no hydraulic gradient measured in July 2012, but a slight hydraulic gradient was measured in that same area in May 2013. Further to the north, towards Peninsula Boulevard, there is a somewhat steeper horizontal hydraulic gradient in the deep UGA, but it is still a much lower hydraulic gradient than observed in the shallow UGA.

In this area of Long Island, the deeper Jameco Gravel, despite its limited extent, is a water-bearing zone of primary importance because of hydraulic conductivity values on the order of 200 feet per day (fpd). The NYAW Plant #5 Well Field adjacent to the Site utilizes the Jameco as its source aquifer. North of the Site, the UGA directly overlies the Jameco. Given the similar hydraulic properties of the UGA and Jameco, there is the potential for significant hydraulic connection between the two units, with data from a broader area of Long Island indicating that to be the case. However, data obtained as a result of supplemental RI and PDI activities indicate that the Gardiners Clay acts as a confining unit in the localized area of the Site and the NYAW Well Field.

Based on United States Geological Survey (USGS) and Nassau County Department of Public Works (DPW) data, the potentiometric surface in the Magothy-Jameco Aquifer system has an elevation (head differential) of nearly 50 feet over the span of approximately 5 miles north to south. Based on head differential and the 5-mile distance, the groundwater flow in the Magothy-Jameco Aquifer is generally toward the south and southwest at approximately 0.0033 feet per foot (ft/ft) (Nassau County DPW, 2005). This flow direction is opposite that of the UGA near the Site.



#### **2.2.4 Land and Groundwater Uses**

Land use at the Site is well developed with little remaining natural area. The immediate area consists of commercial and residential properties, with most commercial properties located along the principal thoroughfares of Mill Road, Peninsula Boulevard, Broadway, and West Broadway. Several hundred single-family residences are also present, along with some small apartment buildings and commercial buildings containing medical and professional offices. All residences and commercial buildings are connected to the public water supply. Land use at the Site is not expected to change.

Groundwater use depends on the water supply available from underlying aquifers. These aquifers are composed primarily of sand and gravel, mixed with lesser amounts of silt and clay. Near the Site, NYAW maintains water-supply Plant #5 Well Field that, along with other area NYAW plants, provides water to a significant population of southwestern Nassau County. NYAW used wells from the shallow UGA aquifer through at least the mid-1990s. Currently, NYAW pumps exclusively from the Jameco Aquifer as their source aquifer for Plant #5. Other NYAW plants in the area use the Magothy as their source aquifer. Water supplied to the residences and businesses at the Site is a blend of water provided through a complex, integrated system of well fields and water treatment and storage plants.

### **2.3 NATURE AND EXTENT OF CONTAMINATION IN GROUNDWATER**

#### **2.3.1 Summary of RI Results**

The RI results (generated between 2006 and 2011) indicated the shallow and deep portions of the UGA were impacted by VOC contamination (HDR, 2011a). VOC groundwater concentrations exceeded EPA drinking water standards (e.g., Maximum Contaminant Levels or MCLs) within the plume area. The highest VOC concentrations were located south of Peninsula Boulevard within the deep UGA, where PCE and TCE were detected at levels up to 30,000 µg/L and 10,000 µg/L, respectively.

The shallow UGA PCE plume (generally 0 to 30 feet bgs) was roughly 3,000 feet long and oriented in a north-south direction. South and upgradient of Peninsula Boulevard, the shallow plume was 1,000 feet wide, while north of Peninsula Boulevard (downgradient) the plume was about 400 feet wide. The deep UGA PCE plume (generally 40 to 75 feet bgs) was about 1,100 feet long, oriented in a northeast-southwest direction.

The RI results indicated the plume in the deeper portion of the UGA, dominated by the presence of PCE, appeared stable and centered in the south-central portion of the Site. The potential for natural attenuation of the VOCs of concern appear to vary across the Site. Analytical evaluation also suggested reductive dechlorination was not the primary natural attenuation mechanism acting on the groundwater plume (HDR, 2011a). In over 70% of the well samples analyzed and evaluated for natural attenuation parameters, limited evidence of reductive dechlorination was identified. The results from only one well displayed adequate evidence of anaerobic biodegradation. While reductive dechlorination may be occurring and contributing to the overall natural attenuation processes at the Site, it was most likely contributing on a limited scale according to the RI.

Some RI results suggested anaerobic biodegradation was possibly taking place, including the presence of TCE, cis-1,2-dichloroethene (DCE), and vinyl chloride in groundwater samples. However, PCE daughter products were not consistently detected in the same wells as PCE detections. In addition, although these VOCs can be formed through reductive dechlorination, they may have been introduced as part of the original release of the sources of contamination or resulted from other degradation mechanisms (e.g., co-metabolism or direct biological oxidation). Also, field parameter measurements, including dissolved oxygen (DO) and oxidation-reduction potential (ORP), yielded levels in a significant number of sampled wells that were outside the range where reductive dechlorination would occur as provided in the EPA *Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater* (EPA, 1998).



## **2.3.2 Pre-Design Investigation Groundwater Results**

### **2.3.2.1 Current Understanding Groundwater Sampling Event (July 2012)**

As part of the PDI, Tetra Tech conducted one round of groundwater monitoring in July 2012 using existing RI wells to obtain a current understanding of plume conditions across the Site. Table 2-2 presents a summary of the detected constituents from the July 2012 groundwater sampling and analysis compared to applicable screening levels. Appendix A-1 presents the relevant analytical data on a side-by-side basis for all wells sampled during the PDI. Appendix A-2 provides the analytical data for the July 2012 groundwater sampling event.

At least one concentration above EPA and/or NYSDEC values was noted for ten compounds in the VOC fraction including: 1,1-DCE, benzene, chloromethane, cis-1,2-DCE, isopropyl benzene, methyl tert-butyl ether (MTBE), TCE, PCE, trans-1,2-DCE, and vinyl chloride (Table 2-2). Isoconcentration contours were prepared for site-specific contaminants of concern PCE and TCE in both the shallow UGA (Figures 2-7 and 2-8) and deep UGA (Figures 2-9 and 2-10).

For the upper UGA plume, the highest PCE levels were detected in well MW-21S in the southeastern part of the Site (130 µg/L) and in wells MW-03S (140 µg/L), MW-06 (180 µg/L), and MW-07 (600 µg/L) in the northeastern portion (Figure 2-7). The shallow plume's TCE levels were generally less than 5 µg/L with the exception of two wells. The groundwater in well MW-07 (near the intersection of Waverly Street and Hamilton Avenue) contained TCE at 18 µg/L, while in well MW-03S (across Peninsula Boulevard), a TCE concentration of 5.7 µg/L was detected (Figure 2-8).

The lower UGA groundwater contained PCE and TCE concentrations that were orders of magnitude higher compared to the upper UGA plumes. As shown in Figure 2-9, a relatively narrow band of elevated PCE concentrations extends from well MW-27D (31,000 µg/L) near the West Broadway/Hewlett Parkway intersection to well MW-03D just west of Peninsula Boulevard (480 µg/L). The approximate extent of TCE contamination in the deep UGA was similar in pattern to the deep PCE plume, but the concentrations were reduced by approximately ten-fold (Figure 2-10). Well MW-27D (6,300 µg/L) also contained the highest TCE concentration for the deep UGA groundwater.

As indicated on Table 2-2, four semi-volatile organic compounds (SVOCs) were detected in groundwater; none were present above screening levels. Aluminum, iron, manganese, and sodium occurred frequently at concentrations greater than EPA and/or NYSDEC comparison values as both total and dissolved fractions, and these concentrations may be indicative of naturally occurring groundwater within the vicinity of the Site. Four other metals (arsenic, cadmium, lead, and zinc) had relatively low frequencies of detections above criteria, and exceedances were only noted for the total fraction in wells MW-25S, MW-26S, MW-27D, and/or N1114. Infrequent exceedances were also found for the following four water quality parameters: chloride, sulfate, sulfide, and filterable residue/total dissolved solids (Table 2-2).

### **2.3.2.2 Pre-Injection Baseline Groundwater Sampling Event for In-Situ Treatability Study (May and June 2013)**

As part of the treatability pilot study, Tetra Tech performed one round of baseline (pre-injection) monitoring using newly-installed PDI wells and existing RI wells in May 2013. Specifically, this sampling event focused on the southeastern portion of the Site, and included 16 new PDI wells near the area of elevated PCE and TCE concentrations detected in the deep UGA plume in July 2012.

Twenty-two well samples were analyzed for VOCs (along with two duplicates), while selected samples were tested for volatile fatty (metabolic) acids (VFA), dissolved gases, and total organic carbon (TOC). Detected constituents, along with corresponding comparison values, are presented in Table 2-3. The baseline results for PCE and TCE are also depicted as isoconcentration contours in Figures 2-11 and 2-12 for the shallow UGA and Figures 2-13 and 2-14 for the deep UGA.



In addition to the above parameters, biological indicators were analyzed via quantitative polymerase chain reaction (qPCR) for samples collected from injection wells IW-01S and IW-01D beginning in June 2013. Results for these constituents are provided in Table 2-4 (detections only) and Appendix A-3 provides the data summary for the May and June 2013 analytical data.

For the shallow UGA, monitoring well MW-21S contained the maximum concentration of PCE at 360 µg/L during May 2013, and other shallow UGA well locations with PCE levels greater than comparison criteria included MW-27S (39 µg/L), MW-18S (26 µg/L), and IW-01S (6.4 µg/L) (Table 2-3 and Figure 2-11). These values are marginally higher (i.e., up to one order of magnitude) than the previous July 2012 event. The extent of the shallow plume appears to reach southwestward to Hewlett Parkway, although the distribution is sporadic with non-detectable or minimal (less than criteria) amounts of PCE also found in wells in this area.

During the May 2013 sampling event, none of the shallow wells near the West Broadway/Hewlett Parkway/Westervelt Place/Sturlane Street area contained TCE at levels greater than EPA and/or NYSDEC values (Figure 2-12). The highest TCE concentration was detected in well MW-27S at 4.9 µg/L. The absence of elevated TCE levels in the shallow plume in this area was relatively consistent with the July 2012 results.

For the deep UGA, assessment of the May 2013 results indicates the area containing elevated PCE and TCE concentrations (i.e., greater than 10,000 µg/L and 1,000 µg/L, respectively) is larger in extent when compared to previous depictions. As shown in Figures 2-13 and 2-14, this increase in size results from the placement of temporary wells in the vicinity and downgradient of the previous “hot spot” around MW-27D. The area now encompasses well TW-01D near the West Broadway/Hewlett Parkway intersection to the southeast, wells TW-06D along Westervelt Place and TW-08D along Sturlane Street to the north, and well TW-02D on Hewlett Parkway to the west-southwest, in addition to wells MW-27D and IW-01D. PCE values were 47,000 µg/L with 43,000 µg/L in a duplicate sample (TW-01D); 80,000 µg/L (TW-06D); 22,000 µg/L (TW-08D); 13,000 µg/L (TW-02D); 22,000 µg/L (MW-27D); and 9,800 µg/L (IW-01D). Concentrations for TCE included 2,600 µg/L with duplicate result of 2,300 µg/L (TW-01D); 2,200 µg/L (both TW-06D and TW-08D); 1,400 µg/L (TW-02D); and 4,000 µg/L (MW-27D). Overall, the area of significant PCE and TCE levels in the deep aquifer apparently begins near the West Broadway/Hewlett Parkway intersection, and includes the general area bordered by Mill Road, Sturlane Street, Hewlett Parkway, and West Broadway (see Figures 2-13 and 2-14).

Among both the shallow and deep UGA wells for the May 2013 sampling event, other VOC constituents detected at concentrations above screening criteria included 1,1-DCE, benzene, cis-1,2-DCE, MTBE, trans-1,2-DCE, and vinyl chloride (Table 2-4). The more elevated levels for the PCE/TCE daughter products were noted within the groundwater from the deep UGA, typically from within the “hot spot” area, and maximum concentrations for cis-1,2-DCE (1,300 µg/L) and vinyl chloride (79 µg/L) occurred in well MW-27D.

### **2.3.2.3 Post-Injection Baseline Groundwater Sampling Event for In-Situ Treatability Study**

The May 2013 baseline data were used to help refine planning for the in-situ treatability study. After in-situ field work was performed in August and September 2013, post-injection monitoring was conducted. These results are presented in Table 2-5 and discussed in Section 4.3, which also provides additional discussion of the May 2013 baseline groundwater results, particularly for analyses other than VOCs.

### **2.3.2.4 Summary of Pre-Design Investigation Results**

The following conclusions were reached based on the PDI groundwater analytical results for the shallow and deep UGA, as well as the results from the Jameco Aquifer investigation:

- PCE and TCE groundwater contamination (along with other VOC constituents greater than EPA and/or NYSDEC criteria) was identified in the shallow and deep UGA groundwater.





- The highest PCE and/or TCE concentrations were detected in samples from deep wells in the southeastern portion of the Site, including TW-08D, TW-06D, TW-02D, TW-01D, and MW-27D. This area is generally bordered by Mill Road, Sturlane Street, Hewlett Parkway, and West Broadway. Land usage in the area predominantly consists of single-family homes, with one business located along Mill Road and another facing West Broadway.
- The potential for dense non-aqueous phase liquid (DNAPL) exists at the Site (specifically in the southeastern portion) based on PCE groundwater concentrations. PCE has a solubility of 200,000 µg/L (Weiner, 2013), and may be present when the PCE level is above 1% of its solubility (i.e., greater than 2,000 µg/L).
- The PCE plume (>5 µg/L) in the shallow UGA was larger in extent than the deep plume, but did not contain the same magnitude of elevated concentrations (i.e., between one to three orders of magnitude less). Based on the multiple sampling events, the shallow PCE plume is roughly more than 2,500 feet in length and 600 feet in width.
- Shallow TCE contamination (i.e., levels greater than its MCL of 5 µg/L) was nearly non-existent, except for wells closer to Peninsula Boulevard (e.g., MW-07 and MW-03S) and a singular occurrence in IW-01S approximately 14 weeks after the in-situ treatability injections.
- The configuration of the lower UGA plumes for PCE and TCE plumes was similar. In general, the PCE concentrations were higher compared to TCE levels in the deep plume (i.e., up to one order of magnitude greater).
- Shallow PCE groundwater contamination was identified east of Mill Road in well MW-26S during the July 2012 sampling event, but not in paired deep well MW-26D. However, utilizing RI results, shallow and/or deep VOC contamination may extend east of Mill Road and perhaps near Harris Avenue in this general direction. Based on the groundwater flow direction, the occurrences near Mill Road may be unrelated, or only partially related, to the elevated VOC levels detected near the Hewlett Parkway/West Broadway intersection.
- No VOCs related to the Site groundwater plume (e.g., PCE and TCE) were present in the groundwater samples collected from the Jameco Aquifer, indicating that the Site is not impacting water quality in this aquifer (Table 2-6).
- The area encompassing the highest groundwater concentrations includes the general area bordered by Mill Road, Sturlane Street, Hewlett Parkway, and West Broadway (Figure 2-15). This land area predominantly consists of single-family homes with one business located along Mill Road and another facing West Broadway.
- When taking into account the area bordered by Mill Road, Sturlane Street, Hewlett Parkway, and West Broadway (Figure 2-15), the extent of this groundwater contamination comprises approximately 15% of the plume with TCE and PCE concentrations greater than 5 µg/L.



### 3.0 REMEDIAL ACTION OBJECTIVES AND COMPLIANCE WITH ARARs

#### 3.1 RA OBJECTIVES

RAOs specify contaminants of concern, exposure routes, and acceptable contaminant levels or range of levels for each exposure route. These objectives typically express both a contaminant level and an exposure route, because protectiveness may be achieved by reducing exposure as well as by reducing actual contaminant levels in the media of concern.

The RAOs to address OU-1 groundwater contamination (as specified in the ROD) include:

- Restore the impacted aquifer to beneficial use as a source of drinking water by reducing contaminant levels to federal and state MCLs.
- Reduce or eliminate the potential for migration of groundwater contaminants towards the NYAW Well Field.

With respect to in-situ chemical treatment, the intent is to use treatment to target areas containing high concentrations of PCE to reduce groundwater restoration time and costs of OU-1 remediation. As such, implementation of the in-situ treatment component will complement and improve the effectiveness of the groundwater extraction and treatment component.

#### 3.2 COMPLIANCE WITH ARARs/TBCs

This section discusses how ARAR attainment and compliance will be addressed by the in-situ groundwater remedy. To Be Considered (TBC) standards are also discussed in this section. Only ARARs and TBCs related to the in-situ remedy are discussed. ARARs associated with the groundwater extraction, treatment, discharge, and groundwater monitoring will be included in the BDR for that component of the OU-1 remedy. Sections 8.0 and 11.0 also discuss environmental protection and regulatory, governmental, and easement requirements.

The selected remedy will comply with all chemical-, action-, and location-specific ARARs and TBCs related to in-situ groundwater remediation for targeted high concentration contaminant areas and long-term groundwater monitoring. A summary of selected (i.e., pertinent) federal and/or state chemical-, action-, and location-specific ARARs and TBCs is presented in Table 3-1. Within Table 3-1, ARARs and TBCs pertinent to the in-situ treatment remedy are highlighted by shading.

**Chemical-Specific ARARs and TBCs:** This groundwater RA is designed to achieve and comply with chemical-specific ARARs and TBCs pertinent to the in-situ treatment of groundwater. ARAR and TBC criteria provide chemical-specific guidance on "acceptable" or "permissible" concentrations of contaminants. This remedy will ultimately reduce the levels of contaminants of concern in the groundwater to comply with MCLs as required by the Safe Drinking Water Act, 42 U.S.C. §§ 300(f) - 300(j), 40 CFR §141, and water quality standards as per New York Code, Rules, and Regulations (NYCRR), Title 6, Chapter X - Division of Water, Part 703. Applicable groundwater aquifer treatment standards for Site-specific chemicals as presented in the ROD are presented in Table 3-2.

**Action-Specific ARARs and TBCs:** Action-specific ARARs and TBCs are technology- or activity-based regulatory requirements or guidance that control or restrict RA activities. The ARARs and TBCs that are related to the in-situ groundwater remedy are summarized in Table 3-1.

**Location-Specific ARARs and TBCs:** Location-specific ARARs and TBCs are location-based regulatory requirements or guidance that would dictate or control remedial action. A list of the ARARs and Other Criteria, Advisories, or Guidance (TBCs) which will be complied with during implementation of the selected remedy is presented in Table 3-1.



### **3.3 PERFORMANCE STANDARDS**

The following performance standards are to be accomplished by the groundwater remedy selected in the ROD.

#### **3.3.1 Groundwater Remediation**

The performance standards in the ROD were developed for groundwater treatment to address unacceptable risks posed by groundwater and to comply with ARARs. The performance standards include federal MCLs and New York State Water Quality Standards for those groundwater contaminants of concern (COCs) as listed in Table 3-2.

By itself, the in-situ groundwater remedy may not meet performance standards throughout the entire plume. The targeted area of in-situ treatment generally includes the portion of the plume with PCE concentrations greater than 10,000 µg/L. This area is roughly bounded by Mill Road, Sturlane Street, Hewlett Parkway, and West Broadway.

#### **3.3.2 Groundwater Monitoring**

Regular monitoring of the performance and operation of the in-situ groundwater remedy system will provide the necessary data to determine the reduction in extent and contaminant concentrations in both the shallow and deep groundwater plumes. Any new monitoring wells will be constructed in accordance with State requirements as appropriate and placed to assess groundwater quality and generate data for evaluation purposes. The groundwater monitoring network will be operated in accordance with all appropriate federal and state requirements regarding well construction, water and waste handling operations, and monitoring protocols.

#### **3.3.3 Institutional Controls**

Institutional controls will be implemented to ensure that current and future activity related to land use at the Site and groundwater use on-site and off-site do not adversely impact the selected remedy. Institutional controls are not addressed in this BDR, but will be deferred to the design of the groundwater pump-and-treat system.





## 4.0 PILOT TEST SUMMARY

### 4.1 OBJECTIVES AND PURPOSE

The objectives of the treatability testing study were to evaluate the applicability of the ISCR strategy and provide the data to aid in the design, installation, and operational parameters for the in-situ groundwater remedy at the Site. The study involved the installation of an ISCR barrier at one area, and enhanced bioremediation activity at a second area to destroy groundwater VOCs on a permanent basis. ISCR included a chemical reductant (i.e., zero valent iron or ZVI) as part of the ISCR barrier and the injection of a bioremediation substrate (e.g., EVO, lactate, plant fiber, guar, and lecithin). This study helped determine design parameters including the ISCR material to be used, dosage, injection point spacing, and frequency of injections.

The study included the following major elements:

- Installation of two permanent injection wells (IW-01S and IW-01D) and 12 temporary PVC observation/monitoring wells (clusters TW-01 through TW-04; single wells TW-05D through TW-08D) in the vicinity of well clusters MW-21 and MW-27.
- Pre-injection monitoring at new wells installed during the PDI (including two wells installed as part of the aquifer evaluation testing) and selected existing wells (Section 4.2.2).
- Injections of bioremediation EVO (i.e., LactOil) into two permanent wells (IW-01S and IW-01D) upgradient of existing well cluster MW-27 along Hewlett Parkway.
- Installation of a ISCR barrier using direct push technology (DPT) equipment and ISCR along Westervelt Place and near its intersection with Hewlett Parkway (ISCR-01 through ISCR-10).
- Post-injection monitoring, data evaluation and reporting.

The intent was to use two test approaches to evaluate the applicability of these in-situ groundwater strategies, and to provide the data to aid in the design, installation, and operational parameters for the in-situ groundwater remedy. The results of the treatability study and subsequent in-situ groundwater design will be used to complement and improve the effectiveness of the groundwater extraction, treatment, and discharge component of the OU-1 remedy.

ISCR and bioremediation were selected to best meet the objectives of the treatability testing and to support the design of the in-situ groundwater remedy. The use of enhanced bioremediation or ISCR reagents was intended to reduce VOC concentrations (including PCE levels) within the targeted areas by creating conditions favorable to stimulate biodegradation of VOC-contaminated groundwater. These processes are also likely to be compatible with the pump-and-treat portion of the OU-1 groundwater remedy and result in less potential impacts to the residential area at the Site than other in-situ treatment processes.

### 4.2 TREATABILITY TESTING STUDY

#### 4.2.1 Well Installation

Two permanent wells (for the LactOil injections) were drilled using HSA and installed upgradient of cluster MW-27. These injection points (IW-01S and IW-01D) were 6-inch stainless steel (for long-term use), flush-mounted wells with approximately 10-foot (shallow) and 25-foot (deep) screen lengths. Table 4-1 summarizes well construction details for new wells installed during the PDI.

DPT equipment was used to install a suitable pattern of temporary 2-inch PVC observation/monitoring wells, after accounting for utilities and physical structures. To reduce the potential for cross-contamination using



DPT technology, separate temporary wells were installed to individually monitor the shallow and deep aquifers. A total of 12 temporary wells were installed near well cluster MW-27 and the general area of the ISCR barrier (west-southwest of the MW-21 cluster), as shown in Figure 4-1. Four of these locations were paired shallow and deep wells (four shallow and four deep wells) installed in a relatively straight line between the location of the injection wells and existing downgradient wells and/or new aquifer evaluation testing wells. They included well clusters TW-01, TW-02, TW-03, and TW-04. The remaining four points were deep wells only, with two points (TW-07D and TW-08D) located along Sturlane Street. Well TW-06D was along Westervelt Place just upgradient of the ISCR barrier, and well TW-05D was installed on Hewlett Parkway.

For the shallow plume, the 2-inch temporary PVC wells were drilled to a depth just above the top of the clayey silt within the UGA. For the deep (lower UGA) plume, the wells were installed just above the top of the Gardiners Clay formation. The shallow and deep screened wells were generally installed to depths of 20 feet and 65 to 75 bgs, respectively. All temporary points had an approximate screen length of 10 to 20 feet depending on subsurface conditions. The temporary PVC wells will be properly abandoned at a later date. Figure 4-1 reflects the locations of wells constructed for the PDI along with several existing wells or well clusters.

#### 4.2.2 Pre-Injection Baseline Monitoring

Once all new wells were installed, one baseline round of groundwater samples was collected in May 2013 to evaluate baseline conditions. Section 2.3.1.2 discusses the VOC results from this sampling event. One round of comprehensive water-levels was also obtained within the study area, and the elevations were compared to previous water-level results.

Baseline groundwater sampling occurred at 22 locations, including the two new injection wells (IW-01S and IW-01D) and the 12 new temporary PVC observation/monitoring wells. Also sampled were the new deep pumping well from the aquifer evaluation testing (PW-01D), the new shallow observation well from the aquifer evaluation testing (OW-01S), and five existing wells (including MW-18S, MW-18D, MW-21S, MW-21D, MW-27S, and MW-27D) (Figure 4-1). During the RI, well MW-27 was installed using Continuous Multichannel Tubing™ and consisted of shallow and deep ports at 25 and 70 feet in depth). Low-flow groundwater sampling procedures were employed with Grundfos Redi-Flo 2™ pumps for 2-inch or larger diameter wells. Peristaltic pumps (Waterra® inertial pumps) were used to sample smaller diameter wells (e.g., temporary 1-inch PVC wells).

Analytical laboratory analyses for some or all of the baseline samples included:

- VOCs.
- Dissolved gases (ethane, ethene, methane, and acetylene).
- TOC.
- VFAs (lactic, pyruvic, acetic, propionic, and butyric).
- qPCR - Bacteria (*Dehalococcoides* spp., Methanogens, and Eubacteria) and Functional Genes (TCE reductase [*tceA*], and Vinyl Chloride reductase [*bvcA* and *vcrA*]).

Ten (10) selected wells (listed in the QAPP) were tested for TOC, dissolved gases, and VFAs. These wells included IW-01S, IW-01D, OW-01S, MW-27S, MW-27D, PW-01D, TW-03S, TW-03D, TW-07D, and TW-08D. Groundwater from the two injection wells (IW-01S and IW-01D) also was tested for dechlorinating bacteria, functional genes, and phylogenetic groups (i.e., qPCR). In addition, select groundwater samples were analyzed in the field using test kits for total alkalinity, total soluble sulfide, and ferrous iron. All samples were also measured for field parameters, including DO, ORP (or redox), pH, temperature, specific conductivity (Eh), and turbidity.



#### 4.2.3 Injections of Enhanced Bioremediation Material

This portion of the treatability study included three segments:

- Implemented injections at two wells utilizing low pressure and gravity feed under static conditions within the targeted area of treatment. Injections included JRW Bioremediation, LLC product (LactOil) formulation as a bioremediation amendment.
- Conducted post-injection monitoring (PIM) to measure the effectiveness of the injections. Monitored for reducing conditions (goal: ORP less than -100 mV), which included the following parameters: DO; methane (CH<sub>4</sub>); ORP; total alkalinity; and pH. Monitored for biodegradation processes of PCE, TCE, and related by-products.
- If required, recirculated substrate from injection wells to improve the effectiveness of the injections.

**Injection Amendment:** LactOil was injected after the two permanent wells (IW-01S and IW-01D) were installed upgradient of cluster MW-27. The LactOil was delivered as an undiluted, soy microemulsion formulation. The liquid was provided in 50-gallon drums. The emulsion contained approximately 45% food grade soy bean oil, 35% fast release substrate (i.e., lactate, plus a small percentage of food additives, emulsifiers, and preservatives), and 20% water (JRW, 2012).

LactOil is a stable, concentrated, buffered, micro-emulsion of controlled-release, food grade carbon and nutrients designed for on-site dilution with cold water. LactOil creates strong reducing conditions, degrading chloroethanes and chloroethenes through reductive dechlorination with the substrate being fermented to produce hydrogen. The addition of soluble carbon to the subsurface supports the growth of indigenous microbes in groundwater. As bacteria feed on the soluble carbon, they consume DO and other electron acceptors, thereby reducing the redox potential in groundwater. As bacteria ferment the organic portion of LactOil, they release various VFAs, which diffuse and serve as electron donors for other bacteria (e.g., *Dehalogenators*).

A total of seven 50-gallon drums of LactOil were added to roughly 9,200 gallons of formation water. The mixing of the LactOil and water was conducted in a 6,000-gallon capacity tanker. Two separate batches of the mixture were generated. The initial batch included 200 gallons of LactOil and 5,100 gallons of water pumped from well IW-01D, which was subsequently injected back into IW-01D. The second batch included 150 gallons of LactOil and 4,116 gallons of water pumped from well PW-01D, which was then injected into IW-01S. Well PW-01D was not considered to be very contaminated (20 µg/L of PCE in May 2013) and was similar to the PCE concentration detected in the shallow UGA based on May 2013 sampling. Water could not be used from IW-01D for mixing the second batch since it contained LactOil from the initial batch injection.

The predetermined amount of LactOil was placed into the tanker for each batch and groundwater was pumped into the tanker until the correct volume was obtained. The mixture was circulated prior to injections using a 2-inch trash pump with the intake line of the pump connected to the tanker discharge port and the discharge line of the pump installed in the top of the tanker. It was not necessary to use a mechanical mixing system since a slurry-type of solution was not made. Since the LactOil contained about 160 gallons of soy bean oil (350 gallons times 45% oil); the injection solution consisted of 0.2% soy bean oil.

The calculated amount of LactOil required for injections was based on a number of inputs and assumptions. The calculations assumed total porosity of 20% for glacial outwash to estimate the amount of PCE in the targeted treatment areas. The thickness of the treatment area was based on the geologic cross-sections and the PCE contaminant contours for MW-27S and MW-27D, which indicated that the shallower (unconfined) UGA aquifer was at least 20 feet thick, and the deep (semi-confined) UGA aquifer was at least 30 feet in thickness.



The area of targeted treatment associated with each injection well was assumed to be an elliptical pattern 25 feet in width and 100 feet in length given available aquifer characteristics developed during the RI, such as horizontal hydraulic conductivity estimates of 5 fpd for the shallow and 50 fpd for the deep UGA (HDR, 2011a). Hydraulic conductivity values and other aquifer characteristics were updated during PDI aquifer testing (Section 5.2). The average PCE concentration in groundwater was assumed to be 5,000 µg/L; however, PCE levels at MW-27D were as high as 30,000 µg/L as reported in 2010 and 22,000 µg/L as detected in May 2013.

**Injections:** The LactOil injections into the two new wells near well cluster MW-27 consisted of proportions and quantities listed in Table 4-2.

At each injection well (one shallow and one deep), the LactOil mixture was transferred from the tankers using readily available equipment by Tetra Tech field staff. The shallow 6-inch well received about 4,116 gallons of the LactOil mixture (three drums of undiluted LactOil product), while the deep well received roughly 5,100 gallons (four drums of undiluted LactOil product) (Table 4-3).

The primary components of the LactOil bioremediation system consisted of injection wells, pumps, hoses, flow meters, valves, and associated piping. For each injection, the pump was connected to the tanker using a 2-inch flexible hose. The pump sent the LactOil solution to each well through a 1-inch PVC pipe which was installed approximately 25 feet below the water table in each well. The injection line had a dedicated pressure gage, flow totalizer, and flow control valve.

The LactOil solution was pulled directly from the tanker. Tanker water pressure and the in-line trash pump forced the solution downstream to the injection well. It was anticipated that one of the two injection wells (IW-01D) would accept flow more rapidly than the other as shown in Table 4-3. Well IW-01D injection was conducted by gravity feed only. The trash pump was not used for this well. Well IW-01S injection was conducted using the trash pump to inject at low pressure due to the low permeability of this well. A compression type well seal cap was installed on the top of this well in order to complete the injection activities under low pressure. The pressure during the injection at this well varied from 5.0 pounds per square inch (psi) to 10.0 psi. The amount of emulsion concentrate was directly proportional to the volume of water entering the system, so variations in water pressure or flow rate had no effect on the dilution.

During injections, field personnel periodically recorded the time, injection pressure, volume injected into each well, and other relevant information. When the flow totalizer indicated that a well had received the required volume of the solution, the control valve was closed.

**Recirculation of Substrate from Injection Wells:** After five rounds of PIM as discussed in Section 4.2.5, the injected substrate was still present in shallow well IW-01S approximately 10 weeks after the injection event. The PIM results revealed that current groundwater conditions within this well were not conducive to optimal bacterial growth due to the high levels of the LactOil substrate present. As such, a strategy was implemented to remove a portion of the substrate and groundwater from this well and transfer this solution into other nearby wells.

A total of 26 gallons of the LactOil/groundwater mixture was removed from the upper well casing of IW-01S using a 4-inch stainless steel bailer attached to nylon rope. The removed mixture was poured into 5-gallon buckets placed adjacent to the well. The bailer was also used to agitate the upper 15 feet of the groundwater within the well casing in order to attempt to mix a thin layer of floating LactOil on the groundwater surface within the well casing.

A total of 10 gallons of the mixture removed from IW-01S were gravity fed into well TW-01D. Eight gallons were gravity fed to TW-02D, and eight gallons were gravity fed to well TW-05D. The mixture was poured directly from the 5-gallon buckets through a funnel into each receiving well.



#### 4.2.4 Injections of ISCR Reagent as a Permeable Reactive Barrier

This portion of the treatability study consisted of the following components:

- Injected ISCR slurry into closely-spaced points at one general area followed by post-injection monitoring. EHC™ was used to establish a small ISCR barrier for plume treatment and management.
- Conducted PIM to measure the effectiveness of the injections.

The EHC material was intended to reduce PCE and other VOC groundwater concentrations by creating low redox potential and producing hydrogen. To evaluate the ISCR barrier's effectiveness and performance, one deep temporary PVC well (TW-06D) was installed just upgradient of the ISCR barrier injection points along Westervelt Place (Figure 4-1). Two deep temporary PVC wells were located downgradient along Sturlane Street (TW-07D and TW-08D).

**ISCR Barrier Material:** The EHC slurry (29% solids) consisted of solid organic carbon, micro ZVI, plant fiber, guar, and water. The dry powder was delivered in 50-lb bags. When mixed with water, the wet density of the slurry was approximately 1.15 grams per cubic centimeter (g/cm<sup>3</sup>).

The ISCR barrier material promotes ISCR by combining abiotic chemical reduction, using ZVI and/or reduced minerals (magnetite, pyrite), with anaerobic bioremediation for the effective treatment of CVOCs and other persistent compounds. Physical, chemical, and biological processes combine to create a reduced environment that stimulates chemical and microbiological dechlorination of otherwise persistent compounds.

EHC is composed of controlled-release, food-grade, solid carbon, fine-grained ZVI particles, and nutrients in a blended light tan powder. EHC is composed of natural compounds that are non-toxic to humans and the environment. The organic component is roughly 50-80% by weight, with iron making up most of the remaining weight (e.g., between 18-48%). After EHC is emplaced into the subsurface, various processes create very strong reducing conditions (e.g., ORP values as low as -500 mV) that stimulate rapid and complete dechlorination of CVOCs. EHC provides both direct and indirect abiotic pathways for reduction as well as biotic reduction of contaminants. The use of EHC helps decompose CVOCs and minimizes the production of cis-1,2-DCE and vinyl chloride through direct chemical reduction of contaminants with ZVI. A further benefit involves the use of neutral pH material that does not create conditions that could adversely affect indigenous reducing bacteria (if present). EHC has an approximate longevity of 4-5 years in field conditions.

The low Eh potentials not only improve the kinetics of the dechlorination reactions but further support decomposition of CVOCs. Providing a carbon source for fermentation to produce VFAs and hydrogen to stimulate anaerobic dehalogenators is one of the key mechanisms of action for EHC.

The estimated amount of EHC required for the injection points was determined based on a number of inputs and assumptions as provided in Table 4-4. Each injection interval received approximately 73 pounds (lbs) of dry EHC powder (about 1.5 bags) blended with approximately 28 gallons of water.

**ISCR Barrier Equipment and Installation Procedures:** Injection equipment included:

- DPT rig/chemical grout mixing unit
- Drive rods and pressure activated tip
- Pumps/hoses
- Valves/pressure gauges
- Water source / water storage tank

The DPT (e.g., Geoprobe® 7822 Model) was set up over each injection point. The subcontractor followed the manufacturer's SOP for the direct push equipment and the SOP for the mechanical mixing equipment. The subcontractor ensured that all probe holes remain vertical. The Geoprobe was fitted with a hammer





designed to advance tooling to greater depths and improved surface pavement coring. The unit was mounted on a remote-controlled, track base with a rear stabilizer and drop rack system.

The subcontractor used 1.5-inch outside diameter (OD)/0.625-inch inside diameter (ID) drive rods. The rods were initially connected to a pressure activated tip (probe) that could direct the slurry laterally into the subsurface. The outlet holes of the probe became blocked and jammed due to fine silts and clays in subsurface soils while advancing the DPT rods to selected intervals and depths. Several attempts were conducted but were not successful. Due to this problem, the subcontractor switched to a drop point style injection tip for all subsequent injection points. The subcontractor maintained sufficient rod lengths and threaded rod caps to cap each completed injection point to prevent backflow.

The injection pump used to install the ISCR barrier had a pressure rating of 500 psi in sandy soil settings. The pump had a minimum delivery rate of 5 gallons per minute (gpm). The use of a positive displacement pump had the pressure necessary to overcome the resistance of the deep UGA materials.

Groundwater was pumped from well PW-01D to make up the water for the slurry mix. It was anticipated that 1,750 gallons of groundwater would be needed. The water was stored near the mechanical mixing equipment in small poly tanks with 250-gallon capacity. A flexible, 2-inch hose connected the pump (e.g., gasoline-powered trash pump) to the mixing tank. Appropriate valves and a flowmeter were used to measure the required volume of water for the EHC slurry.

The EHC slurry was prepared using a single-bin mixing system (e.g., ChemGrout™ unit). The bin of this unit contained a paddle-mixer. After mixing in the bin, a valve on the bottom of the bin was opened to allow the slurry to be transferred to the injection pump. The pump was connected to each injection point individually at the top of the drill rods using high pressure hoses. The pump was capable of handling solids and generating at least 500 psi of pressure at a flow rate of 5 gpm. The EHC slurry was continuously injected at pressures up to 480 psi until injections were completed. The slurry within the mixing bin was continuously agitated with the mixing paddle while injections were performed.

A subcontractor (Zebra Environmental, Inc.) performed the EHC slurry injections with direct oversight by Tetra Tech. The injections began at the 80-foot depth interval near the top of the Gardiners Clay and proceeded upward to just below the “20-foot clay” layer. Slurry was not introduced into the “20-foot clay” layer beneath the Site, the top of which was estimated to be at a depth of 30 feet bgs.

For each injection interval, the rods of the DPT equipment were advanced to the top of the deepest targeted depth interval, and the selected slurry volume was injected before withdrawing upwards. The injection intervals within a point were evenly spaced every 4 feet. For the deep UGA, all individual injection points (with the exception of ISCR-08) had a total of eight intervals. The injection at the deepest interval of ISCR-08 could not be completed since it contained clay or fine silt/clay which would not allow the slurry to be injected; therefore, only seven individual injections were completed at this location. Additional DPT rods and rod caps were available to allow for the injection points to be capped between intervals and at the end of each day to prevent overflow. As required, the subcontractor injected a small volume of water (15 gals) to clear the injection rods at the completion of each interval.

The injection points were located 7 ft. on-center and were installed in a linear, barrier configuration. A simple mixing and injection system was set up to control the flow rate into each injection point. Small polyethylene tanks were used to store make-up water. These tanks were filled with Site-related groundwater from well PW-01D.

**Injection Procedures:** A pressure gauge was placed between the pump outlet and the delivery sub-assembly to monitor injection pump pressure and detect changes in aquifer backpressures during application. After the sub-assembly was connected to the pump, the field team checked that all connections were secure. Once this check was completed, the EHC slurry was pumped through the delivery system.



Drive rods were advanced through the surface pavement and the drive rod assembly was pushed to the deepest target depth for injecting EHC slurry. The number of drive rods to reach the target depth was pre-counted prior to starting injection activities. Injections of EHC slurry began at 80 feet bgs and were advanced upwards to 48 feet bgs. The average application rate of the ISCR barrier injections was 1.5 gpm with an average pressure of 400 psi.

After DPT drive rods were pushed to the desired depth, the rod assembly was slightly withdrawn. To minimize the injection of air into the deep UGA, and to preclude problems with heaving outwash materials, drive rods were filled with the EHC slurry before activating the injection tool. In some cases, air blocked slurry flow to the targeted treatment interval, especially if larger diameter rods (>1.5-inch OD.) were used, or at depths greater than 60 feet bgs.

Field personnel regularly recorded the time, injection pressure, volume injected into each interval and each injection point, and other relevant information. Some injection points accepted flow more rapidly than others. When the flow totalizer indicated that an injection point interval had received the required slurry volume, the control valve of the mixing bin was closed, a small volume of water was pumped through the system to clear the hoses and rods, the high pressure hose was removed from the top of the rods, the rods were capped, and the DPT drive rods were withdrawn to the next shallower depth interval.

Once the pressure injection was initiated, the pre-determined volume of EHC slurry was pumped into the injection point across the desired treatment intervals. The field team monitored for indications of aquifer refusal. These indications included a spike in pressure, or daylighting of injection materials around the injection rods or previously installed injection points. If backpressure impeded the injection pump's delivery volume of EHC slurry, the pressure relief valve placed between the pump discharge and the delivery subassembly was used to relieve or bypass the pressure build-up. In cases of high back pressure, the subcontractor allowed sufficient time for the deep UGA to equilibrate prior to removing the high pressure hoses from the DPT drive rods.

Once all intervals in an injection point received the required volume of EHC slurry, the subcontractor removed all remaining DPT rods and installed a granular bentonite seal for each borehole above the shallowest interval in that injection point. Quick-set concrete or asphalt was used for surface completion to restore boring locations to pre-existing conditions at the surface. All drive rods were then cleaned prior to being used again. Any residual EHC™ slurry from the rods was returned to the mechanical mixer.

The subcontractor periodically compared the pre- and post-injection volumes of EHC slurry in the holding tank using pre-marked volume levels. The EHC slurry was applied at a rate and pressure that maximized the radius of influence without causing preferential flow. This was achieved by injecting at the minimum pressure necessary to overcome the pressures associated with the subsurface conditions. At the end of each injection day, all moving parts and hoses were flushed with clean water. The mechanical mixer was also flushed with water.

**ISCR Barrier Installation:** Only the deep UGA was targeted for the ISCR barrier. The injection points were located along Westervelt Place near the intersection of Hewlett Parkway and Westervelt Place. As shown in Figure 4-2, this entire area contained elevated PCE and other VOC concentrations in the deep (semi-confined) UGA. The length of the barrier emplaced with the EHC slurry was approximately 70 feet. The work was performed in August and September 2013.

The configuration of the points was a relatively straight line along Westervelt Place after accounting for utilities. The injection points were spaced roughly 6 to 8 feet apart (an average of 7 feet) and generally lie perpendicular to the 10,000 ug/L PCE isoconcentration contour for the deep UGA based on 2010 sample results (HDR, 2011a). A total of 10 injection points were needed as part of the barrier. The spacing of points varied depending on accessibility. Only one line of injection points was used (i.e., the width of the ISCR barrier was relatively negligible).



After work was completed for an individual point, the subcontractor moved to the next injection point location, and repeated the steps outlined above. The field team chose to inject into every other injection point until all points were installed. This approach reduced the potential for excessive head buildup in the deep UGA, minimized short circuiting between adjacent injection points, and provided better distribution of the EHC slurry between injection points.

#### **4.2.5 Post-Injection Monitoring**

Following the LactOil and EHC slurry injections, groundwater samples and water-level measurements from selected wells were obtained on a periodic basis. Samples were collected from the wells for both chemical and physical parameter analyses. The monitoring program helped determine the effectiveness of the injections and measured the spread of the solutions (both laterally and vertically).

After the injection events/ISCR barrier installation were completed, the same list of wells as for the baseline pre-injection event were evaluated to determine if they were affected by the LactOil material and EHC slurry. Two types of post-injection monitoring were performed: process monitoring and performance monitoring. Table 4-5 summarizes the program.

**Process Monitoring:** Six rounds of PIM were performed, with events occurring approximately two weeks, four weeks, six weeks, eight weeks, 10 weeks, and 14 weeks after the LactOil injections and EHC slurry emplacement. The schedule for these events was adjusted based on the results from the previous process monitoring event. Process monitoring events involved the use of only field instruments (for water quality parameters such as pH, DO, ORP, turbidity, conductivity, and temperature) and test kits (total alkalinity, total soluble sulfide, and ferrous iron), and these results were compared to pre-injection groundwater quality results.

**Performance Monitoring:** After the injections, two rounds of performance monitoring were performed in October 2013 and December 2013. These rounds were conducted concurrent with the process monitoring events during Weeks 6 and 14. These results were evaluated to determine the subsequent frequency of bioremediation and ISCR reagent injections, any necessary modifications to the dosage of oxidants, and the design of the full-scale in-situ groundwater remedy.

After the injection event was completed, distribution of the injected solution was monitored in nearby wells, including the two injection wells, along with TW-01S/D, TW-02S/D, TW-03S/D, TW-04S/D, TW-05D, TW-06D, TW-07D, TW-08D, MW-18S/D, MW-21S/D, MW-27S, PW-01D, and OW-01S. Selected wells were sampled throughout the PIM program based on the continuous evaluation of sampling results (i.e., redox monitoring, NA parameters monitoring, bio-trap and fixed-base laboratory analysis). While all pre-injection (baseline) wells (i.e., those sampled in May 2013) were sampled in December 2013, only a portion of these wells were sampled in October 2013 consistent with the QAPP.

The monitoring program generated information to evaluate changes in VOC and degradation/transformation products; ORP; and other physical parameters (e.g., pH, conductivity, temperature, dissolved oxygen, and turbidity). For each of the two post-injection performance monitoring events, samples were collected from selected wells for laboratory analyses and general chemistry measurements. Groundwater was analyzed for Target Compound List (TCL) VOCs (trace level except wells MW-18S, MW-21D, and MW-27D due to historically high concentrations), TOC, dissolved gases, and/or volatile fatty (metabolic) acids. Field test kits were used to measure total alkalinity, total soluble sulfide, and ferrous iron levels so that these results could be compared to pre-injection groundwater quality results. Groundwater was also collected using four Bio-Trap® devices placed in the two injection wells, and analyzed for dechlorinating bacteria, functional genes, and phylogenetic groups (eubacteria and methanogens) using qPCR.

**Amendment Distribution Monitoring:** As noted in Table 4-5, amendment distribution monitoring periodically continued for three months after the injections. Field instruments were used to record measurements for DO, ORP, turbidity, and pH.





The presence of the substrate in a particular observation well was determined based on visual observations (milky color of groundwater indicating LactOil presence), and confirmed by analytical laboratory (higher-level volatile fatty acids). The turbidity readings evaluated LactOil concentrations in conjunction with visual comparison to dilution standards.

**Redox Reduction Monitoring:** The next phase of the PIM program was redox reduction monitoring. The main goal of this phase was to identify if the ORP levels in the pilot study area decreased. An ORP value less than -100 millivolts (mV) was an indication that sufficiently reducing conditions existed for anaerobic biodegradation. The redox reduction phase continued throughout the PIM program.

**Bio-augmentation Evaluation:** When an ORP level of -100 mV or less was observed, the need to perform bio-augmentation was evaluated. The following criteria were used to determine if bio-augmentation was necessary:

- Time-series data from Bio-traps placed in IW-01S and IW-01D
- Clear and consistent reduction in CVOC trends
- Vinyl chloride at approximately 100 µg/L
- Ethene at approximately 50 µg/L
- *Dehalococcoides* at >100/mL

Bio-trap samples were analyzed for dechlorinating bacteria (i.e., *Dehalococcoides* spp.), functional genes (*tceA* [TCE RDase], *bvcA* [BAV1 VC RDase], and *vcrA* [VC RDase]), and phylogenetic groups (i.e., Eubacteria and methanogens). Bio-augmentation with *Dehalococcoides* spp. cultures was not conducted as part of the pilot study.

**CVOC Reduction Monitoring:** CVOC reduction monitoring was performed following the positive results observed during ORP reduction monitoring and after the injected substrate in selected wells was recirculated. The CVOC reduction monitoring phase began after three rounds of monitoring (between September and October 2013) were performed. For consistency, the procedures for redox reduction and CVOC reduction monitoring were the same. The CVOC reduction monitoring program included two rounds of fixed-base laboratory analysis.

The first round of CVOC reduction monitoring was performed during the week of October 22, 2013. The second round occurred during the week of December 17, 2013. In addition to VOC analysis, well samples were analyzed for dissolved gases, anions, VFAs (i.e., metabolic acids), TOC, and qPCR. This report presents the results from both rounds of CVOC reduction monitoring and the evaluation of these results to determine the effectiveness of the bioremediation injections.

#### **4.2.6 Data Evaluation**

After post-injection monitoring was completed, Tetra Tech compiled, evaluated, and reported the results of the pilot testing. This task included reducing, tabulating, and validating field investigation data for subsequent evaluation, interpretation, and presentation. Data subject to these activities included hydraulic head data obtained during water-level measurements and the chemical/physical data obtained during monitoring activities, including well sampling. Specific activities included:

- Compiled water-level data and water chemistry data from the in-situ treatability study task.
- Interpreted hydraulic head data from the water-level measurements and prepare contour maps.
- Summarized and interpreted data from pilot testing to determine the number of injection wells required for the in-situ groundwater remedy, and determined the rates, volumes, and concentrations of contaminated groundwater that would be treated in-situ.



- Compiled chemical and physical data from the rounds of monitoring well sampling and prepared plume maps using field investigation results and treatability testing data.
- Prepared a brief report to present the integrated interpretations of the hydraulic head and chemical data, updated the present understanding of Site conditions based on these data, and presented the recommendations and rationale for the RD.

### 4.3 TREATABILITY TESTING STUDY RESULTS AND DISCUSSION

The results of in-situ treatability testing are discussed in this section. While three primary biological degradation processes can reduce chlorinated ethenes (including aerobic co-metabolism and direct oxidation), reductive dechlorination was the process employed during testing. In reductive dechlorination, chlorinated ethenes serve as electron acceptors in which a chlorine atom is removed and replaced by a hydrogen atom. Three primary conditions are generally required for biodegradation of PCE, TCE, and other CVOCs under reductive dechlorination:

- Presence of bacteria (e.g., *Dehalococcoides* spp.) capable of complete degradation of TCE to ethane.
- Reducing (redox) conditions (e.g. ORP < -100 mV).
- Electron donors and nutrients in sufficient concentrations to promote bacterial population growth.

All of these conditions must be naturally present or artificially established for complete biodegradation to occur. Note that the presence of competing electron acceptors, such as sulfates, nitrate, and iron can reduce the effectiveness of reductive dechlorination.

#### 4.3.1 Overview of Evaluation Process to Measure Biodegradation

Biodegradation processes can be measured through lines of evidence. The treatability testing results were considered according to three, arbitrarily defined, lines of evidence for contaminated groundwater:

- Primary - Decreasing CVOC trends.
- Secondary - Geochemistry and bioremediation-stimulated attenuation parameter evaluation.
- Tertiary - Biological growth and activity.

Though the terms primary, secondary, and tertiary seem to assign an order of importance, these terms were used to organize the evaluation of data. The evaluation of tertiary data was no less important than primary data. Primary data were used to determine the overall effectiveness of bioremediation, while secondary and tertiary lines of evidence were utilized to support the rationale for effectiveness.

**Decreasing CVOC Trends:** The first line of evidence with respect to measuring the effectiveness of bioremediation is determining that a decreasing trend in contaminant mass and/or concentration exists. More specifically, data should demonstrate a decrease in the concentration of the parent compound (i.e., PCE or TCE) coupled with the generation or increase in concentration of daughter or breakdown products (i.e., cis-1,2-DCE, vinyl chloride, and ethene). Since dechlorination occurs sequentially, dechlorination of a parent compound may result in a temporary increase, then decrease, in concentrations of daughter products. Eventually though, the concentration of all parent and breakdown products (i.e., total mass of contaminant and daughter products) needs to decrease.

**Geochemistry and Natural Attenuation Parameters:** A secondary line of evidence includes geochemistry data to illustrate biodegradation is occurring. Natural attenuation parameters are generally used to evaluate the suitability of geochemical conditions in the aquifer for biodegradation. The complex relationship among some of these parameters is described below.



- DO - DO acts as a primary substrate or co-substrate during the initial stages of metabolism. For chlorinated hydrocarbon degradation, anaerobic pathways are more efficient. If DO concentrations are greater than 0.5 to 1.0 mg/L, anaerobic bacteria will not exist sufficiently, and reductive dechlorination will not occur.
- Dissolved Methane - Since methane is not a chemical component of solvents, its presence at concentrations greater than background provides strong evidence of methanogenic fermentation (and carbon dioxide utilization). The measurements of background concentrations of methane are important since some natural sources of methane may exist.
- Dissolved Ethene/Ethane - Ethene and possibly ethane signify the final degradation step of chlorinated ethenes. Concentrations of ethene greater than 0.01 mg/L and ethane greater than 0.1 mg/L provide strong evidence of such degradation.
- Dissolved Acetylene - Acetylene is a major transformation intermediate in the abiotic degradation of TCE. While this process differs from the sequential biodegradation pathway, acetylene and its byproducts may be generated from the beta elimination pathway during abiotic degradation. Abiotic degradation has been demonstrated in the presence of ZVI and other types of iron, but not in a natural or bio-stimulated environment.
- ORP - ORP is a measure of the relative tendency of the groundwater solution to accept or donate electrons and the amount of energy released during electron transfer. ORP (in millivolts or mV) can provide evidence of the type of biodegradation processes that are active in a particular plume or area within a plume. The range of ORP values representing favorable conditions for reductive dechlorination is typically within the range of -100 to -350 mV. ORP is an important qualitative indicator of the overall oxidation/reduction state.
- Total Alkalinity - A result of both aerobic and anaerobic biodegradation is hydrogen production. When hydrogen is produced, alkalinity will be reduced. In low alkalinity aquifers, the pH may decrease to levels outside the range of microbial activity. Thus, to have optimum conditions for microbial growth, the aquifer must be properly buffered.
- pH - pH concentration is an indicator of the amount of free hydrogen available in a solution. Optimum conditions for microbial growth are within the range of 6.5 to 8 standard units (SU).
- TOC - TOC is an indicator of the amount of organic electron donor available for biodegradation. Levels of TOC are expected to decline over time as microbial growth/activity increases, thus consuming the available substrate. Optimal TOC concentrations are greater than at least 10 mg/L to determine if wells are impacted by edible oil or a similar substrate.
- Temperature - Temperature affects the metabolic activity of bacteria, as well as the solubility of geochemical species. Microbes are generally more active and efficient in warmer water. Biochemical processes are accelerated at temperatures greater than 20°C.

**Biological Growth and Activity:** Quantitative polymerase chain reaction, qPCR, is a molecular biological tool that can quantify the number of gene copies for a particular bacterial species (i.e., through the amplification of target 16S rRNA) or for a target functional gene (i.e., through the amplification of a target DNA sequence that codes for the functional gene). qPCR is a molecular method that amplifies a specific sequence of DNA as defined by primer sequences that anneal to specific, known genetic DNA sequences. As each gene copy is made, a fluorescent marker is released, measured, and used to quantify the number of target genes present in the sample. Tertiary lines of evidence use qPCR to quantify specific bacterial populations in groundwater and whether these bacteria possess functional genes necessary for complete reductive dechlorination.



There are consortia of microbes responsible for various degradation steps of CVOCs. However, *Dehalococcoides* spp. are the only bacteria that have been identified to date that can completely reduce TCE to ethene. Therefore, increasing concentrations of *Dehalococcoides* spp. are a good indication that a complete reductive dechlorination pathway of chlorinated ethenes is present.

Based on discussions with vendors, Table 4-6 presents a general assessment of how the *Dehalococcoides* spp. 16S rRNA molecular results can be qualitatively used to determine the performance of a biological anaerobic reductive dechlorination (ARD) system (ESTCP, 2006). The assessment of *Dehalococcoides* spp. should also consider CVOc trends and ethene/ethane production. Because the primary line of evidence supporting bioremediation is CVOc trends, biological activity and the presence of ethene/ethane support conclusions that complete reductive dechlorination is occurring.

The last critical piece of information to understanding the biological activity in the aquifer is the molecular analysis of functional genes present within the *Dehalococcoides* spp. in the aquifer. Three genes are important to complete reduction of TCE to ethene: *tceA*, *vcrA*, and *bvcA*. These genes encode for RDase proteins that are necessary to complete the reductive dechlorination pathway. Of these three genes, *vcrA* and *bvcA*, both encoding for vinyl chloride RDase, are the most important because they can efficiently reduce vinyl chloride to ethene while still capturing energy necessary for cellular growth.

In addition to *Dehalococcoides* spp. growth, the growth of methanogens and other bacteria that indicate anoxic conditions exist are significant indicators that the aquifer is under strongly reducing conditions that are the most favorable for efficient degradation. Molecular analysis of methanogens will typically yield higher copy numbers than *Dehalococcoides* spp. Correlations between the presence of methanogenic growth and pH, organic acid formation, and methane and carbon dioxide generation may prove useful in understanding the biological activity in the aquifer. The metabolic balance between fermentation and methanogenesis will be indicated by changes in pH, organic acid loading, and methane and carbon dioxide generation. Maintaining a neutral pH, sustaining a methanogen population, and balancing organic acid loading and methane production are all critical factors in promoting reductive dechlorination and encouraging *Dehalococcoides* spp. growth.

Data collected at several wells during treatability testing indicated that subsurface aqueous geochemistry was supportive of reductive dechlorination. Specifically, records compiled for the injection wells, as well as for several monitoring wells, suggested that sequential reductive dechlorination was actively proceeding.

For purposes of evaluating the effectiveness of the treatability testing, wells most likely to be affected by the LactOil injections or ISCR barrier installation were divided into two groups as shown in Table 4-7.

#### **4.3.2 Groundwater Results Related to LactOil Injections**

The results of the treatability study using LactOil injections with regard to monitoring criteria (i.e., ORP, VOC trends, dissolved gas trends, and VFA trends) are presented in this section. A summary of the monitoring well responses is included in Table 4-8. The evaluation of the responses for each criterion was subjective in nature, and was based on a qualitative interpretation of the data. Two or more combined favorable and moderate individual responses were required to receive an overall evaluation of favorable or moderate in Table 4-8. The baseline (pre-injection) and post-injection groundwater analytical results are summarized in Appendix A for sampling events conducted in July 2012, May 2013, October 2013, and December 2013. Field parameter measurements are summarized in Appendix A-7.

For this evaluation, the four primary VOCs of concern were considered to be PCE, TCE, cis-1,2-DCE, and vinyl chloride. In general, the LactOil injections resulted in decreased PCE and TCE groundwater concentrations for nearby wells, with some exceptions. The October 2013 sampling event was performed roughly 6 weeks after the injections, while the December 2013 event was conducted 14 weeks later. Notably, the more significant decreases in PCE, and in some cases TCE levels, were for deep wells IW-01D, TW-01D, TW-02D, TW-04D, TW-05D, and TW-07D. The shallow wells were less affected; however, primary VOC concentrations were fairly low in the shallow wells during pre-injection monitoring. Table 4-9



summarizes the PCE, TCE, cis-1,2-DCE, and vinyl chloride results for the one pre-injection and two post-injection events.

As presented in Figure 4-3, the characteristic decreasing trends in PCE and TCE concentrations with an increase in cis-1,2-DCE and vinyl chloride levels are typically indicative of sequential reductive dechlorination. Baseline cis-1,2-DCE and vinyl chloride levels increased or remained relatively unchanged for all wells near the injection wells, based on post-injection sampling results. One possible exception was noted for well TW-01D, for which the post-injection vinyl chloride concentration was non-detect (100 µg/L was the reporting limit) in December 2013 compared to 2.6 µg/L in May 2013.

Notable exceptions to general trends in post-injection groundwater concentrations were the results for wells IW-01S, MW-18S, and MW-27D. For these wells, PCE, TCE, or both VOC levels increased after the injections. These results were considered anomalous. Well MW-27D was constructed during the RI with continuous multi-channel tubing instead of a screened interval, which may have affected water quality by possibly intercepting a more concentrated part of the VOC groundwater mass. Well MW-18S was screened between 10 and 15 feet below ground surface and may have been too far away and too shallow in depth to be affected by ISCR barrier construction.

For well IW-01S, the well was pumped prior to sampling to remove stagnant substrate as discussed in Section 4.2.3. Pumping might have mobilized some contaminated mass in the shallow UGA, thus increasing VOC concentrations.

Several figures referenced throughout Section 4.0 provide trends for contaminant concentrations (e.g., CVOCs) and other analyte levels or field measurements. For ease of presentation, non-detect results were assumed to be “zero” for graphical purposes. In many cases, non-detect results are more reflective of reporting or method detection limits used by the laboratory for specific analyses. As such, values of “zero” for these figures should be interpreted as results that do not exceed the relevant reporting limit.

#### 4.3.2.1 Injection Well Cluster IW-01

The two injection wells were located between well cluster TW-01 and wells MW-27S and MW-27D. As previously noted, PCE and TCE concentrations in the shallow injection well increased during PIM (Figure 4-4). Cis-1,2-DCE levels also increased in both wells, which was anticipated.

There did not appear to be a significant change in concentration with respect to vinyl chloride contained in well IW-01S; however, the change could not be precisely determined based on elevated reporting limits. For well IW-01D, the vinyl chloride level increased from 3.5 µg/L (May 2013) to 15 µg/L (October 2013) then decreased to 5.5 µg/L (December 2013). In summary, the PIM results for the injection wells were as follows:

- Surprisingly, ORP values did not decrease for IW-01S and IW-01D after the injections (Figure 4-5). The baseline ORP results for both injection wells were less than -100 mV. For IW-01D, a small drop in ORP was measured, but by December 2013, the ORP value was similar to the baseline result. DO measurements also decreased after injections and remained at very low levels (e.g., less than 1 mg/L) (Figure 4-6).
- The pre-injection PCE concentration for IW-01D was 9,800 µg/L compared to the December 2013 result of non-detect (reporting limit was 5U µg/L). The TCE level was also non-detect (5U µg/L was the reporting limit) in December 2013 vs. the May 2013 result of 400 µg/L.
- For wells IW-01S and IW-01D, VFA levels significantly increased between May and December 2013 (Figure 4-7). The December 2013 VFA results for lactic, acetic, propionic, and butyric acids were the highest reported during PIM for well IW-01S. The presence of these acids indicated that fermentation was occurring by anaerobic bacteria.





- Dissolved gas concentrations were also elevated for IW-01S, but not for IW-01D (Figure 4-8). Acetylene, methane, ethane, and TOC levels were higher after injections for IW-01S compared to baseline data. However, the methane result for well IW-01D (7,000 mg/L) was the highest post-injection concentration reported for this substance, which suggested that methanogenesis was occurring.

The microbial and functional gene results for well cluster IW-01 (Table 4-10 and Figure 4-9) indicated that the aquifer was not able to support bacteria populations, including *Dehalococcoides* spp., after injecting LactOil. Based on bacterial results, *Dehalococcoides* spp. was not present in groundwater. Increasing levels of total eubacteria and methanogens revealed that these phylogenetic groups were naturally present in the aquifer.

Analysis of the functional genes results for well cluster IW-01 documented that *bvcA*, *vcrA*, and *tceA* were not present along with *Dehalococcoides* spp. The absence of these genes indicated that complete sequential reductive dechlorination was not possible within the aquifer without bio-augmentation, bio-stimulation, or both.

#### 4.3.2.2 Well Cluster TW-01

The nearest upgradient wells to the injection wells were associated with cluster TW-01. The shallow well (TW-01S) appeared generally unaffected by LactOil injections; however, deep well TW-01D showed significant decreases in PCE and TCE levels and a moderate increase in cis-1,2-DCE concentrations (Figure 4-10). In summary, the PIM results for cluster TW-01 were as follows:

- ORP values decreased for both TW-01S and TW-01D shortly after injections and then increased to pre-injection values (Figure 4-11). DO readings also decreased after injections and remained at very low levels (e.g., less than 1 mg/L) (Figure 4-12).
- The pre-injection PCE concentration for TW-01D was 45,000 µg/L (May 2013) compared to 1,700 µg/L (December 2013) after the injections. TCE levels considerably dropped as well (2,450 µg/L in May 2013 vs. 610 µg/L in December 2013).
- For cis-1,2-DCE, levels consistently increased from the baseline result of 24.5 µg/L to 920 µg/L in December 2013.

Biological data were not collected for well cluster TW-01. VFA, dissolved gas, and TOC analyses were also not performed.

#### 4.3.2.3 Wells MW-27S, MW-27D, and Well Cluster TW-02

These wells were the nearest downgradient wells and were up to 150 feet away from the two injection wells. Based on the geochemical data, TW-02D and MW-27S were influenced by injections but the TW-02S and MW-27D wells were not (Table 4-8). Observations revealed that the groundwater in these wells had a grayish to gray-black tint and a sulfur-like odor, which were interpreted to reflect the effects of the LactOil solution. Well TW-02S did not contain PCE or TCE during baseline sampling and therefore was not very useful to measure bioremediation effects. As discussed earlier, the PIM results for well MW-27D were considered anomalous. PCE and TCE levels in well MW-27S may have dropped after injections; however, elevated reporting limits made this conclusion uncertain. Cis-1,2-DCE concentrations slightly increased.

The PIM results for well cluster TW-02 and wells MW-27S and MW-27D revealed the following:

- ORP decreased after injections in wells MW-27S and TW-02S to -100 mV or lower (Figure 4-13). ORP values did not decrease for TW-02D and eventually increased to levels higher than the baseline result. Well MW-27D was not included in the PIM process monitoring program due to the presence of other nearby deep wells.





- DO measurements greatly fluctuated for wells TW-02S, TW-02D, and MW-27S, but by December 2013 were both less than 1 mg/L (Figure 4-14).
- Well TW-02D showed a decrease in PCE levels and increases in cis-1,2-DCE and vinyl chloride concentrations after the injections, but the TCE results were inconclusive (Figure 4-15). PCE concentrations decreased from 13,000 µg/L (May 2013) to 2,300 µg/L (December 2013). Cis-1,2-DCE levels rose from 49 µg/L in May 2013 to 3,000 µg/L in December 2013, which was the highest cis-1,2-DCE concentration reported during treatability testing. Vinyl chloride levels increased from 6 µg/L during baseline sampling to 14 µg/L in October 2013 to non-detect (reporting limit of 100U µg/L) in December 2013.
- For well MW-27S, PCE and TCE levels decreased to non-detect (5U µg/L was the reporting limit); cis-1,2-DCE concentrations increased; and vinyl chloride levels remained below reporting limits throughout the baseline and PIM sampling events.

Among other analytical parameters, concentrations of dissolved gases and VFAs increased in wells MW-27S and MW-27D, but the increases were more apparent in well MW-27S (Figures 4-16). For example, acetic acid levels rose from 0.088 µg/L to 25 µg/L and methane levels increased from 2.5 µg/L to 8,000 µg/L between May and December 2013 (Figure 4-17). This was the maximum methane detected in groundwater during treatability testing.

Biological data were not collected for these wells. VFA, dissolved gas, and TOC analyses were not conducted for well cluster TW-02.

#### 4.3.2.4 Wells TW-05D, OW-01S, and Well Cluster TW-03

These wells were downgradient from the injection wells and near the intersection of Hewlett Parkway and Westervelt Place. Among these four wells, well TW-05D was most affected by LactOil injections based on geochemical results; well cluster TW-03 was somewhat impacted; and OW-01S was not influenced at all. Shallow wells TW-03S and OW-01S did not contain elevated VOC concentrations during baseline sampling and therefore were not helpful in evaluating contaminant trends.

Other conclusions included:

- ORP values for well OW-01S did not decrease to less than -100mV (Figure 4-18). During one sampling event (October 2013), ORP measurements were less than -100mV for well TW-03S. Although below -100 mV, ORP values did not appreciably decrease compared to baseline results.
- DO results for well OW-01S during PIM did not fall below 1 mg/L (Figure 4-19). By December 2013, DO measurements for wells TW-03S, TW-03D, and TW-05D were non-detect.
- PCE levels in well TW-03D dropped considerably after the injections (Figure 4-20). PCE concentrations decreased from 54 µg/L in May 2013 to 0.36J µg/L in December 2013, while TCE results were between 1.6 µg/L (May 2013) and 4.1 µg/L (December 2013). There were no significant increases in cis-1,2-DCE levels for well cluster TW-03 and well OW-01S.
- For well TW-05D, PCE and TCE concentrations decreased compared to baseline results. PCE concentrations dropped from 2,500 µg/L to 69 µg/L, while TCE levels fell from 590 µg/L to 120 µg/L. There was a three-fold increase in cis-1,2-DCE levels in this well (140 µg/L vs. 480 µg/L). Vinyl chloride results were all less than 2 µg/L during testing; however, some reporting limits for this compound were elevated (e.g., 50U µg/L in December 2013).
- The treatability testing results for dissolved gases, VFAs, and TOC for wells OW-01S and TW-03D were similar before and after injections (Figures 4-21 and 4-22). There was a slight increase in some



of these concentrations for well TW-03S. TOC levels were not significantly higher after injections for well TW-03S. Well TW-05D was not tested for these parameters.

- Based on PIM results, well TW-03S appeared to be the furthest downgradient shallow well influenced by injections.

#### 4.3.2.5 Well PW-01D and Well Cluster TW-04

These wells were located near the intersection of Hewlett Parkway and Sturlane Street and may have been potentially affected by the ISCR barrier installation, although that was considered more unlikely for the shallow aquifer. These wells were not significantly influenced by injections based on the PIM results. Similar to other more downgradient wells, baseline VOC concentrations were not elevated in wells PW-01D, TW-04S, and TW-04D, which made the evaluation of dechlorination effects difficult. Highlights included:

- ORP measurements for wells PW-01D and TW-04D did not decrease after injections (Figures 4-23). For well TW-04S, ORP values dropped to less than -50 mV six weeks after injections, but then increased during the remaining process monitoring events.
- DO results fluctuated for all three wells (PW-01D, TW-04S, and TW-04D), but eventually decreased to non-detect in December 2013 (Figure 4-24). The baseline DO values for wells PW-01D and TW-04D were less than 1 mg/L.
- Primary VOC concentrations for PCE, TCE, cis-1,2-DCE, and vinyl chloride contained in well PW-01D slightly increased after injections, and except for vinyl chloride, were above groundwater clean-up goals in December 2013. PCE levels in well TW-04D dropped from 8 µg/L (May 2013) to 0.96 µg/L (December 2013) as shown in Figure 4-25. Based on the December 2013 PIM results, well cluster TW-04 did not contain VOCs at concentrations greater than groundwater clean-up goals.
- For PW-01D, dissolved gases, VFAs, and TOC results indicated generally higher concentrations of these substances during pre-injection sampling (Figures 4-26 and 4-27). One exception was for methane, for which levels increased from 85 µg/L (May 2013) to 390 µg/L (December 2013). Well cluster TW-04 was not tested for these parameters.

#### 4.3.2.6 Summary

Based on the geochemical data, LactOil injections favorably affected wells IW-01D, TW-05D, and TW-03D. Impacts on shallow wells downgradient of injection well IW-01S were less notable. This was possibly due to several contributing factors, including the length of the IW-01S screened well interval (10 feet), its slot size (0.01-inch), or locally low hydraulic conductivity of the shallow aquifer that prevented the substrate from migrating an appreciable distance from IW-01S.

The need to purge IW-01S of the substrate further indicated that shallow flow was not sufficient to dilute the material injected. After IW-01S was purged, DO readings for this well decreased to less than 1 µg/L and ORP measurements decreased below 0 mV. ORP values, however, did not fall below pre-injection readings.

Although well cluster TW-01 was considered upgradient from the injection wells, the distance was less than 75 feet. Significant decreases in PCE and TCE concentrations contained in well TW-01D, along with an increase in cis-1,2-DCE levels, suggested that this location was impacted by the deep injection, perhaps due to the flatness of the hydraulic gradient in this general area. The zone of influence around these wells may be highly variable due to local conditions since well TW-01S showed a weak response to shallow LactOil injection.

Biological data collected from injection wells did not reveal the long-term, significant presence of bacteria that can dechlorinate VOCs such as PCE and TCE. The associated degree and consistency of contaminant



transformation were variable, which suggested bio-augmentation is needed to create or stimulate conditions more favorable for reductive dechlorination. If favorable bacterial populations are not present in the shallow or deep aquifers, bio-stimulation alone would not be effective.

The effects of the LactOil injections should be interpreted with some degree of uncertainty. Injection procedures could have contributed to lower VOC concentrations found in wells during PIM. For example, Site-related groundwater used to mix LactOil material may have been aerated during both pumping and injections, thus reducing the amount of VOCs present and possibly diluting subsequent VOC levels detected during post-injection sampling events. Although standard sampling techniques were used, these methods may have introduced some variability in the analytical results.

#### **4.3.3 Groundwater Results Related to ISCR Barrier Installation**

The results of the treatability study near the ISCR barrier points along Westervelt Place are highlighted below. Monitoring well responses are summarized in Table 4-8. The pre-injection and PIM analytical results along with field parameters are provided in Appendix A.

In contrast to injections at wells IW-01S and IW-01D, the ISCR barrier addressed only the deep aquifer. There were fewer monitoring wells in which to evaluate the post-installation results, and the available well locations were limited to roads in the neighborhood. Nonetheless, the presence of the ISCR barrier resulted in decreasing PCE groundwater concentrations for several nearby wells, including wells TW-06D TW-07D, and to a lesser degree well TW-08D (Table 4-9). The furthest downgradient location evaluated during the treatability study was MW-18D, which was possibly affected by the study based on the PIM results.

Prior to the study, well TW-07D was anticipated to best demonstrate the effects of reductive dechlorination since it was the closest downgradient monitoring well and along the suspected deeper groundwater flow path. Based on the PIM results, PCE and TCE concentrations significantly decreased in this well by two orders of magnitude.

Baseline cis-1,2-DCE and vinyl chloride levels generally increased or remained non-detect (below respective reporting limits) for the wells near, or downgradient of, the ISCR barrier based on post-injection sampling results. However, some increases that were noted 7 weeks after the ISCR barrier points were installed were no longer apparent after 15 weeks.

##### **4.3.3.1 Well TW-06D**

Well TW-06D, located just upgradient of the ISCR barrier points, contained the highest baseline concentration of PCE (80,000 µg/L) reported during the study, as well as the maximum PCE level detected during PIM (63,000 µg/L). The PIM results revealed the following:

- ORP values for well TW-06D increased during post-injection monitoring compared to the baseline result but were less than -100mV in December 2013 (Figure 4-28).
- DO results fluctuated during PIM (Figure 4-29). By December 2013, the DO value was non-detect for this well.
- PCE contained in well TW-06D decreased after the ISCR barrier was installed (Figure 4-30). PCE concentrations decreased from 80,000 µg/L in May 2013 to 58,000 µg/L in October 2013 and then increased to 63,000 µg/L in December 2013. There was also an increase in cis-1,2-DCE levels about 7 weeks later from 25 µg/L to 350J µg/L. By December 2013, the concentration was non-detect; however the reporting limit was 2,500U µg/L due to dilution of the sample by the laboratory.
- TCE levels did not decrease after installation. The concentrations during May and October 2013 were 2,200 µg/L, but increased to 3,000 µg/L by December 2013.



- Vinyl chloride concentrations slightly increased and then decreased for TW-06D compared to baseline results. By December 2013, the vinyl chloride level was non-detect, but the reporting limit was elevated in a manner similar to cis-1,2-DCE. As noted previously, EHC acts to minimize production of cis-1,2-DCE and vinyl chloride through chemical reduction of contaminants with ZVI.

Based on these results, it was uncertain if well TW-06D was within the influence of the ISCR barrier points. Additional monitoring may be needed to determine long-term effects. The high concentrations of PCE detected in TW-06D may be related to sampling variability, degradation of this compound by ISCR, or both.

#### 4.3.3.2 Wells TW-07D and TW-08D

Both of these deep wells were installed along Sturlane Street downgradient of the ISCR barrier. With respect to deep groundwater flow, well TW-07D was probably better located. The VOC results for TW-07D strongly indicated that reductive dechlorination was occurring. Due to the presence of ZVI in the EHC material, cis-1,2-DCE and vinyl chloride concentrations contained in well TW-07D did not significantly increase after the ISCR barrier points were emplaced. The results for well TW-08D were more inconclusive. Other findings included:

- ORP values for wells TW-07D and TW-08D initially increased after ISCR barrier installation and did not decrease to less than baseline ORP measurements (Figure 4-28), both of which were less than -150 mV. However, by December 2013, ORP readings were less than -100 mV.
- DO results fluctuated for both wells and eventually decreased to non-detect in December 2013 (Figure 4-29). The baseline DO values for wells TW-07D and TW-08D were around 1 mg/L.
- PCE contained in well TW-07D dropped from 4,300 µg/L (May 2013) to 16 µg/L (December 2013) as shown in Figure 4-30. TCE levels decreased from 270 µg/L to 1.6 µg/L during this period. The baseline and PIM cis-1,2-DCE and vinyl chloride concentrations were generally similar with a slight increase in vinyl chloride levels.
- For well TW-08D, PCE concentrations decreased from 22,000 µg/L to 17,400 µg/L before and after ISCR barrier emplacement. TCE levels remained approximately the same. Cis-1,2-DCE contained in well TW-08D significantly increased from 44 µg/L in May 2013 to 625 µg/L in December 2013.
- For TW-07D, concentrations of several dissolved gases, VFAs, and TOC decreased compared to baseline results (Figures 4-31 and 4-32); however, some levels (i.e., lactic acid, butyric acid) slightly increased. Methane levels decreased from 190 µg/L (May 2013) to 15 µg/L (December 2013); one of the few instances where this occurred during treatability testing. Similar results were reported for well TW-08D although methane concentrations slightly increased. Both wells were not tested for biological indicators.

#### 4.3.3.3 Wells MW-18S and MW-18D

These wells were located at the intersection of Hewlett Parkway and Sturlane Street. Baseline concentrations for the primary VOCs were generally low or at trace levels for these wells. As an overall conclusion, the PIM results indicated that the wells were not affected by either treatability test, although the presence of the LactOil™ substrate was noted during PIM. Other highlights included:

- ORP trends were increasing for both wells after ISCR barrier emplacement compared to the baseline results (Figure 4-33). By December 2013, however, ORP in well MW-18D was less than -150 mV, which is conducive for reductive dechlorination. The post- ISCR barrier ORP levels were still higher in well MW-18D than the baseline concentrations. The ORP reading in well MW-18S was mostly positive during PIM.



- DO values mostly decreased for well MW-18S, but varied up and down for well MW-18D (Figure 4-34). DO results for these wells were less than 0.5 mg/L by December 2013.
- PCE contained in well MW-18S increased from 26 µg/L (May 2013) to 410 µg/L (December 2013) (Figure 4-35). This was not anticipated. For comparison, the July 2012 PCE result was 3.8 µg/L.
- For TCE, cis-1,2-DCE, and vinyl chloride, the results showed that baseline levels were similar to post-ISCR barrier data. Cis-1,2-DCE and vinyl chloride results were non-detect (5U µg/L was the reporting limit) for all groundwater sampling events for this well.
- For well MW-18D, primary VOC concentrations were at low or trace levels during all sampling rounds. Cis-1,2-DCE concentrations rose from 2.5 µg/L in May 2013 to 14 µg/L in October 2013 to 13 µg/L in December 2013. Only trace vinyl chloride levels were detected.

Samples from wells MW-18S and MW-18D were not tested for dissolved gases, VFAs, TOC, or biological indicators.

#### 4.3.3.4 Wells MW-21S and MW-21D

These wells were side gradient and east of the ISCR barrier points along Westervelt Place. They were not expected to be significantly affected by the ISCR barrier and EHC material. The wells were only included in the baseline sampling event for VOCs (May 2013) although they were both part of process monitoring using field instruments. Treatability testing did not demonstrate that these wells were influenced by the ISCR barrier emplacement. The evaluation indicated the following:

- ORP readings for well MW-21S decreased roughly 7 weeks after ISCR barrier installation and then increased after about 11 weeks (Figure 4-36). The measurements did not fall below -100 mV, which is the start of the range for more favorable reductive dechlorination conditions.
- For well MW-21D, ORP values were generally similar before and after the ISCR barrier was constructed. By December 2013, ORP for this well was just below -100 mV.
- DO measurements for well MW-21S varied during testing, but were around 1 mg/L on one occasion in early October 2013 (Figure 4-37). Subsequently, DO readings increased and were greater than the baseline result for this well. For well MW-21D, DO values were similar throughout the monitoring program and did not fall below 1 mg/L.

Groundwater samples from these were not analyzed for dissolved gases, VFAs, TOC, and biological indicators.

#### 4.3.3.5 Summary

Based on geochemical data, the use of EHC within the ISCR barrier clearly impacted well TW-07D, and to a lesser extent, wells TW-06D and TW-08D. Since ISCR barrier emplacement only addressed the deep UGA, impacts on shallow wells were not anticipated. Also, new well locations were restricted to roadways that precluded drilling a more robust monitoring network to evaluate reductive dechlorination effects. The nearest downgradient wells (TW-07D and TW-08D) were about 250 feet away. While groundwater monitoring was performed for 15 weeks, the ISCR barrier is expected to continue to degrade and destroy VOCs for a considerable length of time. Additional sampling events may be needed to more fully evaluate the effectiveness of the ISCR barrier.

The location of the ISCR barrier appeared to be well-situated for treatability testing. Adjacent well TW-06D contained the highest PCE groundwater concentrations (ranging from 80,000 µg/L in May 2013 to 63,000 µg/L in December 2013) reported for the Site. Samples from the closest downgradient well





(TW-07D) revealed that PCE and TCE levels dropped by two orders of magnitude after the ISCR barrier was installed.

For the most part, cis-1,2-DCE and vinyl chloride concentrations for wells near the ISCR barrier increased after installation, but only for a short period of time. The increase in concentrations of daughter or breakdown products like cis-1,2-DCE and vinyl chloride is indicative of sequential dechlorination of the parent compound (e.g., PCE). ORP and DO measurements for the same wells (i.e., TW-06D, TW-07D, TW-08D, well cluster MW-18, and well cluster MW-21) showed mostly inconclusive results with respect to demonstrating reductive dechlorination.

Similar to the post-injection results related to LactOil injections, the effects of the ISCR barrier on groundwater quality are subject to some uncertainty. Only a few wells (e.g., TW-07D, TW-08D, and possibly several wells located along Hewlett Parkway) were available for post-injection monitoring, and they may have been located too far away from the ISCR barrier to adequately measure biodegradation processes. The PDI aquifer pumping tests involving well PW-01D also could have influenced groundwater flow, hydraulic characteristics (e.g., gradient and velocity), and CVOC contaminant concentrations for the deep UGA.

#### 4.4 OTHER TESTING RESULTS

With respect to LactOil injections (or injections involving other edible oils or edible oil emulsions), the treatability testing results indicated that some form of bio-augmentation with *Dehalococcoides* cultures would likely be required to stimulate and support this type of in-situ groundwater remedy for the Site. Bio-augmentation would not be necessary if long-term data trends revealed a clear reduction in PCE groundwater concentrations; the presence of elevated vinyl chloride and ethene concentrations relatively shortly after fieldwork; the presence of sufficient bacterial populations (i.e., *Dehalococcoides* spp.), or a combination of these trends.

Based on the PIM results, trends in pH are shown in Figure 4-38. The average range of pH values was between 6 to 8 SU, which is close to neutral and conducive to stimulating healthy microbial growth. About half of the wells monitored reflected a generally flat trend for pH. This was especially true for shallow wells. No pH measurements exceeded 8.0 SU during treatability testing. Only a few pH readings were less than 6.0, including wells IW-01S (4.5 SU); TW-02D (5.2 SU); and TW-05D (5.6 SU). Injections of LactOil and other edible oils may lower pH due to the formation of VFAs, particularly at sites with low groundwater flow rates or where groundwater mixing could be limited (USAF, 2007).

Chemetrics® field test kits were used to evaluate trends in alkalinity ( $\text{HCO}_3^-$ ), ferrous iron ( $\text{Fe}^{2+}$ ), and sulfide ( $\text{S}^{2-}$ ) during treatability testing. Alkalinity measurements usually increased after the LactOil injections compared to baseline readings. In May 2013, alkalinity ranged from 45 to 130 mg/L or ppm; in October 2013, results varied between 100 and 175 mg/L; and in December 2013, alkalinity ranged from 45 to 350 mg/L. Well IW-01S revealed the maximum value. Alkalinity is a general water quality parameter and measures buffering capacity.

For ferrous iron, the in-situ treatability study results revealed a wide range of values from non-detect to more than 10 milligrams per liter (mg/L). The ex-situ treatability study noted that ferrous iron ranged from 29.7 to 40.25 ppm in the deep UGA and 1.2 to 7.73 ppm in the shallow UGA. Between baseline and post-injection monitoring events, there were some increases in  $\text{Fe}^{2+}$  for wells IW-01D and TW-03D. Other post-injection increases greater than 10 mg/L could not be measured due to the maximum range of the ferrous iron test kit procedure. As a general rule, the deep wells contained higher concentrations of ferrous iron compared to shallow wells.

All sulfide results were non-detect, except for a trace amount (0.6 mg/L) in well IW-01D (December 2013). Sulfide is a byproduct of sulfate reduction. Elevated sulfide levels may inhibit some biological processes and degrade secondary water quality.





The Basis of Design for Ex-Situ Groundwater Treatment (Tetra Tech, 2014) contains additional information regarding the analysis of aquifer pump test samples.



## 5.0 TARGET TREATMENT AREA DELINEATION

### 5.1 INTRODUCTION

The majority of the current 10,000 µg/L PCE contour is defined as a target treatment area for in-situ remedy (Drawing C-2). This target treatment area is approximately 650 feet long, by 150 feet wide, by 40 feet in thickness (i.e., roughly 90,000 square feet [ft<sup>2</sup>] in area), and encompasses the areas of elevated PCE concentrations in the deep UGA detected during the PDI, the RI, and other sampling events conducted by EPA. Figures 5-1 and 5-2 reflect the extent of deep and shallow UGA groundwater contamination, respectively, based on December 2013 analytical data for PCE. Figures 5-3 and 5-4 display the deep and shallow groundwater December 2013 results for TCE. The in-situ remedy, including the selected target treatment area, has been designed to address variability among potential plume configurations and observed data sets.

The ROD (EPA Region 2, 2011) did not specify the size or dimensions of the target treatment area, only that in-situ chemical treatment would be used for high concentration contaminant areas. To help determine the target concentration, several factors were considered, including the frequency and magnitude of PCE and TCE groundwater detections, extent of the contaminant plume, proximity to suspected source area(s), and feasibility of effectively employing in-situ treatment. Within the groundwater contaminated area bordered by Mill Road, Sturlane Street, Hewlett Parkway, and West Broadway (Figure 5-1), the extent of deep UGA groundwater contamination comprises roughly 15% of the plume with TCE and PCE concentrations greater than 5 µg/L (i.e., groundwater clean-up goals). These concentrations significant decrease with distance from the 10,000 µg/L PCE contour for the deep UGA.

Given a fairly well-defined pattern of elevated VOC concentrations attributable to the Site, with PCE and TCE levels at least three orders of magnitude greater than their clean-up goals, the selection of the 10,000 µg/L PCE contour to delineate the high concentration contaminant area is appropriate and reasonable for the in-situ treatment component of the groundwater remedy.

### 5.2 HYDROGEOLOGY

The hydrogeology at the Site primarily focuses on the characteristics of the UGA. The UGA is split into two similar, but distinct regimes. The upper and lower portions are divided by the discontinuous “20-foot clay,” which acts as a leaky aquitard. For the upper UGA, groundwater elevations are indicative of a typical unconfined, water-table aquifer. In the deeper, semi-confined portion of the UGA, elevations are similar to or lower than shallower wells at the same location, suggesting the “20-foot clay” does not constitute a fully confining unit.

The depth to groundwater within the unconfined portion of the UGA ranges from about 3 to 15 feet bgs, and varies from 6 to 17 feet bgs in the semi-confined portion. The thickness of the upper UGA ranges from 10 to 35 feet; the deeper unit is approximately 55 to 65 feet thick (Tetra Tech, 2008). An apparent significant downward vertical gradient (e.g., -0.1 ft/ft) exists between the two portions, particularly toward the southern edge of the Site along Broadway and West Broadway.

Several characteristics of the UGA act to influence groundwater contaminant migration, including stratigraphy, porosity, and hydraulic conductivity. While no direct measurements of intergranular porosity or specific yield (Sy) have been made at the Site, approximate values may range from 25% porosity (approximately 22% Sy) for sandier zones within the UGA to 50% porosity (with <5% Sy) for the lower confining unit of the Gardiners Clay (Heath, 1983).

The shallow portion of the UGA is composed of predominantly sand of varying grain size combined with variable amounts of interbedded silt and occasional coarse sand and even gravel zones. For the shallow UGA, the estimated transmissivity was highly variable when measured during ex-situ aquifer testing, with a representative transmissivity value of approximately 17,400 square feet per day (ft<sup>2</sup>/d). Given a saturated



thickness of 29 feet, this translates to a representative hydraulic conductivity (K) of 600 fpd (Tetra Tech, 2014). Based on an estimated effective porosity of 15% for Pleistocene Deposits (Fetter, 1994), the groundwater seepage velocity for the shallow UGA could be 16 fpd.

Materials encountered below the “20-foot clay” in the semi-confined lower UGA are composed of fine to medium sand. For the deep UGA, the representative transmissivity value was 2,500 ft<sup>2</sup>/d. The representative K value for the deep UGA was estimated as 70 ft/day when given a thickness of 35 feet (Tetra Tech, 2014). Groundwater seepage velocity for deep UGA was estimated as slightly less than 0.5 fpd.

Groundwater elevations collected during the PDI yielded horizontal gradients from the shallow and deep portions of the UGA of roughly 0.004 and 0.001 ft/ft, respectively. Figures 2-3 and 2-4 reflect the July 2012 water-level measurements; Figures 2-5 and 2-6 show the pre-inspection May 2013 measurements.



## 6.0 IN-SITU TREATMENT SYSTEM DESIGN

### 6.1 INTRODUCTION

For the in-situ treatment groundwater remedy, anaerobic reductive dechlorination (ARD) is selected as a remedy. ARD is the primary biological degradation mechanism by which CVOCs are transformed to innocuous compounds, such as carbon dioxide, ethene, ethane, and chloride. In the presence of an adequate electron donor (e.g., hydrogen), the appropriate microbial consortia, and favorable geochemical conditions, a hydrogen atom can replace a chlorine atom on a chlorinated ethene molecule. This microbial process occurs under anaerobic conditions. Hydrogen is typically generated when organic carbon is fermented. The organic carbon supply can come from natural organic carbon, anthropogenic carbon (e.g., hydrocarbon contaminants such as benzene and toluene), or applied/injected carbon substrates. In the presence of hydrogen, CVOCs (such as PCE and TCE) can be reduced to DCE isomers. DCE isomers are subsequently reduced to vinyl chloride; which, in turn, can be reduced to ethene/ethane, or carbon dioxide, water, and chloride (via mineralization).

In general, treatability test results indicated that biodegradation of CVOCs was occurring within the study area. However, the associated degree and consistency of contaminant transformation was variable, due to a limited source of biologically available carbon and the absence of favorable microbial populations. The addition and recirculation of sufficient electron donor mass and de-chlorinating cultures (e.g., *Dehalococcoides sp.*) are anticipated to reduce CVOc levels within the targeted treatment area at the Site.

The electron donor will be provided through the application of a carbon (nutrient) substrate to the deep UGA. The bioremediation system will be capable of introducing additional nutrients, vitamins, minerals, and cultures to the formation, if desired. The CVOcs impacts in the shallow UGA are several orders of magnitude lower than in the deep UGA. Therefore, this design focuses on the deep UGA only.

### 6.2 OVERVIEW OF IN-SITU TREATMENT REMEDIAL DESIGN

Design features of the in-situ groundwater remedy include these components:

- Conduct bench-scale microcosm study to determine conditions for a complete degradation of PCE and TCE within the targeted treatment area (Section 6.2.1).
- Install one new ISCR barrier (designated as ISCR barrier "A") across the plume axis (Section 6.2.2).
- Extend existing ISCR barrier (designated as ISCR barrier "B") along Westervelt Place (Section 6.2.2).
- Install five new, permanent remediation wells in two separate areas to help distribute biological amendments. To address the deep UGA plume, wells will be drilled between the bottom of the "20-foot clay" and above the top of the Gardiners Clay formation (approximately 65 to 75 feet bgs in depth) (Section 6.2.3).
- Install new temporary PVC wells to monitor groundwater concentrations during in-situ treatment and the progress of attaining groundwater clean-up goals. Wells will be drilled in a manner similar to the new remediation wells.
- Perform base-line monitoring, sampling, and analysis. Obtain water-level measurements and collect groundwater samples from new injection wells, new temporary PVC wells, and existing wells as specified in the QAPP (Section 6.2.4).
- Initially distribute biological amendments into two targeted areas (Zones "A" and "B") across the CVOcs plume through short-term recirculation. The targeted areas are within the current PCE contour at levels



possibly exceeding 10,000 µg/L. This component will focus on reducing the mass of VOCs associated with the most contaminated portion of the deep UGA plume attributable to the Site, and will be conducted in phases as described in Section 6.2.5.

- Conduct process and performance monitoring; evaluate monitoring results and clean-up progress; and perform additional short-term recirculation events until the pump-and-treat system is constructed and operational (Section 6.2.6).
- Evaluate measures to optimize the in-situ treatment remedy and implement as required over time.

The location of the ISCR barriers will be established based on access to affected properties and to avoid subsurface utilities and other physical structures. The biobarriers are not intended to be a single in-situ treatment approach for contaminated groundwater. Used in conjunction with the injection of substrate at two areas, the barriers will reduce the mass flux of plume contaminants. As with the injection component of the in-situ remedy, the ISCR barriers will focus on the deep UGA. The ISCR barriers will be installed prior to the distribution of biological amendments to help minimize generation of cis-1,2-DCE and vinyl chloride concentrations within the amendment distribution zones since levels of these contaminants are expected to increase from biological degradation activity. Due to the recirculation events being short-term and local in nature, it is not anticipated that recirculation will negatively affect the performance of the ISCR barriers.

Since the design of the ex-situ groundwater remedy will include deep extraction wells downgradient of the ISCR barriers (i.e., along Wheatley Street), these extraction wells will induce a hydraulic gradient through the pair of ISCR barriers. The injection of biological amendments in Zones “A” and “B” are intended to complement the effectiveness of the barriers. The in-situ groundwater remedy may operate independently of the ex-situ remedy for an undetermined period of time (e.g., up to 2 years). The initial and subsequent biological amendment injections will not be hydraulically drawn through the ISCR barriers until ex-situ extraction wells are operational. Given the linear distance, hydraulic gradient, and microbial activity to break down the amendments, it is not expected the amendments will significantly reduce the conductivity of the ISCR barriers over time. However, post-injection monitoring, including laboratory analyses and groundwater elevation measurement, will provide information to evaluate the magnitude of any reductions.

Any biological amendments used during in-situ treatment have the potential to reach ex-situ extraction wells once they begin pumping. There are several measures to mitigate possible adverse effects (e.g., cease injections, change to a different amendment, change to a more diluted dosage, pump at lower flow rates, pump shallow extraction wells only, etc.). Some process equipment (e.g., air stripper) may need to be backwashed or cleaned more frequently if amendments are captured by the extraction wells. However, it is unlikely additional equipment will be needed to treat contaminated groundwater attributable to the site, even with increasing bacterial growth.

Groundwater contamination associated with the shallow UGA is not being addressed by the in-situ treatment remedy. PCE and TCE concentrations in the shallow UGA within the targeted treatment zone were present at much lower levels compared to the deep UGA (Figures 2-9 through 2-12). Within this zone, the highest PCE levels were detected in well MW-21S (360 µg/L; May 2013) and well IW-01S (75 µg/L; December 2013); all other December 2013 PCE results (i.e., wells OW-01S, TW-01S, TW-02S, TW-03S, and MW-27S) were less than the groundwater clean-up goal of 5 µg/L. As such, there is uncertainty with respect to the extent of shallow VOC contamination within the targeted area.

Due to low CVOC concentrations, the mass of VOCs present in the shallow UGA is significantly less than the deep UGA. Injections into shallow well IW-01S during treatability testing revealed that the substrate remained present in the well for a considerable period of time. Until the pump-and-treat system extraction well network is established to help capture shallow groundwater contaminants and create a more favorable hydraulic gradient, in-situ treatment of the shallow plume will not be a cost-effective solution. For these reasons, in-situ treatment of the shallow UGA was deferred to the ex-situ remedy.



### 6.2.1 Bench-Scale Microcosm Study

Treatability test results indicated a lack of native PCE-degrading bacteria, such as *Dehalococcoides*. Therefore, a microcosm bench-scale study will be performed using Site groundwater to determine conditions required for complete degradation of PCE to ethane. Several different amendment formulations (substrate, nutrients, additives, and bacterial cultures) will be tested.

The microcosm tests will be conducted by setting up several bench studies using unpreserved Site groundwater collected from one or several locations. Several liters of groundwater will be required for the microcosm tests. The specific microcosm testing laboratory procedures and supplies will be utilized for the groundwater collection. Groundwater samples will be collected in a manner to reduce exposure to air.

The microcosm testing results will be used to refine any specific design parameters such as the selected electron donor, nutrients, additives, and dechlorinating bacteria cultures. Several *Dehalococcoides* cultures are commercially available (e.g., KB-1®, KB-1® Plus, and Bio-Dechlor INOCULUM® Plus). It is anticipated that KB-1® will be used (Appendix B-1). Final specifications for the *Dehalococcoides* mixture will be made in consultation with vendors, based on groundwater conditions following the introduction of substrate and buffering agent.

### 6.2.2 Installation of ISCR Barriers Across Plume Axis

Key variables in designing an effective ISCR barrier include:

- CVOC groundwater concentrations.
- Targeted treatment zone configuration and dimensions (length, width, and thickness).
- Amount of materials required for treatment, including source of water used for mixing.
- Amendments, nutrients, reagents, or enhancements to support the growth of heterotrophic bacteria.
- Spacing of barrier injection points and injection intervals.
- Construction of the injection points.

This component consists of injecting ISCR slurry into closely-spaced points at two areas followed by post-injection monitoring. EHC will be used to establish a pair of ISCR barriers for plume treatment and management. The slurry will reduce PCE and other VOC groundwater concentrations by creating low redox potential and producing hydrogen. Only the deep UGA will be targeted for the ISCR barrier.

One ISCR barrier (ISCR barrier “A”) will be installed across the plume axis at an approximate location about halfway between the two areas selected for injection of amendments (Appendix C; Drawing C-3). The length of this ISCR barrier will be approximately 154 feet and will traverse at least one residential property and Hewlett Parkway. The barrier will address the deep UGA plume characterized by PCE concentrations approaching or exceeding 10,000 µg/L.

The ISCR barrier “A” injection points are to be spaced 7 feet apart and generally lie in a straight line and perpendicular to the 10,000 ug/L PCE isoconcentration contour for the deep UGA. The spacing of points may vary depending on accessibility, subsurface features, and property owner considerations. Approximately 23 injection points will be required for ISCR barrier “A”. Near the eastern end of this ISCR barrier, one new, deep temporary PVC well (TW-10D) will be installed, following the installation of this ISCR barrier, to monitor groundwater quality within the targeted treatment area.

The second ISCR barrier (ISCR barrier “B”) will extend from the existing 70-foot barrier along Westervelt Place. The extended barrier will be approximately 220 feet long and be located just downgradient of one of the two areas targeted for amendment injections and perpendicular to the deep PCE plume. The extension will add roughly 30 feet to the west and 120 feet to the northeast to the existing barrier.

The configuration of the ISCR barrier “B” points will be a relatively straight line along Westervelt Place after accounting for utilities. The injection points are to be spaced 7 feet apart. Approximately 22 new injection





points will be needed as part of the barrier. The spacing of points may vary depending on accessibility. ISCR barrier "B" will extend near well cluster MW-21.

Combined, the two ISCR barriers will target groundwater mass flux or discharge through the targeted treatment area. The type of material used for injections will degrade the primary COCs and minimize generation of cis-1,2-DCE and vinyl chloride through direct chemical reduction of contaminants.

The EHC slurry consists of solid organic carbon, micro ZVI, plant fiber, guar, and water. The dry powder can be delivered in 50-lb bags, which is the preferred method for ease of handling, or in 2,000-lb collapsible sacks.

The EHC slurry is to be prepared using a 2-bin mixing system. One bin will contain a paddle-mixer. After mixing in the first bin, the slurry will be transferred to the second tank (the feed tank), which will be connected to the injection pump. The pump will be connected to each injection point individually or through a manifold system. The pump will be capable of handling solids and generating at least 200 psi of pressure at a flow rate of 5 gpm. The EHC slurry will be continuously injected.

If practicable (e.g., sufficient space for placing frac tanks without potential interference with residential traffic), water for the EHC slurry will be actual groundwater from the Site. Untreated groundwater will be obtained by pumping from available nearby wells. Site-related groundwater is preferred since it is more representative of the quality of groundwater present at the Site. At no time will groundwater containing more elevated levels of VOCs be injected into an area with lower VOC concentrations.

The injections will begin just above the Gardiners Clay and proceed upward. Injections will start at approximately 80 feet bgs and will advance up to the bottom of the "20 foot clay" (estimated at 50 feet bgs). Slurry will not be introduced into the "20-foot clay" layer if it is present (Appendix C, Drawing C-7).

For each injection interval, the rods of the DPT equipment will be advanced to the top of the targeted depth interval, and the selected slurry volume will be injected before advancing deeper. The depth to groundwater within the shallow UGA ranges from 3 to 15 feet bgs; the depth to groundwater within the deep UGA varies from 6 to 17 feet bgs. A pressure activated tip with multiple openings will direct the slurry horizontally. The injection intervals within a well will be evenly spaced every 4 feet. The total number of intervals at an individual injection point will depend on the distance between the Gardiners Clay and the "20-foot clay" (if present) at the specific injection location. If necessary, additional DPT rods and injection tips will be available to allow for the injection points to be capped at the end of each day to prevent overflow.

The estimated amount of EHC required for the injection points was based on a number of inputs and reasonable assumptions. The ISCR reagent requirements for the slurry are provided in Table 6-1.

Each interval will receive approximately 75 lbs of dry EHC powder (about 1.5 bags) blended with 28 gallons of water. As some points will likely be installed through existing roadways or vegetated areas, after the injections are completed, the points will be resurfaced with an appropriate asphalt mix, or reseeded with top soil.

To evaluate the ISCR barriers' effectiveness and performance, one new temporary PVC well (TW-11D) will be installed upgradient of ISCR barrier "A" (Appendix C, Drawing C-3).

### **6.2.3 Well Installation**

Five permanent wells for the substrate distribution will be drilled using HSA and installed as shown in Drawing C-3 (Appendix C). These wells will be 6-inch stainless steel (for long-term use), flush-mounted wells with 25-foot (deep) screen lengths (depending on subsurface lithology). The new permanent wells will be screened in the most suitable/best zone to allow for substrate distribution. Appendix C, Drawing C-6 displays well construction details.



Two 2-inch temporary PVC wells will be drilled to monitor the progress of in-situ groundwater treatment for the deep UGA (Appendix C, Drawing C-3). The deep screened wells will be installed to a depth of 65 to 75 bgs and just above the top of the Gardiners Clay formation. All temporary wells will have an approximate screen length of 10 to 20 feet depending on lithology.

Additional temporary PVC wells may be installed at the Site to better determine the lateral distribution of injected materials. Installation of these monitoring/observation points, if necessary, will occur roughly 12 months after the injections are completed. Data to be collected from the additional wells (if required) will include VOC and other analyses and water-quality measurements to evaluate the effectiveness of the in-situ remedy.

The groundwater contours for May 2013 showed a depression in the water table near the targeted treatment area. However, the overall flow appeared to be to the north, or slightly northwest. Water levels will be measured during pre-injection groundwater sampling and the groundwater flow direction determined. A recommendation will be made at that time regarding the potential need for additional temporary wells.

#### **6.2.4 Baseline Monitoring, Sampling, and Analysis**

Once the new permanent remediation wells and temporary PVC wells are installed, one round of groundwater samples will be collected. One round of comprehensive water-levels will also be obtained near the targeted treatment area, and the elevations will be compared to previous water-level results.

Groundwater sampling will occur at the locations detailed in Specification 02 54 19.19 – Enhanced In-situ Bioremediation, which include the five new injection wells, the new temporary PVC observation/monitoring wells, and existing wells. Low-flow groundwater sampling procedures will be employed with Grundfos Redi-Flo 2™ pumps (or equivalent) for wells of 2-inch or larger diameter. If any new temporary PVC wells are less than 2 inches in diameter, either peristaltic pumps, micro-bladder pumps, or Waterra® inertial pumps will be used to collect samples.

All pre-injection groundwater samples will be analyzed for TCL VOCs. Ten (10) selected wells will be tested for TOC, dissolved gases, and volatile fatty acids. Groundwater from several injection wells will also undergo testing for dechlorinating bacteria, functional genes, and phylogenetic groups (i.e., qPCR). In addition, all samples will be tested in the field for pH, DO, ORP, turbidity, conductivity, and temperature. Field test kits will be used for total alkalinity, total soluble sulfide, and ferrous iron.

The results will be evaluated to determine the subsequent frequency of bioremediation injections, and any necessary modifications to the dosage of the reagents.

#### **6.2.5 Distribute Biological Amendments**

Substrate, as well as other biological amendments (e.g., dechlorinating cultures, nutrients, buffering chemicals), must be delivered, dispersed, and distributed throughout the formation in order for in-situ bioremediation to proceed. Effective mixing of substrate and other amendments with the contaminant plume is one of the most difficult design challenges for enhanced anaerobic bioremediation (Parsons, 2004). Injection of large volumes of substrate may cause significant displacement of the contaminant plume. One approach is to inject a low volume/high concentration substrate mixture and rely on mechanisms of advection and dispersion for mixing; however, this requires relatively high rates of advection and dispersion to occur. Because groundwater velocity at the Site is low, substrate delivery that depends on groundwater dispersion and advection is not viable.

Recirculation techniques may be required for sites with low rates of groundwater flow to obtain effective mixing of the substrate and contaminated groundwater (Parsons, 2004). As such, recirculation is the recommended approach for the targeted treatment area. Section 6.3 provides more information regarding the recirculation event volume and duration.



Amendments will be distributed initially in two small areas (~6,000 ft<sup>2</sup> each area) across the plume via a short-term recirculation (~10 days for each area) where active treatment zone (including PCE-degrading bacterial population) is created. These small areas will serve as sources for electron donor and PCE-degrading bacteria and will eventually be distributed across the rest of the high concentration PCE plume by groundwater flow.

Groundwater velocity at the Site is very slow, and thus, it could be several years before amendments are adequately distributed by groundwater flow within the main portion of the targeted treatment area (i.e., PCE concentrations in the deep UGA approaching or exceeding 10,000 µg/L). The latter can be potentially aided by future pump-and-treat system operations if extraction wells are located and installed in such a manner as to pull groundwater flow in the desired direction to distribute the amendments. The main advantage of this approach is that limited infrastructure is needed (piping, equipment, power lines) and thus logistical difficulties for remediation in a residential area will be reduced.

Amendment distribution will be performed in two phases: bio-stimulation (Phase I) and bio-augmentation (Phase II). During Phase I, substrate (such as LactOil or similar) with proper additives (nutrients, yeast, vitamin B12, etc.) will be recirculated to stimulate biological activity and create strongly reducing groundwater conditions characterized by negative ORP measurements. However, based on treatability testing results, due to a lack of native PCE-degrading bacteria such as *Dehalococcoides*, it is not anticipated that bio-stimulation alone will be sufficient to degrade PCE to ethene. Therefore, Phase II will include bio-augmentation with *Dehalococcoides* after anaerobic conditions are created. This is to be performed via a recirculation event similar to Phase I, but with *Dehalococcoides* cultures injected through the bio-augmentation port (after untreated extracted groundwater passes through the bag filter and before sodium bicarbonate is added to the flow to the injection wells). Bio-stimulation and bio-augmentation recirculation events are to be separated by at least 2 weeks. Process monitoring must be conducted after the initial bio-stimulation event and prior to the first bio-augmentation event to ensure anaerobic conditions have been achieved. See Appendix F for a detailed schedule.

As discussed in Section 6.6, pH buffering may be needed to support the optimal growth of the microbial population.

The in-situ design of this component will involve installing five new extraction/injection wells complemented by one existing well (IW-01D, which is to be designated EW-S). There will be six wells oriented in two rows as shown in Drawing C-3. Each row will consist of three wells spaced approximately 50 feet apart. In each row, a central well will be used for extracting groundwater and the two periphery wells will be employed as injection wells. The amendments will be distributed along each row in a roughly elliptical shape with an approximately 6,000 ft<sup>2</sup> area.

Based on a 40-foot treatment zone thickness for the deep UGA and 20% effective porosity, the pore volume within each recirculation row (or targeted treatment area) is 360,000 gallons. Assuming a 25-gpm pumping rate from the single extraction well in each area, the entire pore volume will be exchanged in 10 days (minimum recirculation duration for each row). Section 6.3 provides more details regarding the recirculation volumes and durations.

Recirculation equipment will include substrate drums, metering pumps, extraction/injection manifold, and instrumentation. This equipment will be housed in a small (e.g., 20-foot x 8-foot) enclosure or container. Electrical service to the equipment enclosure at each treatment area will be provided using temporary power poles. Temporary aboveground piping with appropriate protection from vandalism (i.e., hose guard) will be used. The total estimated length of these temporary lines in each area is less than 150 feet.

The equipment trailer will be located near or above the single extraction well in each area so the power line to the well pump will be very short (<20 feet). As stated above, an estimated duration of each recirculation event will be 10 days. At least two recirculation events may be needed (i.e., Phase I and Phase II), but more than two events will likely be required (e.g., two events to create reducing environment and one event



to bio-augment). Recirculation events will be performed several months apart based on post-injection monitoring results.

After initial recirculation events are completed, the results will be assessed and additional events will be repeated as required, factoring in modifications as warranted by operation and performance monitoring. Alterations to the remediation scheme may include bio-augmentation, a change in substrate material or dosage, or adjustments to recirculation parameters.

The injection approach allows a significant degree of flexibility in selecting and modifying parameters such as amendment type, quantity, dilution ratio, injection rate, and recirculation event volume and duration. Sections 6.5 and 6.6 discuss the substrate selection process and dosage requirements, respectively.

#### **6.2.6 Long-term Monitoring**

Long-term monitoring of the dechlorination process will be necessary to evaluate future changes in water quality, both temporally and spatially. Samples collected from selected wells will be analyzed for CVOCs and parameters used for the assessment of in-situ treatment (i.e., ethene, ethane, sulfate, sulfide, nitrate, TOC, methane, chloride, pH, temperature, DO, specific conductance, ORP, presence of *Dehalococcoides* spp., etc.). Groundwater sample collection and analysis is to occur at the locations detailed in Specification 02 54 19.19 – Enhanced In-situ Bioremediation. .

For planning, two recirculation events per year will be performed during three years of system operation. Each recirculation event will be followed by process monitoring events with the performance monitoring occurring quarterly during the 1st and 2nd years and semi-annually during the 3rd year of in-situ system operation. For planning, process events will occur one and two months after completion of each recirculation event. Process monitoring will only involve the use of field instruments and test kits. The schedule for process and performance monitoring events may need to be adjusted based on previous results. Monitoring data will be evaluated to determine the subsequent frequency of recirculation events, modifications to the amendments dosages, injection volumes/durations, recirculation rates, and other operational parameters.

For each round of performance monitoring, groundwater samples are to be analyzed for VOCs using EPA SW-846 Method 8260B; for TOC using EPA Method 415.1 or Microseeps SOP WC21; for dissolved gases using EPA RSK SOPs 147/175 or Microseeps SOP AM20-GAX; and for volatile fatty (metabolic) acids using Microseeps SOP AM23G. Field test kits will be used to measure total alkalinity (e.g., CHEMetrics K-9810), total soluble sulfide (e.g., CHEMetrics K-9510), and ferrous iron (e.g., CHEMetrics K-6210) levels. The monitoring program is to be described in the final O&M plan.

Bio-trap devices will be placed in wells shown in the long-term monitoring tables within Specification 02 54 19.19. The Bio-trap samples are to be analyzed for qPCR (dechlorinating bacteria), functional genes (TCE R-Dase, BAV1 Vinyl Chloride R-Dase, and Vinyl Chloride R-Dase), and Phylogenetic Groups (Eubacteria and Methanogens) using Microbial Insights SOP qPCR.

After each monitoring event, the results will be compiled, evaluated, and reported. Data subject to these activities include hydraulic head data obtained during water-level measurements and the chemical/physical data obtained during monitoring activities, including well sampling. The Contractor will prepare a brief report that presents the integrated interpretations of the hydraulic head and chemical data, updates the present understanding of groundwater conditions based on these data, and presents recommendations for any necessary adjustments to the in-situ remedy.



### 6.3 RECIRCULATION EVENT VOLUME AND DURATION

The recirculation event volume ( $V_i$ ), and the recirculation event duration ( $T$ ) are important design parameters to efficiently achieve the amendments distribution. These parameters are estimated based on the approximate pore volume of the defined initial amendments distribution zones A and B, and the achievable recirculation rate.

For each initial amendments distribution zone (zones A and B as shown in Appendix C, Drawing C-3), the pore volume can be calculated using the following equation, based on the initial amendments distribution dimensions and the estimated formation porosity.

$$V_i = 7.48 \frac{\text{gal}}{\text{ft}^3} \cdot A_i \cdot H \cdot \phi \quad (6-1)$$

Where

$V_i$  = initial amendments distribution zone pore volume (gallons)

$A_i$  = initial amendments distribution zone area (square feet)

$H$  = initial amendments distribution zone thickness (feet)

$\phi$  = effective formation porosity (dimensionless)

The assumed input values for the equation above, and the calculation result is shown below:

- |  |   |                          |
|--|---|--------------------------|
| • Initial amendments distribution zone area ( $A_i$ )    | - | 6000 square feet         |
| • Initial amendments distribution zone thickness ( $H$ ) | - | 40 feet                  |
| • Effective porosity ( $\phi$ )                          | - | 20% (sand and fine sand) |
| • Calculated pore volume ( $V_i$ )                       | - | 360,000 gallons          |

The recirculation event duration ( $T$ ) can be calculated using the following equation, based on the initial amendments distribution zone pore volume ( $V_i$ ), and the estimated achievable recirculation rate ( $Q$ ).

$$T = \frac{V_i}{Q \cdot 1440 \text{ min/day}} \quad (6-2)$$

- |   |   |                            |
|---|---|----------------------------|
| • Achievable recirculation flow rate          | - | 25 gpm (1 extraction well) |
| • Calculated injection duration event ( $T$ ) | - | 10 days                    |

This calculation is only an estimate of the injection volume ( $V_i$ ), and recirculation event duration ( $T$ ) needed to distribute amendments within each of two initial amendments distribution zones. The initial amendments distribution zones A and B were selected to be placed across the 10,000  $\mu\text{g/L}$  PCE contour.

It is anticipated that the RA objectives for the in-situ groundwater remedy will be eventually achieved within three years of recirculation system start-up. However, the actual time of groundwater restoration cannot be practically estimated.

### 6.4 TARGET AREA PORE VOLUME

The target area is defined as the area of the 10,000  $\mu\text{g/L}$  PCE contour downgradient from the initial amendments distribution zone A as shown on Drawing C-3. This area includes the majority of the current 10,000  $\mu\text{g/L}$  PCE contour (~85%). The target area pore volume ( $V_t$ ) is an important design parameter to determine the overall amendments dosage. This parameters ( $V_t$ ) is estimated based on the approximate pore volume of the defined target area using Equation 6-1.





## 6.5 SUBSTRATE SELECTION

Various carbon substrates are available for use in anaerobic reductive dechlorination. Carbon substrates fall into two general categories: (1) soluble electron donors and (2) slow-release electron donors. Soluble electron donor substrates include lactate, ethanol, and other short-chain hydrocarbons. These materials dissolve in water and are typically used more quickly by microorganisms. One advantage of soluble electron donors is that delivery and distribution are more easily achieved in a heterogeneous environment. A second advantage relates to the larger areal coverage of soluble electron donors, when compared to slow-release electron donors. These two advantages are expected to be helpful at the Site. A notable disadvantage of soluble electron donors is that they are generally consumed within three to six months.

Slow-release electron donor substrates include hydrogen-releasing compounds, vegetable oil, and chitin. These compounds gradually release fatty acids into the surrounding groundwater, which are subsequently metabolized and utilized by microbes. Many substrates persist for months or years before being exhausted. EVOs are commercially available, and have been engineered to exhibit enhanced transport properties while slowly releasing carbon. An added benefit of these oils is their ability to preferentially partition CVOCs from the dissolved phase into the oil itself.

Substrate formulations that demonstrate the physical properties of a soluble electron donor, while retaining the slow-dissolving capabilities of a slow-release electron donor, are now available. These hybridized substrates are preferable, as they combine advantages of both materials. The JRW Bioremediation, LLC product LactOil™ is representative of this type of substrate. Other equivalent products may be available, such that LactOil™ is not strictly required to meet RA objectives for in-situ treatment. The injection approach will allow for the injection of a wide range of substrates (as warranted), with a minimal need for equipment modification (e.g., storage tanks, metering pumps).

## 6.6 SUBSTRATE DOSAGE

The substrate quantity or electron donor demand necessary for degrading CVOCs depends on factors such as total contaminated pore volume, organic carbon fraction in soil and groundwater, concentrations of competing electron acceptors (e.g., sulfate, iron, etc.), DO, ORP, CVOC concentrations, substrate distribution effectiveness, and additional substrate parameters (i.e., solubility, mobility, matrix retention, etc.). Table 6-2 reflects several Site-specific parameters that may be relevant to an approximation of the overall electron donor demand.

Table 6-2 suggests that substrate demand for contaminated groundwater at the Site is expected to be relatively high. When estimating substrate quantities, two main methods are employed. The first method is based on an approximated formation electron donor demand. The second method depends on a (pre-determined) target substrate concentration calculated for a formation pore volume. Both methods are presented for comparison purposes.

The formation electron donor demand consists of a contaminant mass demand and a demand associated with competing species, such as dissolved iron ( $\text{Fe}^{+2}$ ) and sulfate ( $\text{SO}_4^{-2}$ ). For the targeted treatment area, primary electron donor demand is due to contaminant mass. Concentrations of species (such as dissolved iron and sulfate) are low compared to contaminant concentrations; therefore, their electron demand can be omitted from supporting calculations.

The total contaminant mass can be represented as a sum of the dissolved-phase and adsorbed-to-soil-phase contaminant fractions. The dissolved-phase mass fraction is estimated using the target area-averaged, total dissolved CVOC concentration. The adsorbed-to-soil-phase mass fraction is conservatively estimated using partition coefficients for PCE (155 L/kg), an assumed value for fraction of organic carbon in soil (0.2%), and the target area-averaged, total dissolved CVOC concentration (40.25 mg/L). Total CVOC mass within the target area (as determined by this method) is approximately 6,120 lbs (Table 6-3). The theoretical stoichiometric substrate demand (assuming use of LactOil™ as substrate) is calculated as





approximately 2,400 lbs. Using a conservative safety factor of 10 (i.e., to account for theoretical versus actual substrate demand), the total estimated substrate demand is approximately 24,000 lbs (Table 6-4).

The substrate quantity calculated according to a (pre-determined) target substrate concentration is summarized by the following text. Based on practical experience, target substrate formulation pore volume concentration is often assigned a default value of 0.5 to 1 g/L (i.e., 500 to 1,000 mg/L, or 0.05% to 0.1%) for projects involving LactOil™. The LactOil™ micro-emulsion is comprised of 35% ethyl lactate, 45% soy bean oil-based hydrocarbons, and 20% water by-weight. Therefore, 1,000 mg/L substrate formulation will contain approximately 350 mg/L of ethyl lactate and 450 mg/L of soy bean oil. Assuming LactOil™ carries a density [ $\rho$ ] of approximately 8.7 lbs/gal (specific gravity = 1.05), and based on the total target pore volume ( $V_t$ ) of 5.4 million gallons, the overall mass of LactOil™ will be approximately 2,550 to 5,100 gallons per recirculation event (22,500 to 45,000 lbs). Assuming four injection wells, on average, are used during for each injection, roughly 650 to 1,300 gallons of substrate will be injected into each well during each recirculation event.

Substrate quantities calculated using the two described methods are similar in magnitude (i.e., 22,500 to 45,000 lbs if formation-derived vs. 24,000 lbs if field-controlled). For cost estimating purposes, it is assumed that approximately 45,000 lbs (5,000 gallons) of substrate will be used during each recirculation event. These values are solely initial estimates, and were determined with a significant degree of uncertainty. Actual substrate quantities, as well as concentrations, will likely be adjusted based on physical observations and operating conditions during implementation of the RA.

## 6.7 pH BUFFERING

Based on the pilot study results, the majority of the groundwater has a near-neutral pH that is generally favorable for reductive dechlorination of PCE to ethane. However, certain locations within the initial amendments distribution zones may have groundwater pH below the optimal range for active ARD. *Dehalococcoides ethenogenes* strain 195 (i.e., the only known bacterium capable of complete reductive dechlorination of PCE to ethene) thrives in an environment of pH 6.8 to 7.5 SU. Likewise, optimal pH ranges for several *Desulfitobacterium* species (capable of reductive dechlorination of chlorinated ethenes and ethanes) are near neutral. As a result, it is unlikely that the in-situ treatment will need to incorporate measures to increase groundwater pH to improve the performance of the system. However, it is prudent to account for pH adjustment measures in case if the future site conditions warrant such measures.

Common chemicals used to raise pH include caustic (sodium hydroxide), magnesium hydroxide, lime (calcium hydroxide), and baking soda (sodium bicarbonate). Sodium bicarbonate ( $\text{NaHCO}_3$ ) was selected for pH adjustment based on the accompanying rationale:

- $\text{NaHCO}_3$  is safe and easy to handle.
- Maximum pH of  $\text{NaHCO}_3$  solution is approximately 8.5 SU, so it cannot be overdosed.
- $\text{NaHCO}_3$  is relatively soluble (compared to lime and magnesium hydroxide).

If pH adjustment is needed, the  $\text{NaHCO}_3$  buffering solution could be prepared in a 300 gallon tank. Based on a conservative estimate (i.e.,  $\text{NaHCO}_3$  solubility of 75 grams per liter at 10°C), approximately 150 pounds of sodium bicarbonate can be dissolved in a tank of this volume. To ensure complete dissolution, 150 lbs of sodium bicarbonate will be mixed into 300 gallons of water, resulting in a 6% solution.

This solution will be prepared during regular site visits.  $\text{NaHCO}_3$  powder will be stored in bags inside the equipment enclosure.  $\text{NaHCO}_3$  product will be proportioned in a tank with site-related water, and will be mixed using a conventional sump pump (equipped with a side outlet) to create a circular fluid motion inside the tank.

$\text{NaHCO}_3$  dosing is not estimated as part of the in-situ treatment design since the majority of the Site groundwater currently does not appear to require pH adjustment. Baseline groundwater monitoring (Section 6.2.3) and performance monitoring (Section 6.2.6) will help determine if pH adjustment is required.



## 6.8 RECIRCULATION EVENT METHODOLOGY

To deliver amendments (e.g., substrate, and sodium bicarbonate) to each initial amendments distribution zone, groundwater will be pumped from a central extraction well and returned to the periphery injection wells. Groundwater recirculation will take the form of a closed loop configuration. LactOil™ (substrate), and a sodium bicarbonate solution (buffer), will be metered into the groundwater stream prior to re-injection. Aboveground equipment (housed in a small enclosure) will contain metering pumps, piping manifolds, process instrumentation (e.g. safety interlocks, flow-meters, pressure sensors, etc.), control panel, substrate drums, sodium bicarbonate solution tank, and other required appurtenances.

The lines running from extraction and injection wells to the equipment enclosure will use polyethylene tubing (i.e., 1-inch PEX for both extraction lines and injection lines) installed aboveground and protected by heavy-duty traffic-rated house ramps (e.g., steel Brahman boards). Appendix C provides a general amendment delivery system layout. Each injection and extraction well will have a dedicated tubing line connected to the treatment system enclosure.



## **7.0 MEASURES TO MINIMIZE ENVIRONMENTAL IMPACT**

### **7.1 INTRODUCTION**

This section addresses the labor, materials, equipment, and work required to prevent environmental pollution both during, and as a result of, the construction and operation of the in-situ groundwater treatment remedy at the Site. Environmental pollution is defined as the presence of chemical, physical, and/or biological elements or agents that adversely affect human health or welfare; unfavorably alter ecological balances of importance to human life; affect other species of importance to man; or degrade the utility of the environment for aesthetic and recreational purposes. The control of environmental pollution requires consideration of air, water, and land, and includes earth moving, noise, solid waste management, and management of toxic or hazardous materials.

The design specifications will require the contractor to comply with all applicable federal, state, and local laws and regulations concerning environmental pollution control and abatement.

### **7.2 LAND RESOURCES**

Upon completion of construction, the land resources outside the limits of permanent work performed during the RA will be preserved in their present condition or be restored to a condition that will not detract from the appearance of the Site. The contractor will confine construction activities to the following:

- Areas defined by the plans or specifications.
- Areas to be cleared for other operations.
- Approved quarry, borrow, lay-down, or waste areas.

Waste and laydown areas will be leveled or trimmed to regular lines and shaped to provide a neat appearance. In all instances, the restored areas will be well drained to prevent the accumulation of stagnant water.

Except in areas shown on the plans or specified for clearing, the contractor will neither deface, injure, nor destroy trees or shrubs, nor will the contractor remove or cut them without EPA approval. Any landscape feature scarred or damaged during construction activities will either be restored substantially to its original condition or replaced.

### **7.3 HISTORICAL AND ARCHAEOLOGICAL RESOURCES**

Care and precautions will be taken to ensure that any known, existing, historical, archeological, and/or cultural resources within the work area are preserved as they existed prior to construction activities. Protective devices such as off-limits markings, fencing, and barricades will be installed to ensure that such resources are not disturbed.

All items with apparent historical or archeological significance discovered during construction activities will be carefully preserved. The archeological find will remain undisturbed and a 50-foot radius area around the find will be flagged. EPA will be immediately notified of the find.

### **7.4 WATER RESOURCES**

Construction activities must not pollute or create objectionable conditions in any streams, lakes, or reservoirs with fuels, oils, bitumens, calcium chloride, acids, construction wastes, or other harmful materials. All federal, state, and county laws and regulations concerning pollution of wetlands, rivers, and streams will be strictly observed. Grading operations and/or temporary erosion and sediment control measures such as berms, dikes, drains, or silt fences will be used to limit soil erosion. An erosion and sediment (E&S) control plan will be prepared and implemented during construction to protect water resources.



## 7.5 SPILL PREVENTION

The threat of spills during this project is greatest during construction and during fuel transfer operations from tanks or tankers to construction equipment. Spill response kits equipped with sorbent materials and shovels will be available during these activities to mitigate any spills. The RA contractor will promptly notify EPA and local officials of spills and the corrective action taken.

## 7.6 DUST CONTROL

The RA contractor will implement appropriate controls and properly maintain all excavations and work areas within or outside the project boundaries, ensuring that such areas remain free of dust which have the potential to cause a hazard or nuisance to others. Such controls will include misting and/or covering potential dust emission sources with plastic, truck rinsing, and other necessary road maintenance.

## 7.7 STORMWATER POLLUTION PREVENTION

Earth disturbance activities are anticipated to result in a total earth disturbance of approximately 200 ft<sup>2</sup> associated with ISCR barrier "A", ISCR barrier "B", and the two new temporary well locations. Due to the small areal extent of planned construction activity and non-inclusion in a larger common plan of development, a National Pollution Discharge Elimination System (NPDES) permit for stormwater runoff is not required. However, if directed to do so by the government, the Contractor may need to apply for a waiver qualification, promulgated by EPA's construction stormwater permit program, and supported by 40 CFR 122.21(b), or New York State's general permit for stormwater discharges (GP-0-10-0001).

An erosion and sediment control plan will be prepared by the RA contractor for the control of adverse effects resulting from erosion and sedimentation during the RA. The plan will specify applicable E&S control measures and best management practices (BMPs) in accordance with the New York Standards and Specifications for Soil Erosion and Sediment Control (NYSDEC, 2005) or latest edition. Sediment filter fences will be used to control water runoff from disturbed areas. Other E&S control measures and BMPs will be developed for construction.

## 7.8 HAZARDOUS, TOXIC, AND RADIOACTIVE WASTES

Hazardous, toxic, and radioactive waste (HTRW) classifications are typically defined by regulation. Hazardous wastes are defined in the Resource Conservation and Recovery Act (RCRA) and, in some instances, by state governments. Toxic wastes are defined in the Toxic Substances Control Act (TSCA). Radioactive wastes are wastes that emit, by spontaneous nuclear disintegration, corpuscular or electromagnetic emanations.

**Hazardous Wastes:** Potentially hazardous wastes include those that are ignitable, corrosive, reactive, toxic, or listed. No listed, reactive, or corrosive wastes will be generated during this project. Potentially ignitable wastes (wastes having a flash point of less than 140°F) or toxic wastes [wastes having toxic characteristics as determined by concentrations measured through toxic characteristic leaching procedure (TCLP) analysis] that may be encountered include soils contaminated with solvents.

No HTRW is known to exist in areas of proposed construction except in the groundwater below the surface. If such wastes are encountered or generated during construction of the groundwater treatment facility, the contractor must establish proper controls for HTRW activities.

Surface and near surface soils (0 to 5 feet deep) in the area have been extensively characterized in the RI and PDI and should not pose a hazard during construction and system O&M. If encountered, contaminated soils (as determined by field techniques) must be analyzed to determine suitable disposal methods. Prior to disposal, the contaminated soil will be placed on and covered by an impermeable liner or placed in containers. If analyses indicate that the contaminated soil is not a RCRA waste, the soil may be treated by land farming, incineration, or other appropriate means. If analyses show the contaminated soil to be a



RCRA waste, EPA will be immediately notified to facilitate waste disposal at a permitted treatment, storage, or disposal facility (TSDF) in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Off-Site Rule (Section 121(d)(3)).

Drill cuttings and water generated by injection point construction, well installation and development, and equipment decontamination will be containerized, sampled, and analyzed prior to the determination of final disposition. Analytical results must demonstrate compliance with established standards.

**Toxic and Radioactive Wastes:** No TSCA-regulated wastes, such as soils contaminated with polychlorinated biphenyls (PCBs), or radioactive wastes are known to exist at the Site and none will be generated during construction and operation of the remedial system.

## **7.9 WASTE MINIMIZATION AND POLLUTION PREVENTION**

To reduce the potential of polluting the environment, the RA contractor must proactively incorporate pollution prevention and waste minimization techniques for construction activities. Such techniques include engineering controls to prevent the commingling of hazardous materials and non-hazardous materials, reducing the use of materials that generate waste, reusing materials still effective for their intended uses, replacing hazardous materials with non-hazardous materials, and recycling materials when appropriate.

Generated wastes requiring treatment or disposal will first be considered for reclamation or recycling. Non-regulated wastes such as paper wastes, plastic wastes, aluminum wastes, and construction debris will be recycled or reused if possible.



## **8.0 PROJECT DELIVERY, CONSTRUCTION SCHEDULE, AND COST**

### **8.1 PROJECT DELIVERY**

This project will be executed in accordance with the procedures described in Division 1, General Requirements, of the specifications (Appendix D). A single subcontract is envisioned for installation of wells and injection points, fabrication and assembly of the in-situ treatment components, start-up and operation of the initial recirculation system, performance monitoring, and supporting tasks. The RA implementation documents have been prepared so that a single remediation contract can be used, and the RA subcontractor can be selected through a competitive bid process.

The RA subcontractor will be responsible for all work identified in the construction documents, including groundwater monitoring for three months following implementation of the in-situ treatment components and installation of wells. The government will select the subcontractor to perform future injections and monitoring on a long-term basis.

Prior to construction, the RA Contractor shall prepare and submit all of the required Pre-Construction submittals for approval, including but not limited to, the following documents:

- Construction Work Plan: This plan is the work plan that identifies personnel, equipment, and details the procedures to be used in executing the requirements of the RD documents. This Plan includes the Enhanced In-Situ Bioremediation Work Plan and the Installation Work Plan for the ISCR barriers.
- Construction Quality Control Plan: This plan describes all quality control measures that will be implemented by the RA subcontractor, as required by the RD specifications.
- Environmental Protection Plan: This plan details how the RA subcontractor will implement the RD in a manner to protect the environment.
- Contractor Accident Prevention Plan (APP) and Site Safety and Health Plan (SSHP): The AAP and SSHP must meet all OSHA and all other applicable standards/requirements, including the most current version of EM 385-1-1.
- Construction Schedule.

The RA Contractor will be required to submit specific product data for approval by the Government. The Contractor will also be required to submit as-built documentation after work is completed and accepted by the Government.

The RA Contractor will provide a 12-month warranty for remediation equipment (i.e., EISB system enclosure) starting from the time all activities are completed.

### **8.2 CONSTRUCTION SCHEDULE**

The RA subcontractor will provide a schedule in accordance with the specifications. Appendix F provides an anticipated and general construction schedule. For planning, it is estimated that RA final completion can be completed about three years after the installation of the two ISCR barriers and start-up of the recirculation system in the two targeted distribution zones. The actual duration of groundwater restoration for the in-situ treatment component will be based on the results of the groundwater monitoring program.

### **8.3 CONSTRUCTION COST**

A construction cost estimate is presented in Appendix E. The cost estimate is based on generally available cost information, experience based on similar projects constructed elsewhere, and engineering judgment.





## 9.0 ROD VARIANCE

No specific deviations from the ROD have been identified regarding the in-situ groundwater remedy planned for OU-1.



## 10.0 PERMITS, EASEMENTS, AND ACCESS AGREEMENTS

According to OSWER Directive 9355.7-03 (EPA 1992), "CERCLA response actions are exempted by law from the requirement to obtain Federal, State, or local permits related to any activities conducted completely on-site." As a result, no permits are needed for activities that occur fully within the Superfund-designated property boundary. Notwithstanding, certain permits may be considered for use at the Site, due to the potential for environmental disturbance during construction activities.

### 10.1 FEDERAL PERMITS

No federal permits are required; however, the RA must comply with substantive requirements of CERCLA, RCRA, and other pertinent regulations, as well as meet requirements of the Occupational Safety and Health Administration (OSHA). For these issues, contact:

U.S. EPA Region 2  
290 Broadway  
New York, NY 10007-1866  
(877) 251-4575

Under the Underground Injection Control Program, an inventory of the quantity and type of reductant that will be injected; the number, size, and location of injection wells; and the quantity of reductant injected at each location will be submitted to EPA Region 2. The wells will be operated in a manner that do not jeopardize any underground source of drinking water (USDW). Upon completion of remediation, the injection wells will be properly closed.

The RA work area will be subject to OSHA inspections during all phases of construction and operation. Safety infractions and accidents must be reported to:

Occupational Safety and Health Administration  
201 Variek Street, Room 670  
New York, NY 10014  
(212) 337-2378

OR

Occupational Safety and Health Administration  
Long Island Area Office  
1400 Old Country Road, Suite 208  
Westbury, NY 11590  
(516) 334-3344

### 10.2 STATE AND COUNTY PERMITS

No state permits are required; however, relevant permits issued by New York State may be adopted with respect to RA implementation:

**Erosion and Sediment Control Permit:** New York State Standards and Specifications for Erosion and Sediment Controls will be used as guidance in the development of the Erosion and Sediment Plan. The total amount of soil disturbance associated with the construction activities is expected to be less than one acre; therefore, a formal Stormwater Pollution Prevention Plan (SWPPP) approval is not required.



**Road/Sidewalk Openings and Closures:** Permits are required for closures of roads and sidewalks affected by the implementation of the in-situ treatment remedy. Permits are also needed for restoration of road payment surfaces disturbed by the RA. Applicable fees may need to be paid unless waived.

Nassau County Department of Public Works  
Permits Unit  
1194 Prospect Avenue  
Westbury, NY 11590-2723  
(516) 517-6900

AND

Town of Hempstead  
Highways Division  
350 Front Street  
Hempstead, NY 11550  
(516) 489-5000, ext. 3471

**Occupational Safety:** No permits are required, but the RA system construction and operation will be subject to rules and regulations enforced by New York State.

New York Department of Labor  
Division of Safety and Health  
One Hudson Square  
75 Varick Street, (7<sup>th</sup> Floor)  
New York, NY 10013  
(212) 775-3540

### 10.3 LOCAL PERMITS

New York City/Long Island One-Call Service (800-272-4480) will be contacted prior to any Site activity to ensure required utility clearances are maintained.

No local permits are required; however, relevant permits issued by the Town of Hempstead may be adopted with respect to RA implementation. These permits may include activities related to any road openings and closures, and permits related to local building and electrical requirements.

### 10.4 EASEMENTS AND ACCESS AGREEMENTS

Easements for the in-situ groundwater remedy will be required. Access for the in-situ treatment components (including monitoring network) will be needed for access to private properties. If required, the government will pursue separate agreements for access to associated monitoring locations not within the property. The government will arrange to execute easements and access agreements with individual landowners. All long-term access arrangements will be recorded in Nassau County.

The properties potentially impacted by in-situ groundwater treatment remedy include those affected by the installation of ISCR barrier "A" and the two new temporary monitoring wells (TW-10D and TW-11D).



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