

Final Remedial Investigation Report

Tutu Wells Superfund Site Operable Unit 2
St. Thomas, USVI
Focused Source RI/FS

EPA Contract No. EP-W-09-009
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Abbreviations and Acronyms

1,1-DCE	1,1-dichloroethene
Aestus	Aestus, LLC
amsl	above mean sea level
APE	Area of potential effects
ARAR	Applicable or Relevant and Appropriate Requirements
bgs	below ground surface
BHHRA	Baseline Human Health Risk Assessment
BTEX	Benzene, Toluene, Ethylbenzene, and Xylene
Cascade	Cascade Technical Services
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cis-1,2-DCE	cis-1,2-dichloroethene
CLP	Contract Laboratory Program
COCs	Contaminants of Concern
COPC	Constituents of potential concern
CSM	Conceptual Site Model
CVOC	Chlorinated Volatile Organic Compound
DCE	dichloroethene
DESA	Division of Environmental Sciences and Assessment
DFN	Discrete Fracture Network
DI	Deionized
DNAPL	Dense non-aqueous phase liquid
DPNR	U.S. Virgin Islands Department of Planning and Natural Resources
EAB	Enhanced Anaerobic Bioremediation
EB	Equipment Blank
ELCR	Excess lifetime cancer risk
EPA	United States Environmental Protection Agency
EPIC	Environmental Photographic Interpretation Center
ERT	Environmental Response Team
FD	Field duplicate
FS	Feasibility Study
FSRI	Focused Source Remedial Investigation
gpm	gallons per minute
GWTF	Groundwater treatment facility
HDR	Henningson, Durham and Richardson Architecture and Engineering, P.C., in association with HDR Engineering, Inc.

HI	Hazard index
IDW	Investigation-Derived Waste
LAGA	LAGA Industries, Limited
LNAPL	Light non-aqueous phase liquid
LTRA	Long-term response action
MCL	Maximum Contaminant Level
mg/kg	Milligrams per kilogram
mg/l	Milligrams per liter
ml	Milliliter
NAPL	Non-aqueous phase liquid
NCP	National Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
PA	Preliminary Assessment
PCE	tetrachloroethene
PCS	Potential cleanup standards
PID	Photo-ionization detector
PP	Purposed Plan
PVC	poly-vinyl chloride
O&M	Operations and Maintenance
OU	Operational Unit
QAPP	Quality Assurance Project Plan
RAC	Remedial Action Contract
RAPR	Remedial Action Progress Report
RAO	Response Action Objective
RD	Remedial Design
RI	Remedial Investigation
ROD	Record of Decision
SARA	Superfund Amendments and Reauthorization Act
SGS	SGS North America
SSL	Site-Specific Screening Levels
SVE	Soil Vapor Extraction
TBC	To-Be-Considered
TCE	trichloroethene
TCL	Target compound list
trans-1,2-DCE	trans-1,2-dichloroethene
µg/kg	Micrograms per kilogram
µg/l	Micrograms per liter

USVI	U. S. Virgin Islands
SHPO	State Historic Preservation Office
VC	vinyl chloride
VIDE	Virgin Islands Department of Education
VIHA	Virgin Islands Housing Authority
VISL	Vapor intrusion screening level
VIWMA	Virgin Islands Waste Management Authority
VOC	Volatile Organic Compound

1 Introduction

This report was prepared for the United States Environmental Protection Agency (EPA) by Henningson, Durham and Richardson Architecture and Engineering, P.C., in association with HDR Engineering, Inc. (HDR). The report presents the findings of the Focused Source Remedial Investigation/Feasibility Study (FSRI/FS) for Operational Unit (OU)2 of the Tutu Wells Superfund Site (the Site), located in St. Thomas, U.S. Virgin Islands (USVI). The Site location is shown on **Figure 1-1**.

The OU2 FSRI was conducted to further investigate the source or sources of groundwater contamination in the northern portion of the Tutu Wells Superfund Site. A groundwater treatment system has been operating in this area, at the USVI Department of Education (VIDE) Curriculum Center property (the Curriculum Center), since 2004, as part of OU1 (site-wide groundwater). The EPA created OU2 after the second 5-year review for OU1 indicated that the remedy for the Tutu Wells Site was not functioning as intended. The review concluded that the current system would not achieve the remedial action objective (RAO) of restoring the Tutu aquifer to drinking water standards (EPA 2014). Of particular concern to EPA at the time was the potential presence of dense non-aqueous phase liquid (DNAPL) in the source area at the Curriculum Center. The purpose of the OU2 FSRI/FS is to investigate the continuing source of contamination at the Curriculum Center, evaluate risks to human health, and identify and evaluate remedial alternatives in support of a Record of Decision (ROD) for OU2.

The FSRI/FS is being performed under Work Assignment Number 031-RICO-021D of EPA RA Contract (RAC) 2 Contract Number EP-W-09-009. Work associated with the FSRI and reported herein was conducted between April 2016 and June 2017. FSRI activities were performed in accordance with the approved work plan (HDR 2015a) and Quality Assurance Project Plan (QAPP) for the project, and in accordance with the *Guidance for Conducting Remedial Investigation/Feasibility Studies under the Comprehensive Environmental Response, Compensation, and Liability Act* (EPA 1988).

HDR prepared this FSRI report to present the results of the FSRI field investigation, and along with results of historical investigations, to:

- Update and refine characterization of ongoing sources (e.g. DNAPL) and the nature and extent of contamination in environmental media at the OU2 area of the Site;
- Provide an increased level of detail for the hydrogeologic framework and contaminant fate and transport characterization in the OU2 area;
- Present the findings of the groundwater-focused Baseline Human Health Risk Assessment (BHHRA); and
- Provide the conclusions needed to support a Focused Feasibility Study (FS) that will address the specific concerns related to the OU2 area.

1.1 Site Background

1.1.1 Site Description

Tutu Wells Superfund Site

The Tutu Wellfield Superfund Site encompasses an area of approximately 1.5 square miles of the Tutu Valley in the Anna's Retreat section of St. Thomas, east of the city of Charlotte-Amalie (**Figure 1-1**). The site is within the Upper Turpentine Run surface drainage basin, which covers approximately 2.3 square miles. The basin is oriented along a north-south axis, and is bordered by steeply sloping hills. Turpentine Run is an intermittent stream that traverses the length of the basin from north to south.

The original RI (Geraghty & Miller 1995) identified a plume of groundwater contaminated with chlorinated volatile organic compounds (CVOCs) and two plumes of groundwater contaminated with gasoline components (the Texaco and Esso plumes) that co-mingled with the CVOC plume. The CVOC plume originated at or near the VIDE Curriculum Center, and extended beyond the former O'Henry Dry Cleaners building (potential secondary source), following an eastward path towards the discharge area of Turpentine Run.

The CVOC and petroleum sources are briefly described below:

- **Curriculum Center** – The northernmost (upgradient) source of CVOC groundwater contamination is located on the Curriculum Center property, and is currently owned and operated by the USVI Department of Education. The Curriculum Center building and property were previously occupied by LAGA Industries, Ltd. (LAGA). LAGA owned and operated a textile manufacturing plant at this location from 1971 to 1978. The plant included an industrial-sized dry cleaning process that utilized tetrachloroethene (PCE) as the dry cleaning solvent. The RI documented the presence of CVOC contaminants in the soils and groundwater at the Curriculum Center property. The Curriculum Center property is the focus of this OU2 FSRI/FS.
- **Texaco Service Station (now Puma)** – The RI documented the presence of benzene, toluene, ethylbenzene and xylene (BTEX) and other petroleum constituents in soil and groundwater at the Texaco Caribbean, Inc., (Texaco) service station. The Texaco station is located approximately 90 feet downgradient (southwest) of the Curriculum Center property (beyond the adjoining Tutu fire station). Historically, an automotive service station was also operated at the Texaco facility. This facility overlies the CVOC plume originating at the Curriculum Center.
- **Esso Service Station (now Total Petroleum)** – The RI documented the presence of CVOC, BTEX, and other petroleum constituents in soil and groundwater at the Esso Standard Oil, U.S.A., Inc., (Esso) service station. The Esso station is located approximately 750 feet southwest (downgradient) of the Curriculum Center. An automotive service station also operated at the Esso facility.

- **O’Henry Dry Cleaners** – The RI documented the presence of CVOC contaminants in soils at the O’Henry dry cleaning facility located approximately 1,300 feet south/southwest (downgradient) of the Curriculum Center. The O’Henry facility was in operation at the time of the original RI. Currently this facility does not overlie the current CVOC plume originating at the Curriculum Center but it is within the historical footprint of the plume.

The current land use surrounding the Tutu Wells Superfund Site and the Curriculum Center ranges from institutional and commercial to residential (**Figures 1-2 and 1-3**).

The focus of this OU2 FSRI is the Curriculum Center. The overall site history and remedial progress of the Tutu Wells Site is available in the following documents:

- Final Pre-Design Report (CDM 2001a);
- Remediation System Evaluation Report (TetraTech GEO 2011);
- EPA’s Second 5-Year Review (EPA 2014); and
- The most recent annual RA Progress Report (RAPR) for the groundwater treatment systems (Arrowhead 2017).

U.S. VI Department of Education Curriculum Center – OU2 Area

This OU2 FSRI focuses on characterizing the northernmost (upgradient) source of CVOC groundwater contamination of the Tutu Wells Superfund Suite plume, at the VIDE Curriculum Center property. The Curriculum Center is located at 386 Smith Bay Road (Highway 38), Anna’s Retreat, St. Thomas.

The Curriculum Center property is occupied by a single-story building housing offices, maintenance shops, warehouse space and walk-in freezers that support the school district cafeterias. A paved parking lot is on the south side of the building, facing Smith Bay Road. An unpaved parking area for employee vehicles and school buses and loading docks are located on the west side of the building. Additional loading and parking areas are located on the north side of the building (**Figure 1-4**). The northern OU1 groundwater treatment system is also located on the north side of the building. The groundwater treatment system is described in detail in **Section 1.1.4**, Previous Remedial Actions.

Terrain at Curriculum Center generally slopes from east to west across the property, with approximately 15 feet of relief between the highest points in the east and northeast and the lowest point near the southwest corner. During the construction of Curriculum Center, the property was graded using imported fill. Fill material was observed during the OU2 drilling activities and reported by previous investigations (e.g., Geraghty & Miller 1995).

The Curriculum Center property is bordered to the east by a steep wooded hillside, approximately 30-foot high, and the Virgin Islands Housing Authority (VIHA) property. The VIHA property includes maintenance areas, offices, and a police station (**Figure 1-2**). An elementary school borders the property to the north. The property is bordered to the west by an automobile dealership (Metro Motors) and the Tutu fire station. Smith Bay

Road (Highway 38) and a Seventh Day Adventist church and school border the property to the south. The surrounding properties to the north, east and south are generally higher in elevation than the Curriculum Center, while properties to the northwest, west and southwest are generally lower in elevation. Turpentine Run crosses the adjoining school and car dealership properties to the north and west of the Curriculum Center.

1.1.2 Site History

The Curriculum Center property is currently owned and occupied by VIDE. The site was originally owned by LAGA Industries, Ltd. (LAGA), who began operation of a textile manufacturing facility at the property in 1969. In 1970, LAGA was sold to the Duplan Corporation at which time Duplan reportedly began dry cleaning operations at the property, with industrial-sized dry cleaning equipment, using PCE as the dry cleaning fluid. Duplan filed for bankruptcy in 1976 and ceased all operations at the property in late 1978. Panex Co. (a corporation formed by the former owners of LAGA) purchased the facility from Duplan's bankruptcy trustee in 1979 and sold it to VIDE in 1981 (Delaware Chancery Court 2007). Information on site operations during Panex' ownership was not available. Since 1982, the building has been used by VIDE as a book repository/library, warehouse with cold storage, maintenance shop and school district administrative offices (TetraTech GEO 2011).

1.1.3 Previous Investigations

This section provides a summary of previous inspections and investigations conducted at the Site.

1982 Groundwater Sampling of VIHA Well No. 1

In 1982, Geraghty & Miller conducted an aquifer pumping test and water quality sampling of a supply well (VIHA #1) at the VIHA property to the northeast (upgradient) of the Curriculum Center (Geraghty & Miller 1995). A sample collected after five hours of pumping had concentrations of 12 micrograms per liter ($\mu\text{g/l}$) of cis-1,2-dichloroethene (cis-1,2-DCE), 55 $\mu\text{g/l}$ of PCE, and 10 $\mu\text{g/l}$ of trichloroethene (TCE). At the time, drinking water standards had not been established by EPA

1987 EPA Well Sampling

Mr. Eric Tillett, owner of Tillett Gardens, contacted USVI U.S. Virgin Islands Department of Planning and Natural Resources (DPNR) about an odor emanating from the water of his supply well, which is on the south side of Smith Bay Road, approximately 450 feet southwest of the Curriculum Center. DPNR requested help from the EPA and between July and October 1987, EPA collected groundwater samples from 26 wells and water samples from approximately 50 cisterns. Twenty-four wells and five cisterns were found to be contaminated. Elevated concentrations of petroleum hydrocarbons and CVOCs were detected in the Tillett supply well; VIHA Well No. 1, located approximately 120 feet northeast of the Curriculum Center building; and four other supply wells. The Tillett supply well had total volatile organic compound (VOC) concentrations above 1,000 $\mu\text{g/l}$. Both the Tillett well and VIHA Well No. 1 were taken out of service, along with other contaminated commercial, institutional, and private wells (Weston 1988).

1989 Preliminary Assessment

The EPA Field Investigation Team (FIT) contractor, NUS Corporation, conducted a Preliminary Assessment (PA) of the LAGA building in 1989 (NUS 1989). The PA identified a drum disposal area located less than 100 feet to the northwest of the LAGA building. Twenty-two drums were in an area of thick brush. Several drums were on their sides, some were corroded, and at least one drum contained an unknown liquid.

1995 Phase II Remedial Investigation

A Phase II RI/FS was completed from May 1994 to 1995 by Geraghty & Miller at the site on behalf of the Tutu Environmental Investigation Committee (Geraghty & Miller 1995). Prior investigations completed by Geraghty & Miller from December 1989 until May 1993 (e.g., preliminary reconnaissance activities and field activities for the Tutu Service Station investigation) were subsequently referred to as the Phase I RI and were reported to the EPA in technical memoranda (Geraghty & Miller 1992a, 1992b, and 1993).

During the multi-phase Phase II RI, Geraghty & Miller collected groundwater samples from 51 monitoring wells and 15 supply wells in the Tutu Valley. The samples were analyzed for target compound list (TCL) organic compounds, target analyte list (TAL) inorganic substances, and various geochemical parameters.

The results showed a CVOC plume and two separate plumes of gasoline components (the Texaco and Esso plumes) that co-mingle with the northern portion of the CVOC plume. The CVOC plume starts at or near the VIDE Curriculum Center creating a ¾-mile long plume. This plume is divided into a northern, central and southern portion. The data showed an additional CVOC source near the O'Henry Dry Cleaners building within the southern portion of the CVOC plume (**Figure 1-2**).

The CVOCs detected at Curriculum Center were DCE, PCE, TCE, and vinyl chloride (VC). The highest concentrations detected were 2,100 µg/l of cis-1,2-DCE, 1,300 µg/l of VC, 360 µg/l of PCE, and 78 µg/l of TCE; all exceeded their respective Maximum Contaminant Levels (MCLs). Soil and groundwater at the former Texaco and Esso service stations were found to be impacted with BTEX and other petroleum hydrocarbon-related compounds). Historically, BTEX compounds have not exceeded MCLs in groundwater at the Curriculum Center (Geraghty & Miller 1995).

In 1995, the northern portion of the CVOC plume (i.e., groundwater with concentrations above cleanup standards) extended 1,600 feet from the Curriculum Center to Four Winds Plaza. The plume was approximately 500 feet wide.

The highest concentrations of total CVOCs, were observed in shallow zone monitoring wells near the northern source area at Curriculum Center. Groundwater at the Curriculum Center below a depth of 50 feet was not investigated during the RI.

Monitoring well groundwater samples between Tillett Gardens and Four Winds Plaza contained 140 µg/l of PCE, 100 µg/l of DCE, and 33 µg/l of TCE. VOC concentrations in the southern part of the plume were higher in deeper monitoring wells than in shallow wells.

1995 EPA and DPNR Investigation

In March of 1995, EPA and USVI DPNR discovered oil (containing 30 percent PCE) in subslab piping beneath the Curriculum Center building. The piping was traced from the floor drains to a room that apparently held a PCE reclamation still. There was no evidence of leakage in the section of pipe investigated; however, the full extent of the piping and its integrity remained unknown.

Soil samples contained from three to 180 micrograms per kilogram ($\mu\text{g/kg}$) of PCE at eight locations near the north-central side of the main building, in the vicinity of the former discharge pipe and former waste pit. TCE was detected in four soil samples at concentrations from one to 130 $\mu\text{g/kg}$. Although no samples were collected from beneath the building, it was suspected that higher concentrations of CVOCs might have been present in soil beneath the building or in the unsaturated bedrock.

BTEX and other petroleum-related compounds exceeded EPA's site-specific soil screening levels (SSLs) in two surface soil samples collected from the northern corner of Curriculum Center where a drain from the paint shop sink discharged to the ground. Benzene, toluene, total xylenes, and a number of naphthalenes and polycyclic aromatic hydrocarbons were present at high concentrations in these samples. Concentrations of both toluene and total xylenes exceeds their soil saturation limits of 289 milligrams per kilogram (mg/kg) and 168 mg/kg , indicating that residual saturation levels of non-aqueous phase liquid (NAPL) may have been present. One CVOC, 1,1,1-trichloroethane (TCA) also exceeded EPA SSLs in the sample that exhibited the highest toluene concentration.

The RI concluded that the elevated concentrations of CVOCs in groundwater adjacent to and immediately downgradient of the Curriculum Center indicated a high probability that PCE was present as DNAPL in the saturated or unsaturated bedrock.

1996 Record of Decision

The ROD for the Tutu Wells Site was signed on August 5, 1996 (EPA 1996). A summary of the ROD requirements was included in the Final Interim Remedial Action (RA) Report (CDM 2004a) and is presented below.

a) Groundwater

Requirements in the ROD to address site-wide groundwater impacted by CVOCs included the following:

- Installation of three recovery wells for hydraulic control of the northern and southern portions of the plume
- Installation of two recovery wells for hydraulic control of the CVOC contamination; one each at the Curriculum Center and the O'Henry Drycleaner location source areas.
- Construction of a groundwater treatment facility, with discharge water quality criteria to be determined during the design phase.

- Semi-annual groundwater sampling to monitor groundwater quality and contamination migration.
- Natural attenuation of low-concentration contaminants near the plume edges where groundwater contains less than 100 parts per billion of total CVOCs.
- Implementation of institutional controls to prohibit unauthorized use of groundwater and installation of new wells within the plume area.

Based upon the results of the pre-design investigation and subsequent design analysis, a number of modifications were proposed and approved by EPA as part of the Final Remedial Design (RD). A summary of the approved modifications to the ROD was included in the Final Interim RA Report (CDM 2004a). The modifications included:

- The configuration of the recovery wells at the Curriculum Center was changed from one well at the downgradient property boundary to three wells installed within the source area.
- The groundwater recovery well at the O'Henry Drycleaner location was eliminated based upon groundwater concentration trend analyses, which indicated that the southern portion of the groundwater plume was contracting with concentrations steadily decreasing in most wells.
- Monitored Natural Attenuation was selected as an alternative to hydraulic control for the southern portion of the plume.
- Construction of two smaller groundwater treatment facilities instead of one centralized larger one for the northern and central portions of the plume.
- Investigation of enhanced anaerobic bioremediation (EAB) for its potential to reduce cleanup time.
- Determination by EPA, in consultation with DPNR, to discharge treated groundwater to Turpentine Run, with effluent water quality meeting the discharge requirements of the Territorial Discharge Pollutant Elimination System permit equivalency for the site.

b) Soil

Requirements in the ROD to address Curriculum Center soils included the following:

- Excavation of impacted soils, followed by either off-site disposal, or ex-situ soil vapor extraction (SVE) and re-depositing of the treated soil on site.
- In-situ SVE treatment in unsaturated bedrock areas and in soil areas not suitable for excavation.
- Thermal oxidation or off-gas treatment.

In the absence of promulgated federal or territorial regulatory standards for soils, EPA developed site-specific cleanup standards based on EPA SSL methodology for protection of groundwater (i.e., SSLs were developed based on residual concentrations remaining in soil such that the resulting groundwater concentrations would be at or below the MCLs).

Based upon the results of the pre-design investigation and subsequent design analysis, a number of modifications were proposed to the ROD remedy for Curriculum Center soils. The modifications were approved by EPA as part of the Final RD and included:

- Excavation of impacted soil was not required because the pre-design investigations indicated that overburden soils did not contain CVOCs at concentrations above the ROD soil cleanup goals.
- Activated carbon adsorption followed by potassium permanganate oxidation was determined to be more cost-effective than thermal oxidation for reducing CVOC concentrations in the off-gas effluent.
- The SSLs defined in the ROD were considered to be inappropriate for evaluation cleanup of fractured bedrock, due to limitations associated with sample collection, analytical methods and representativeness of the sample results. Therefore, performance-based cleanup criteria for SVE treatment were developed during the RD (initial shut-down of the SVE system after asymptotic conditions are reached, followed by a pulse-operation period of the SVE system to determine that significant rebound in soil vapor CVOC concentrations did not occur).

1998-1999 Pre-Design Investigations

Pre-design field investigations were performed by CDM to further define the extent of CVOCs in Curriculum Center soil and groundwater, and to collect hydrologic and geologic information for use in the RDs (CDM 2001a). Pre-design investigations were performed from August 1998 through October 1999. CDM installed and/or collected soil samples from seven shallow interior building borings, nine shallow exterior building borings and seven deep borings. CDM collected groundwater from nine monitoring wells and two extraction wells. CDM collected soil gas from 26 vapor probes. CDM also conducted water level measurements, aquifer testing of extraction wells, packer testing of six supply wells, geophysical logging of 10 supply and two extraction wells, sediment and surface water sampling, and wetland delineation.

Subslab drain and pipe tracing was completed at the Curriculum Center using building architectural drawings, visual observation, hand augering, and concrete coring to identify unknown discharge points. Six core holes inside the building and three hand auger boreholes outside the building were drilled to confirm the presence of suspected pipes. Solvents encountered in the pipes was sampled and removed by wet vacuuming.

CVOC contamination existed at the Curriculum Center in the unconsolidated vadose zone. The existence of vadose-zone contamination was confirmed during the SVE pilot study completed from October to November 2000. Based upon data collected during this test, the extent of vadose-zone contamination was limited to the immediate area of the work shop behind the Curriculum Center. Approximately 40 pounds of CVOCs were removed during a 5-day SVE pilot test, with a mass removal rate of approximately four pounds per day (CDM 2001b).

2004 Enhanced Anaerobic Bioremediation Pilot Study

In 2004, CDM performed a pilot study to assess the feasibility of enhancing the existing groundwater extraction and treatment system remedy at the Curriculum Center

groundwater treatment facility (GWTF) #1 using EAB (CDM 2004b). EAB was considered to have potential for increasing mass removal of PCE. The pilot study was conducted in two phases: an EAB background groundwater monitoring phase to establish background conditions, and a tracer study/optimization phase to obtain more precise estimates of groundwater velocity and dilution.

During the EAB background groundwater monitoring phase, groundwater samples were collected and analyzed for CVOCs, dissolved gases, electron donors and electron acceptors to assess the nature and extent of EAB activity in the shallow and deep zones in the source area. Findings and conclusions for the background monitoring phase included:

- PCE, TCE, cis-1,2-DCE, and VC were detected in all monitoring wells, indicating that reductive dechlorination of PCE to VC was occurring;
- CVOC concentrations detected in the shallow zone were approximately two orders of magnitude lower than in the deep zone;
- Low concentrations of ethene/ethane, methane, and dissolved hydrogen in the shallow zone indicated that complete conversion of PCE to end products was occurring via reductive dechlorination;
- Higher concentrations of ethene/ethane ($>10 \mu\text{g/l}$) and methane (up to $240 \mu\text{g/l}$) in the deep zone indicated that conversion of VC to the end products was occurring via reductive dechlorination at depth;

Based on these findings, CDM concluded that significant reductive dechlorination was not occurring within the shallow zone. The presence of the PCE daughter products appeared to be representative of historical reductive dechlorination activity (i.e., before the shallow groundwater in the source area was continually flushed with uncontaminated, oxygen-rich groundwater as the result of the operation of GWTF#1). CDM further concluded that reductive dechlorination was occurring within the deep zone but that it was limited by electron donor availability.

Separate tracer studies were completed for the shallow and deep zones EAB Pilot Study. Tracer was injected in wells IW-1S and IW-2S and samples were collected at extraction wells RW-7, BP-1, BP-2 and BP-3 for the shallow zone study. Tracer was injected in IW-2 and samples were collected at wells BP-1 through BP-3 for the deep zone study. Based on the results of the investigation, CDM reported the following findings:

- Multiple, well-defined flow paths exist between shallow zone wells IW-1S and IW-2S and extraction well RW-7, and deep zone well IW-2 and the extraction well;
- Well BP-2 is not in the shallow flow paths between IW-1S/IW-2S and extraction well RW-7 (based on detected tracer concentrations and the breakthrough curve for this well);
- When injecting into deeper well IW-2, upward flow into the shallow, more productive zone was observed with tracer detected at BP-3;
- Estimated average linear groundwater velocities were on the order of 45 feet per day for the shallow zone and 8 feet per day for the deep zone.

Conclusions for the EAB pilot study can be summarized as:

- Travel times between the upgradient edge of the study area and RW-7 are extremely short and indicative of rapid effective pore volume exchange (i.e., "flushing") for both the shallow and deep zones. Rapid flushing was expected to decrease the dissolved-phase CVOC concentrations within the shallow, productive zone very quickly;
- The dissolved CVOC contamination present in the deep, less productive zone and in dead-end pore spaces within the shallow zone will not be flushed by remedial pumping. Such contamination will tend to persist and continue diffusing into the productive zone over the long term;
- EAB processes are occurring within the deep, less productive zone of study area. However, reductive dechlorination was not significant within the shallow, productive zone at the time of the pilot study;
- Estimated groundwater velocities within the shallow (45 ft/d) and deep zones (8 ft/d) were significantly greater than the targeted value of 1 ft/d under the controlled-gradient flow conditions associated with Treatment Facility #1 operation. Such flow conditions would not provide the retention time required for efficient substrate distribution and microbial utilization as part of an EAB pilot process involving a one-time, batch injection of slow-release substrate, as planned during the RD.

2007 & 2011 Vapor Intrusion Investigations

EPA's Environmental Response Team (ERT) performed two investigations to characterize the potential for vapor intrusion into the Curriculum Center building. The investigations were performed in December 2007 and December 2011 (Lockheed Martin 2008, Lockheed Martin 2012). Sub-slab vapor and indoor air samples were collected on both occasions.

In December 2007, the EPA ERT contractor installed 16 permanent sub-slab gas wells at the Curriculum Center building. Three wells were located in the maintenance area, nine were located in the warehouse area, and four were located in the Curriculum/office area). A total of 32 air sampling locations, including three indoor air locations from the maintenance area, 12 indoor air locations from the warehouse area, 15 indoor air locations from the Curriculum/office area, and two ambient air samples were also selected. Sub-slab and air samples were collected over a period of 24 hours, using SUMMA® canisters, and were analyzed for PCE, TCE, cis-1,2-DCE, trans-1,2-dichloroethene (trans-1,2-DCE), 1,1-dichloroethene (1,1-DCE), and VC using EPA Method TO-15 with selective ion mode to achieve lower detection limits. The 2007 sampling event was replicated by ERT in December 2011 (Lockheed Martin 2012). One sub-slab vapor point was found to be compromised and was replaced at the time.

The analytical results for sub-slab, indoor air and ambient air samples, and a comparison to action levels are summarized in **Tables 1-1 and 1-2**. The source of the action levels was not identified in the trip reports. However, it is believed that the 2008 report used New York State Department of Health Vapor Intrusion Guidance and the 2012 report used 2002 EPA Vapor Intrusion Guidance. A comparison of these data to current EPA Vapor Intrusion Screening Levels (VISLs) (version 3.5.2 using November 2017 RSL

toxicity values) is provided in the BHHRA Section 6.4 Vapor Intrusion Evaluation and BHHRA Tables 6-4, 6-5 and 6-6. Figures, showing sample locations and results, from the trip reports for the two sampling events are presented in Appendix A.

The extent of soil vapor with elevated concentrations of PCE and TCE did not change noticeably between the two sampling rounds. All but one sample exceeded the soil vapor action level for PCE. The area of the highest sub-slab concentrations was found in the warehouse area located in the central portion of the Curriculum Center building and extends into the adjoining maintenance and office areas. The extent of TCE concentrations that exceeded action levels in soil vapor falls within the area of highest PCE concentrations.

1.1.4 Previous Remedial Actions

This section provides a summary of previous remedial activities conducted at the Site.

Following extensive RI activities and completion of the RD September 2001, the EPA constructed the GWTF at the Curriculum Center property to achieve hydraulic control of the northern portion of the plume and remove CVOC mass from the saturated zone. The system is referred to as GWTF #1 for the Tutu Wells Superfund Site. GWTF #2 addresses downgradient central portions of the plume, north of the O'Henry drycleaner site.

GWTF #1 became operational in 2004 and initially consisted of three groundwater extraction wells, an equalization tank and transfer pumping system, bag filters, a low-profile air stripper and an off-gas treatment system. Use of the off-gas treatment system was discontinued in April 2006 after CVOC concentrations dropped below the air pollution control permit equivalency limits. One GAC vessel and one potassium permanganate unit remain at the site on standby for emergency use. Chemical feed systems were also included for sequesterant/biocide injection and pH adjustment.

The groundwater extraction system at GWTF #1 consists of three wells; RW-7, RW-9 and RW-6. Extraction wells RW-7 and RW-9 are completed in the shallow, more productive portion of the aquifer, with open-hole sections from 30 to 80 feet below ground surface (bgs) and 40 to 60 feet bgs, respectively. Extraction well RW-6 is completed in the deeper, less productive portion of the aquifer with an open interval from 80 to 130 ft bgs. Extraction well RW-7 is operated on a continuous basis. Extraction well RW-9 operates as required to maintain the target groundwater elevation and is typically operated during and following heavy rain events. Extraction well RW-6 is operated approximately one hour per week, at a flow rate of approximately two gallons per minute (gpm), until the extraction well pump shuts down due to a low water level in the well (EPA 2014, Arrowhead 2017). Treated water is discharged to Turpentine Run on the adjoining property to the northwest.

The treatment system was operated by EPA from 2004 to 2013. Operation and maintenance of the treatment system was transferred from EPA to the USVI government in April 2013. The system is currently operated by Arrowhead Environmental Services under contract to the USVI.

As part of the long-term response action (LTRA) for the Tutu Wells Site, groundwater monitoring is routinely completed to assess RA progress. Groundwater monitoring was completed on a quarterly basis from system startup in 2004 until April 2007, and annually since 2007. A total of 30 monitoring and residential wells are monitored as part of the LTRA. Groundwater levels are measured on a monthly basis from 36 monitoring wells. Influent monitoring is performed monthly at two of the extraction wells (RW-6 and RW-7) using the GWTF influent sampling port.

RAPRs have been prepared by the operations and maintenance (O&M) contractor (Arrowhead) and submitted to DPNR annually to report the progress of the LTRA. Prior to 2014, the RAPRs were prepared by CDM and submitted to EPA under the RAC. The most recent available RAPR (Arrowhead 2017) documented O&M operations and sampling results for the period of May 1, 2016 through April 30, 2017.

An SVE system was constructed in 2004 to remediate the unsaturated zone source of the CVOC groundwater contamination. The system included two SVE wells (SVE-1 and SVE-7), a moisture knockout tank and a blower, and discharge to the GWTF off-gas treatment system. The location of SVE-7 coincides with RW-7, which was constructed as a dual-phase extraction well. The SVE system was operated for approximately two years. The system was shut down in April 2006 due to a significant decrease in influent concentrations and achievement of asymptotic conditions. Based on these conditions, it was determined that the SVE system was no longer cost-effective (EPA 2014).

A 2011 evaluation of the remediation system concluded that extraction well RW-7 was too far upgradient to effectively contain the Curriculum Center source area and recommended considering a new containment system with additional wells screened across the shallow and deep zones (EPA 2011).

The second five-year review was completed in 2014 to determine if the current OU1 remedy was protective of human health and the environment, and whether it was anticipated to be protective in the future (EPA 2014). The review concluded that the remedy for the Tutu Wells Site was not protective in the long-term and would not achieve the remedial objective of restoring the Tutu aquifer to drinking water standards. Of particular concern to EPA was the potential presence of DNAPL as an ongoing source of groundwater contamination for the deep aquifer in the northern portion of the Tutu groundwater plume. The review recommended installation of additional wells to further evaluate the presence of DNAPL, the evaluation of groundwater monitoring results and the development of a conceptual site model (CSM) to determine a strategy for addressing the ongoing sources of CVOC at the Site. As part of the review, the 2014 document summarized findings and groundwater quality for the OU2 area as follows:

- Contaminant transport was believed to be controlled by advection. A discrete plume (with total CVOCs in excess of 1,000 µg/l) originated north of the Curriculum Center and extending approximately 500 feet downgradient to a location just north of the former Texaco service station (now Puma);
- Unexpectedly high concentrations of CVOCs were detected in several wells during the April 2009 annual sampling event. A follow-up sampling event was conducted in October 2009 at monitoring wells MW-2, MW-8, MW-15, RD-13,

and TT-6. The October results did not confirm the concentrations detected in April 2009. The cause of the high results from April 2009 was not determined;

- A spike in concentrations was observed at well RD-9 in April 2011 with 478,500 µg/l total CVOCs. This represented the highest concentration observed at RD-9, including the 2004 baseline concentration (152,020 µg/l). The increase was attributed to nearby extraction wells RW-7 and RW-9 mobilizing contaminants in the vicinity of RD-9. Since RD-9 is screened in the deep zone that is suspected to contain free product, the spike was interpreted as an indicator of free product in the vicinity of RD-9;
- A comparison of total CVOc concentrations at three downgradient wells MW-1D, MW-14 and RD-13, located approximately 300 feet from RD-9, indicated that contaminant mass increased with depth downgradient of the source area. The lateral extent of the deep zone contamination could not be determined because deep monitoring wells did not exist further downgradient of RD-13;
- The 2011 remedial system evaluation indicated that hydraulic capture associated with GWTF #1 area was incomplete and recommended adding more extraction wells. The review concluded that the limits of hydraulic capture were difficult to ascertain due to the lack of monitoring points between the source area and downgradient monitoring wells MW-14, MW-1D and RD-13. It further noted that hydraulic capture in a fractured rock setting is complicated and complete capture could be difficult even with additional wells, especially considering the non-productive deep zone. The reviewers ultimately concluded that CVOc concentrations in the shallow zone had improved, but there might still be a concern for vertical migration from the deep highly contaminated zone to the shallow zone in response to pumping and lateral migration of the deep CVOc plume;
- The majority of contaminant mass remained at high concentrations in the source area near GWTF #1 (likely in the form of DNAPL) in deep fractured rock where hydraulic capture would be difficult. Although the deep zone has low permeability, it was likely to act as a slow and continuous source to downgradient areas and potentially to the shallow aquifer. Enhancing the extraction network could lead to the spreading of source material in the deep low-productive zone rather than improving the conditions in that zone, thus, other strategies might have to be assessed; and,
- The reviewers summarized their findings for the OU2 area groundwater as follows: "Of particular concern is the amount of mass that appears to be present in the source area of the northern portion of the plume. DNAPL remains in the fractured bedrock and although its presence is in a hydraulically low yielding zone, it has the potential to serve as a slow residual contaminant source to the dissolved-phase plume over time. Groundwater monitoring of the DNAPL is limited since the nearest downgradient wells are 300 feet from RD-9 and just one well is screened at a similar depth (RD-13). This well showed a decreasing trend in CVOc concentrations over the 2009-2014 review period, but the next downgradient well (RD-5) screened at a similar depth showed an increasing trend and there no additional monitoring wells exist at this depth further

downgradient. The cause of the increasing trend was unclear, but may be related to downward vertical migration of the plume from shallow bedrock zones or lateral transport from the source area”; and, “Given the RAO to restore the groundwater to drinking water standards, the groundwater extraction remedy was considered to be ineffective at removing the DNAPL material from the low-yielding fractured bedrock. If restoration was going to be achieved, alternative remediation technologies should be considered.”

The review further reported that vapor intrusion concerns had been addressed by sampling in 2007, because, although the sub-slab results exceeded screening values, the indoor air concentrations were negligible and well below risk-based concentrations. The five-year review did not discuss the 2011 sub-slab and indoor air sampling results.

1.1.5 Current Conditions

Based on historical analytical data from LTRA monitoring between 2004 and 2017, CVOC concentrations in most wells in the vicinity of the Curriculum Center have decreased since the startup of the groundwater extraction and treatment facility in 2004, but have remained relatively unchanged for the past five to eight years. The data indicate that the Curriculum Center treatment facility is successfully removing contaminant mass and retarding the migration of a portion of the CVOC groundwater plume. However, the very high and stable CVOC concentrations over the past several years in the shallow zone just downgradient of the facility suggests that there is a continuing source of contamination at Curriculum Center that is not captured by the treatment facility.

Based on the results of the most recent LTRA sampling event, several shallow wells in and near the OU2 investigation area have concentrations of one or more compounds exceeding the MCLs. This includes PCE at wells MW-15, RD-5, Tillett, and TT-6, located on adjoining properties to the west and south of the Curriculum Center. Deep well RD-9, located near the source area, exceeded the MCLs for PCE, TCE, cis-1,2-DCE, and VC (12, 48, 110, and 48 µg/l, respectively). Southwest of the Curriculum Center and downgradient of the known source area PCE, TCE, and VC MCLs were exceeded at MW-1D (42, 11, and 2.8 µg/l, respectively) and VC, cis-, and trans-DCE MCLs were exceeded at RD-13 (120, 120, and 100 µg/l, respectively) (Arrowhead 2017). Exceedances for PCE and TCE were also observed in the OU2 area and other nearby wells, including MW-7 and MW-14 (Arrowhead 2016). The core of the CVOC plume (total CVOC greater than 1,000 µg/l) extends from the source area on the north side of the Curriculum Center building to the southwest in the direction of groundwater flow. Concentrations of total CVOCs of greater than 10 µg/l are present at adjoining properties to the west, southwest and south of the Curriculum Center (Figure 2-1 in Arrowhead 2017). The extent of contamination has not been defined to the southeast, towards Smith Bay Road (Highway 38), because of the lack of shallow wells in that area.

The results of LTRA monitoring indicate that concentrations of total CVOCs in the treatment system influent and mass removal rates at the Curriculum GWTF have significantly decreased since system startup. Total CVOC concentrations in the influent from extraction well RW-7 averaged 85 µg/l for the period of May 2016 to April 2017.

Total CVOC concentrations for intermittently-pumped, deep extraction well RW-6 generally range from less than 5,000 µg/l to 100,000 µg/l. Following a spike to almost 260,000 µg/l in early 2015, concentrations have been below 50,000 µg/l over the last 17 monthly sampling events (to April 2017) (Arrowhead 2017).

The concentrations of CVOCs in shallow zone wells just downgradient of the facility have remained constant over the last few years. Based on this observation, Arrowhead concluded that some contamination from the highly contaminated deeper zone of the aquifer may be migrating upward into the shallow zone (Arrowhead 2017).

The historically high concentrations of PCE, greater than 20 percent of solubility at wells RD-9 and RW-6, indicate the potential presence of DNAPL. The location of the DNAPL is unknown, but previous investigations considered the area underneath the Curriculum Center to be the likely location (CDM 2004a). An unexpectedly high total CVOCs concentration at RD-9 (14,860 µg/l) in April 2009 was considered to be an indication of the presence of DNAPL.

Elevated concentrations of PCE and TCE in soil vapor beneath the Curriculum Center building exceeded action levels in 2007 and 2011 (**Section 1.1.3**). Both rounds of indoor air samples indicated that contaminants were not present at levels that require remediation. A 2014 review of site conditions considered indoor air concentrations to be negligible and well below risk-based concentrations (EPA 2014). Comparison of these subslab and indoor air results to current EPA VISLs (Tables 6-4 and 6-5 of the BHHRA) indicates that PCE and TCE concentrations measured in soil vapor exceed residential and commercial VISLs and that levels of these compounds measured in indoor air exceed the residential VISL.

During Hurricane Irma in early September 2017, the electric grid on St. Thomas sustained widespread damage. The utility pole supplying power to the Curriculum Center GWTF broke and the pump and treat system became non-operational (a backup power generator was not available). A section of the VIDE Curriculum Center building sustained heavy damage when a portion of the roof was ripped away by the hurricane-force winds.

1.2 Investigative Approach

The Site is underlain by fractured and faulted sedimentary volcanic rock from multiple oceanic eruptions. This geologic setting presents unique challenges to characterizing both the occurrence and movement of groundwater and the nature and extent of potential groundwater impacts. The presence of DNAPL acting as a secondary source of contamination within the subsurface further complicates the characterization. An illustration of the conceptual stages in the evolution of a chlorinated solvent DNAPL release in fractured bedrock over time is presented on **Figure 1-5**. One of the most notable challenges is characterizing the mass adsorbed into the matrix (primary porosity) of the bedrock and the role it plays in the mass transport of potential contaminants. The Discrete Fracture Network (DFN) approach was used to characterize the nature and extent of Total VOCs diffused into the bedrock matrix (Parker 2007). The DFN approach described in **Section 2.1** was used as the foundation to the identification and rationale

for the scope of work outlined in **Section 1.3** and is the basis for the bedrock hydrogeologic investigation described in this report.

1.3 Scope of Work

The goal of the FSRI/FS activities for the Tutu Wells site is to refine our understanding of the hydrogeologic framework and distribution of contamination in the OU2 study area and to develop viable remediation alternatives to eliminate, reduce, or control risks to human health and the environment at the Tutu Site, specifically the Curriculum Center. A primary goal of the work assignment was to develop the data necessary to support the selection of an approach for site remediation, and then to use the data in a well-supported Proposed Plan (PP) and ROD.

Based on the approved WP dated October 2015, the following tasks were conducted during the FSRI to achieve those goals:

- Information gathering and background research, including review of existing files from EPA and USVI records;
- Limited site surveys and reconnaissance;
- Surface geophysical surveys;
- Rock matrix diffusion sampling and analysis;
- Monitoring well installation;
- Borehole geophysical investigation;
- Packer testing and sampling at new monitoring well boreholes;
- Groundwater sampling;
- Groundwater elevation measurements;
- Evaluating existing data and on-going site remedial practices; and,
- Completion of Reports.

1.4 Report Organization

This RI report is organized into eight sections:

Section 1 – Introduction includes a general Site description and information on Site history and previous investigations, with emphasis on the OU2 FSRI investigation area.

Section 2 – Methods and Procedures presents the methods and procedures used to conduct the investigation and collect the data presented in this report.

Section 3 – Physical Characteristics describes Site surface features, land use, and topography, climate, geology, soils, surface water hydrology, and hydrogeology.

Section 4 – Cultural Resources Survey includes a Phase 1a archaeological site review and sensitivity assessment.

Section 5 - Nature and Extent of Contamination discusses screening criteria and the determination of contaminants of concern for the OU2 investigation, existing groundwater data for the OU2 area, the analytical data generated during the OU2 investigation and the extent and distribution of contamination in groundwater and the bedrock matrix.

Section 6 – Fate and Transport provides information on the environmental fate and transport mechanisms for the site and contaminants of concern.

Section 7 –Conceptual Site Model presents an element based site conceptual model

Section 8 – Summary of Baseline Human Health Risk Assessment presents the data evaluation, exposure and toxicity assessments, risk characterization, uncertainty analysis and conclusions for the human health risk assessment.

Section 9 – Summary and Conclusions presents summaries of the nature and extent of contamination, contaminant fate and transport, the human health risk assessment, and conclusions of the OU2 FSRI.

Section 10 – References lists the reference documents used in preparation of this FSRI report.

2 Methods and Procedures

This Section describes the methods and procedures used to execute the scope of work outlined in **Section 1.3**. The OU2 FSRI was conducted in accordance with the approved work plan (HDR 2015a) and QAPP (HDR 2015b), and in accordance with the *Guidance for Conducting Remedial Investigation/Feasibility Studies under the Comprehensive Environmental Response, Compensation, and Liability Act* (EPA 1988).

2.1 Matrix Diffusion Investigation (Bedrock Core Sampling and Analysis)

A DFN matrix diffusion investigation was completed at two locations during the FSRI to evaluate the potential presence and vertical distribution of CVOCs in bedrock pore water. Previous investigations identified an andesitic tuff/breccia at the site, which is a volcanogenic sedimentary rock. Previous studies in sedimentary bedrock show CVOCs could diffuse into the porewater contained in the primary porosity and back-diffuse out of the bedrock acting as a long-term secondary source of CVOCs to groundwater.

The two matrix diffusion boreholes were located based on the nature and extent of dissolved phase CVOCs at the Curriculum Center. Boring OU2-MD1 was drilled along the approximate centerline of the dissolved phase CVOC plume, 275 feet downgradient of the GWTF #1 recovery wells. Boring OU2-MD2 was also drilled along the approximate centerline of the dissolved phase CVOC plume, but only 35 feet downgradient of the GWTF #1 recovery wells (**Figure 1-4**).

Rock core sampling, logging, processing, and analysis were completed by an HDR subcontractor, Cascade Technical Services (Cascade). Cascade mobilized personnel, and equipment, including a mobile laboratory, to site. Rock was cored using a triple-tube core barrel (PQ3) to minimize core disturbance and increase core recovery volume over double-tube core barrels. The PQ3 tooling allows core samples to be retained within a second inner stainless steel tube, split lengthwise (liners), within the core barrel. Rock coring procedures are described in **Section 2.2.3**.

The rock core was removed from the core barrel and transferred from the liner to a polyvinyl chloride (PVC) tray lined with aluminum foil. The bedrock cores were logged and samples were collected by a Cascade geologist for matrix diffusion analysis. Samples were selected based on fracture distributions and lithology, with a target frequency of one sample every foot. The bedrock core was photographed with labels indicating site name, borehole identifier, run number, depth bgs (top to bottom), recovery and rock quality designation prior to sampling. Wooden blocks were inserted at the approximate locations of the VOC and physical properties samples. Samples were collected both from fracture surfaces and from the intervening unfractured rock matrix. Bedrock samples were collected at the fracture face to determine if CVOCs had diffused into bedrock. Bedrock samples were collected away from the fracture faces to assess the potential penetration of diffusion into bedrock. Samples approximately 0.1 foot in thickness were cut from the bedrock core using a hammer and chisel. The samples were then wrapped in aluminum

foil and given a unique field ID. The rock cores were logged by the Cascade field geologist.

Rock cores were screened for the presence of VOCs by the HDR field geologist using a photo-ionization detector (PID), both before and after sampling. The remainder of the core was transferred to the investigation-derived waste (IDW) solids container for disposal after completion of geologic logging and sample collection.

Temporary drill casing was seated into the top of competent bedrock. Bedrock was cored from the top of competent bedrock to a depth of 200 feet bgs at both locations. A total of 326.4 linear feet of rock core was collected with a total recovery of 325.2 feet. Boring OU2-MD1 was cored between 33 and 200 feet bgs and OU2-MD2 was cored between 43 and 200 feet bgs.

Sample processing was conducted immediately after sample collection. The portion of the sample that had been exposed to drill tooling and fluids was removed with a hammer and chisel. The remaining subsample was then placed in a stainless steel crucible and crushed using a hydraulic press. The crushed sample was transferred to a pre-labeled and pre-weighed 40 milliliter (ml) VOA vial containing 15 ml methanol. The CVOCs in the crushed bedrock core sample were transferred to the methanol using a microwave extraction process. The methanol extract was analyzed for 15 target VOCs, including 1,1,1-trichloroethane, 1,1-dichloroethane, 1,1-DCE, 1,2-dichloroethane, benzene, chloroethane, cis-1,2-DCE, ethylbenzene, m,p-xylenes, o-xylene, PCE, toluene, trans-1,2-DCE, TCE, and VC. Cascade analyzed the processed rock core and quality control (QC) samples at the mobile laboratory on site or at their fixed laboratory in Montpelier, VT.

Trimming cells, crushing cells, chisels, and all other equipment associated with sample collection and processing were decontaminated between each subsample. Equipment blank (EB) samples were collected at a minimum of one per every 20 samples. EB samples were collected as wipe samples from the inside of decontaminated crushing cells and other equipment that had come in contact with subsamples.

A total of 325 rock samples were collected for VOCs analysis, along with 19 field duplicates, 18 matrix spike/matrix spike duplicate sample pairs (36 samples), 18 EB samples, and 14 methanol blank samples. In addition, one sample of the potable water used by the driller was collected and analyzed for VOCs.

Fourteen core samples were collected for physical property analyses. The physical properties samples were analyzed at Golder Associates Laboratory in Mississauga, Ontario for wet and dry bulk density, specific gravity, porosity, percent moisture, and organic carbon content.

A rock matrix diffusion report prepared by Cascade is included as **Appendix B** and the results of the investigation are discussed in **Section 4.4.1**.

2.2 Groundwater Investigation

The groundwater portion of the OU2 FSRI was completed in four phases:

- **April 2016** - Completed a surface geophysical investigation to identify potential fault, fracture trends and preferential flow pathways for groundwater flow and to support the selection of monitoring well locations;
- **October 2016 to January 2017** - Completed matrix diffusion sampling, borehole geophysical logging, packer testing, groundwater packer sampling, monitoring well installation, and long-term groundwater level monitoring;
- **February to March 2017** – Completed first round of synoptic groundwater elevation measurements and collected groundwater samples from newly installed and existing monitoring wells; and,
- **June 2017** - Completed second round of synoptic groundwater elevation measurements and removed DNAPL from well OU2-MD2.

2.2.1 Surface Geophysical Investigation

Aestus GeoTrax Survey

HDR subcontracted Aestus, LLC (Aestus) of Loveland, CO, to complete an electrical resistivity imaging survey. Specific goals of the survey were to identify subsurface anomalies that can be consistent with high concentrations of aqueous-phase CVOCs and DNAPL in bedrock that can be used to optimize monitoring well placement.

Aestus used GeoTrax Survey technology (GeoTrax) to complete the survey around the Curriculum Center. GeoTrax Survey™ is a specialized non-intrusive electrical resistivity tomography technology based on conventional electrical resistivity imaging. The GeoTrax Survey™ yields vertical two-dimensional imagery of the subsurface below each transect line, that can be used to graphically illustrate the presence or absence of subsurface anomalies. GeoTrax Survey™ data were collected along 10 transects at Curriculum Center:

- One line was oriented southwest to northeast parallel to the southeast side of the Curriculum Center (TWS-01);
- Four lines were oriented southwest to northeast parallel to the northwest side of the Curriculum Center (transects TWS-02, -03, -04, and -05); two lines were oriented southeast to northwest parallel to the southwest side of the Curriculum Center (TWS-06 and TWS-07);
- One line was oriented southeast to northwest perpendicular to the northwest side of Curriculum Center (TWS-08); and,
- Two lines were oriented southeast to northwest parallel to the northeast side of Curriculum Center (TWS-09 and TWS-10).

The lengths of the transects ranged from 316 to 822 feet, with electrode spacing of 1.75 feet (TWS-06), 2.0 feet (TWS-02, -03, -05, -08, and -09), 3.75 feet (TWS-04), 4.0 feet

(TWS-01, TWS-10), and 4.5 feet (TWS-07) corresponding to image depths of 63 feet, 72 feet, 135 feet, 144 feet, and 162 feet, respectively. The GeoTrax Survey™ lines are shown on **Figure 2-1**. All transects were surveyed by Aestus. End point markers of each transect line were installed so that individual points along the transects could be identified.

Aestus integrated historical Site data (drilling, analytical results, etc.) and their GeoTrax Survey™ data into a 2- and 3-dimensional (2-D and 3-D) visualization model. Aestus then provided recommendations for confirmation drilling locations and target sampling depths to HDR. Aestus also recommended bacteria sampling to evaluate whether some observed anomalies could be related to leakage from an upgradient sewer line or septic systems.

After completion of the FSRI field activities, HDR provided Aestus with observations and data. Aestus used the FSRI information to generate their final report.

Findings from the surface geophysical investigation were used in developing the FSRI report sections on site-specific geology and hydrogeology (**Sections 3.4.2 and 3.4.3**) and were integrated into the cross section presented in **Figure 5-5** and the CSM presented in **Section 7**. Aestus' electrical resistivity imaging geophysical survey report is included as **Appendix C**.

2.2.2 Borehole Geophysical Logging

Borehole geophysical logging was conducted at 17 locations (eight existing monitoring wells, six new monitoring wells, two matrix diffusion boreholes, and one former supply well) by Geophysical Applications, Inc., Holliston, MA. The borehole geophysical logging locations are shown on **Figure 1-4**.

Fluid temperature, fluid resistivity, three-arm mechanical caliper, heat-pulse flowmeter (under ambient and pumping conditions), and acoustic televiewer logging was performed at each borehole with some exceptions. Flowmeter testing was omitted from five locations: at IW-1, where the logging probes repeatedly became stuck; at OU2-MW5 because the well was dry; and at RD-5, RD-9, and RD-12 because the wells were screened with limited sections open to the formation. Optical televiewer augmented acoustic televiewer imaging at five locations (OU2-MD2, OU2-MW1, OU2-MW6, MW-13D, and the Tillett supply well) to obtain visual logs of wells with highly fractured intervals. Optical televiewer imaging was substituted for acoustic televiewer imaging at two locations: at RD-12 where steel well screen prevented acoustic televiewer imaging of bedrock; and, at OU2-MW-5 where acoustic televiewer imaging could not be conducted because the well was dry. The borehole equipment was decontaminated after logging each borehole. Decontamination consisted of an Alconox scrub and tap-water rinse of the logging cable and probes after each logging run. A citrus cleaner was also used (prior to the Alconox scrub) at two wells where the logging probes may have come into contact with free product floating on top of the water (IW-1) or chlorinated DNAPL (OU2-MD2). Decontamination fluid was transferred to the on-site IDW liquids storage container and treated on-site with other IDW liquid.

The borehole geophysical logging report prepared by Geophysical Applications, Inc. is included as **Appendix D**.

2.2.3 Borehole and Well Installation, Borehole Testing, and Development

The drilling program for the OU2 FSRI included the drilling of two rock matrix diffusion boreholes and the drilling, installation, and well development of six new monitoring wells. Boreholes were drilled using air rotary methods. Borehole advancement was completed with a 10-inch casing advancement system (Tubex® XL 230) whenever difficult or potentially unstable borehole conditions were encountered or anticipated

SGS completed all drilling-related activities. SGS obtained permits for the new monitoring wells and rock matrix diffusion boreholes from DPNR. The permit for rock borehole OU2-MD2 was resubmitted to convert the borehole to a monitoring well following the discovery of DNAPL. The well permits are included in **Appendix E**. SGS also obtained and maintained USVI driller's and business licenses for the duration of the project.

SGS used a 2005 Schramm 450WS drill rig, along with a support truck equipped with a generator/welder combination, heated pressure washer, and a 275-gallon water tank. Other equipment and supplies, including rods and well construction materials, were shipped to site and stored in a 40-foot shipping container. SGS obtained potable water for their operations from a local vendor (Mahogany Run Golf Course). Analytical results of water quality testing were provided by the vendor and confirmed with onsite analysis by Cascade. Results of these analyses are discussed in **Section 5.4**.

Prior to drilling, each boring location was hand-excavated to five feet bgs or to the top of bedrock, if shallower, to confirm the absence of underground utilities. After utility clearing, the drillers installed surface casing into the borehole that contained a diverter to direct drill cuttings from the borehole to a mud tub. The handling of the IDW by the drilling subcontractor during the different phases of the drilling program is described in **Section 2.4**.

Rock Core Borehole Drilling

SGS drilled two bedrock core borings, OU2-MD1 and OU2-MD2, for the rock matrix diffusion investigation (**Section 2.1**). Ten-inch diameter boreholes were drilled until competent bedrock was encountered. Six-inch carbon steel surface casing was grouted in place. The grout was allowed to harden for more than 24-hours before coring.

Coring at the two matrix diffusion boreholes was continuous from the bottom of the casings to a depth of 200 feet bgs. PQ3 cores were 5 feet long and 3.25 inches in diameter.

The OU2-MD1 borehole was grouted to the ground surface with cement-bentonite grout (Portland/bentonite mix) after borehole geophysical logging was completed. The surface casing was then cut below grade and the surface was restored to previous conditions

(gravel parking lot). Borehole OU2-MD2 was completed as a monitoring well because of the presence of DNAPL.

2.2.4 Monitoring Well Drilling

Six boreholes were drilled using air rotary and a down-hole pneumatic hammer to install shallow monitoring wells OU2-MW1 and OU2-MW2, and deep monitoring wells OU2-MW3 through OU2-MW6. Well locations are shown on **Figure 1-4**. A limited amount of PQ3 rock coring was also conducted at five of the locations to obtain confirmatory information for anomalies identified during the Aestus surface geophysical investigation.

Ten-inch boreholes were drilled 10-feet into competent rock. Six-inch carbon steel surface casing was grouted in place. The grout was allowed to harden overnight (between 16 and 23 hours) before resuming drilling operations. Six-inch boreholes were then drilled below the surface casing to the total depth of the wells, except as described below.

Nine discrete intervals were cored with PQ3 tooling during the drilling of wells OU2-MW1 through OU2-MW5. Detailed information on the cored bedrock intervals is presented in **Table 2-1**. SGS switched to water rotary drilling to collect the rock cores. SGS switched back to the larger diameter air rotary and a down-hole pneumatic hammer method between rock cores, reaming the interval that was cored and continuing to the next core interval or the final well completion depth. The bottom five to 7.5 feet of the OU2-MW2, OU2-MW3, and OU2-MW4 boreholes, were not reamed to avoid the additional time and cost of retooling.

Boreholes were advanced to pre-determined depths for the surface casing and total well depths at shallow wells OU2-MW1, OU2-MW2, and deep wells OU2-MW3, OU2-4, and OU2-5. The depth of the surface casing and total depth of OU2-MW6 were determined as drilling progressed, based on vapor readings and fracture intervals observed in the field. This process was used to case off shallow, less impacted groundwater and position the open borehole section to span deeper fracture zones impacted by Site contaminants.

HDR field geologists observed and directed the drilling and coring operations. Drill cuttings were collected from the discharge, visually examined, screened for the presence of organic vapors with a PID, and photo-documented at approximately 5-foot intervals. The geologist described rock type and quality, changes in stratigraphy and the degree and water-bearing properties of fractures encountered in each rock core section and all information was entered on field boring logs. The boring logs are included in **Appendix F**.

2.2.5 Packer Groundwater Sampling

Packer groundwater samples were collected at locations OU2-MW1, OU2-MW2, OU2-MW3, and OU2-MW6 (**Figure 1-4**). Packer groundwater screening samples were not collected from OU2-MW4 and OU2-MW5 because they did not have enough water.

Packer groundwater screening samples were collected using a double packer assembly to isolate the selected water producing zones. The assembly consisted of two pneumatic Viton[®]-coated rubber packers. Sliding end packers allowed the packers to range from 5 to 20 feet in length. When an interval near the bottom of the borehole was targeted, the bottom packer was removed. The individual tested intervals for the FSRI varied in length from six to 14 feet. The packer assembly was lowered into the borehole using 2-inch galvanized piping. The packer assembly and sample pump were decontaminated before sampling the first well and between wells.

Packer testing proceeded from top to bottom of well borings with the exception of OU2-MW1, where an additional, higher interval was added after testing at the bottom of the borehole. The packer assembly was lowered into the borehole and set to collect the first sample. Sampling was accomplished by inflating the rubber seals with nitrogen, isolating portion of the borehole, and pumping groundwater from the interval between the packers before collecting a sample. Transducers were placed above, below, and within each packer interval to monitor water levels that were used to verify the packer assembly had effectively isolated a portion of the borehole. Each packer sampling interval was pumped at the maximum sustainable rate for a minimum of 15 minutes, or until at least five volumes of the test interval plus the volume contained in the rod had been removed. The total volume of extracted water for each test was recorded in the field logbook. A summary of packer test intervals, pumping rate and duration, and other details are provided in **Table 2-2**. The packer groundwater sampling is described in detail in **Section 2.2.8**.

2.2.6 Monitoring Well Installation

Monitoring wells were installed after borehole geophysical logging and packer groundwater sampling. Shallow bedrock wells OU2-MW1 and OU2-MW2 were constructed with 2-inch diameter Schedule 40 PVC casing with 0.020-inch slot screen. A sand pack was installed around each screen from the bottom of the borehole to a point three feet above the top of the screen using U.S. Silica Filpro No. 1 filter sand. A 2-foot thick layer of bentonite pellets was placed on top of the sand pack and allowed to hydrate. The remainder of the borehole, from the top of the bentonite seal to the ground surface, was filled with cement-bentonite grout using the tremie method. Vented protective locking caps were secured to the 2-inch PVC casing. Deep bedrock wells OU2-MW3, OU2-MW4, OU2-MW5, OU2-MW6, and OU2-MD2 were completed using open-hole construction. Vented protective locking caps were secured to the 6-inch steel casings.

Flush-mount protective casings were installed at all monitoring wells and secured in 2-foot square, sloped concrete pads. A summary of construction details for the new wells and the existing monitoring wells used for this FSRI is presented in **Table 2-3**. Well construction logs are included in **Appendix G**.

2.2.7 Monitoring Well Development

Monitoring wells OU2-MW1, OU2-MW-2, and OU2-MW3 were developed using the pump-and-surge method with a 2-inch submersible pump. The wells were developed for

at least two hours or until turbidity stabilized below 50 Nephelometric Turbidity Units (NTUs) for three consecutive measurements taken at 10 minute intervals. Temperature, pH, specific conductance were also monitored. Monitoring well OU2-MW4 was pumped and surged on three different dates until a total of three well volumes had been removed due to its low recharge rate. Monitoring well OU2-MW5 was not developed due to insufficient recharge. Monitoring well OU2-MW6 was developed by air lift methods for approximately one hour. Development activities were terminated when the turbidity of the discharge water was below 10 NTUs. Monitoring well OU2-MD2 was not developed due to the presence of DNAPL. Well development logs are included in **Appendix H**.

2.2.8 Groundwater Sampling and Analysis

Two separate groundwater sampling events were completed during the FSRI:

- Groundwater samples were collected from four boreholes during the packer sampling while vertical profile samples were collected from OU2-MD2;
- Groundwater samples were collected between February 21 and March 6, 2017 from 26 monitoring wells and from the three extraction wells using the treatment system sampling ports.

The following field quality control samples were collected during both events in accordance with the approved QAPP, Worksheet #20 (HDR 2015b):

Field duplicate (FD) samples were collected at a rate of one FD for every 20 investigative samples (frequency of 5 percent). FDs are analyzed to check for sampling and analytical reproducibility. A total of three FDs were submitted to the analytical laboratories as “blind” samples. Actual sample locations were recorded in the field logbook but the samples were given unique location codes on the chain-of-custody. FD samples were analyzed for the same parameters as their parent samples.

Equipment rinsate blank samples were collected to evaluate the potential of environmental sample contamination from inadequate decontamination of field equipment. Equipment rinsate blanks were collected by pouring deionized (DI) ASTM Type II water over and/or through decontaminated equipment and collecting the rinsate. Equipment rinsate blank samples were collected at a frequency of one per day for each day of sampling. Equipment rinsate blanks were analyzed for the same parameters as the associated environmental samples. A total of 13 equipment rinsate blanks were collected during both sampling events and submitted for analysis.

Field blank samples were collected to evaluate if contaminants were introduced during sample collection, storage, and transport. One field blank sample was collected for each day of sampling. A total of 17 field blanks were collected during the two sampling events and submitted for analysis. The field blanks samples were generated by pouring DI water into pre-preserved vials at or near sampling locations at the beginning of the day, transported and stored with the investigative samples and shipped to the laboratory with the investigative samples.

Trip blank samples were collected to detect possible cross-contamination of samples during handling, storage, and shipment. Trip blanks consisted of preserved vials of DI water provided by the glassware vendor and shipped with the glassware to the site. A trip blank accompanied the aqueous environmental samples through collection and shipment to the laboratory. Trip blanks were then stored by the laboratory under the same conditions as the environmental samples. A trip blank accompanied each cooler containing aqueous samples for VOC analysis. A total of nine trip blanks were collected during both sampling events and submitted for analysis.

Packer Groundwater Sampling and OU2-MD2 Vertical Profile Sampling

Groundwater packer samples were collected from nine intervals from four packer-tested boreholes. Groundwater samples were also collected from seven targeted depths within rock matrix diffusion borehole OU2-MD2. Low flow sampling methods were used to collect samples from the matrix diffusion borehole because its diameter was too small for the packer assembly. A total of 17 samples, including one field duplicate sample, four equipment rinsate blank samples, eight field blank samples, and four trip blank samples were collected during this event.

Packer groundwater samples were collected after the required purge volume or duration had been reached. Groundwater screening samples were collected from with a submersible pump that discharged through Teflon[®]-lined polyethylene tubing, dedicated to each borehole. Sampling flow rates were adjusted to around 0.5 liters per minute. A sample was not collected when an interval was purged dry.

The open borehole (OU2-MD2) was sampled after an accumulation of approximately 1.8 feet of DNAPL was discovered at the bottom of the borehole during geophysical logging. HDR selected the sampling depths at borehole OU2-MD2 based on the following factors:

- The depths of the highest analytical results for CVOCs reported by the rock matrix diffusion subcontractor;
- Staining at fractures observed on the log for the optical televiewer indicated potential DNAPL discharge into the borehole; and
- Recommendations from the borehole geophysics subcontractor based on vertical flow within the borehole.

Screening samples collected from the open borehole were collected using EPA's Low Stress/Low Flow sampling protocol (SOP-FS-15, HDR 2015b).

All samples collected during the packer and OU2-MD2 vertical profile groundwater sampling were analyzed for TCL VOCs (Trace Volatiles, Method 524.2) at the Chemtech Consulting Group (Chemtech) Laboratory in Mountainside, New Jersey, under the EPA's Contract Laboratory Program (CLP). Sample information for the packer and OU2-MD2 vertical profile groundwater sampling is summarized in **Table 2-4**.

Well Sampling

Groundwater samples were collected from 29 wells, including two samples from different depth intervals in monitoring well OU2-2016-MW3, and two field duplicate samples. Six of the wells were monitoring wells installed during the OU2 investigation, three were extraction wells for the Curriculum Center groundwater treatment facility, 19 were existing monitoring wells, and one was a former supply well. The wells were located at the Curriculum Center and on three adjoining properties (**Figure 1-3**). Nine equipment rinsate blank samples, nine field blank samples, and five trip blanks were also generated during this sampling event.

All samples collected during the well sampling event were analyzed for TCL VOCs (Trace Volatiles, Method 524.2) at the EPA's Division of Environmental Sciences and Assessment (DESA) laboratory in Edison, New Jersey. Sample information for the event is summarized in **Table 2-5**.

Purging and sampling of the monitoring wells was conducted in accordance with the EPA's Low Stress/Low Flow protocol (SOP-FS-15, HDR 2015b). Monitoring well purging and sampling logs are presented in **Appendix I**.

The samples were collected from the three extraction wells for the Curriculum Center groundwater treatment facility from sampling ports at the treatment facility as follows:

- Groundwater in extraction well RW-7 was collected after purging the sampling port for a short duration because the system had been pumping from this well;
- Groundwater in extraction well RW-9 was collected after purging the piping for approximately 4 minutes with an estimated system flow rate of 5 gpm; and
- Groundwater in extraction well RW-6 was collected after approximately 3 minutes of purging at an estimated rate of 5 gpm.

Groundwater samples were collected for bacterial analysis from seven monitoring wells (MW-1, MW-13, MW-14, MW-16, OU2-MW1, OU2-MW6, and RD-9). Aestus recommended bacteria sampling to evaluate if some observed anomalies could be related to leakage from an upgradient sewer line or septic. The bacteria samples were delivered to a local laboratory (Ocean Systems Laboratory, Red Hook, St. Thomas). The analytical results for these samples were integrated into Aestus' final report (**Appendix C**).

2.2.9 Synoptic Water Level Measurements

Two rounds of synoptic water level measurements were completed during the FSRI. The first round (31 wells) was completed on February 21, 2017. The second round (30 wells) was completed on June 13, 2017. The former Tillett supply well was not accessible for the second round. All depth-to-water measurements were taken from a surveyed mark on the inner casing using an electronic interface probe or water level indicator. If a mark was not present, the measurement was made from the north side of the inner casing.

Information provided by the GWTF #1 operator indicated that the extraction wells at Curriculum Center were pumped at average daily flow rates between 11.0 and 12.6 gpm, with an average of 11.8 gpm, during the two weeks before the February 21, 2017 synoptic event (2/7-2/2017). The treatment system was in operation approximately 85 percent of the time during that two week period. GWTF #1 was not running from midnight to 9:30 a.m. and again after 1:13 p.m. on the day of the gauging event due to power outages. The average flow rate on the day of the gauging event was 11.4 gpm. Water level measurements were collected between 8:10 a.m. and 1:45 p.m.

GWTF #1 was on-line from June 1 through June 12 for 62 percent of the time before the June 13, 2017 gauging event. Flow rates during that period ranged from 8.5 and 21 gpm, and averaged 12.8 gpm. GWTF #1 was operating continuously on the day of the gauging event, with an average flow rate of 11.9 gpm. Water level measurements were collected between 6:56 a.m. and 10:10 a.m.

2.2.10 Long-term Water Level Monitoring/Transducer Study

Long-term water level monitoring was conducted at six shallow wells (BP-1, BP-2, BP-3, IW-1S, IW-2S, and MW-16) in the immediate vicinity of GWTF #1 at the Curriculum Center. Long-term water level monitoring was performed to establish long-term (seasonal) trends, and to gain a better understanding of the radius of influence and hydraulic capture of the groundwater extraction system.

The six wells were located to the north of the primary extraction well RW-7, at distances from approximately 10 to 46 feet from the primary extraction well (**Figure 1-4**). The depths of these wells ranged from 44.6 to 60.55 feet below ground surface, which is consistent with the shallow monitoring zone at the Site (**Table 2-3**).

RW-7 is the primary extraction well for GWTF #1, although RW-9 is also operated for short periods of time when the system is restarted after an alarm condition, to increase the rate of drawdown and to maintain hydraulic control. Both RW-7 and RW-9 are completed in the shallower, more productive portion of the aquifer. Extraction well RW-6, screened in the deeper, less productive zone and recovers only very slowly but exhibits significantly higher CVOC concentrations than the shallower extraction wells. RW-6 is pumped once a week for a period of one to 1.5 hours.

The six wells were monitored using pressure transducers. Transducers were installed on October 21, 2016 and set to record water levels at 5-minute intervals. The long-term monitoring period began on October 21, 2016 and ended on February 1, 2017. The transducers were checked intermittently during this period, and data were downloaded for interim review of trends and pumping influences.

Site operational requirements and equipment malfunctions resulted in data gaps for two (IW-1S and BP-3) of the six wells. The transducer in IW-1S was removed for a few days toward the end of the monitoring period so that geophysical logging of the borehole could be performed. Logging at well BP-3 had to be restarted on October 31, 2016 after the transducer was found to have slipped several feet as a result of the securing line coming loose. The transducer in BP-3 was also found to have malfunctioned sometime between

December 13, 2016 and January 31, 2017. As a result, data are not available for BP-3 from October 21 through October 31, and after December 13, 2016, when the last intermittent data download was made. HDR worked closely with the equipment rental vendor to retrieve the data, however, they were also unable to access the transducer or recover the data.

Precipitation data were obtained from the National Weather Service's National Climatic Data Center for the Redhook Bay station, located approximately 2.5 miles east of the Site. Precipitation data are presented in **Appendix J**. Operational data for GWTF #1 was provided by the plant operator (Carpenter, personal communication 2017; Guenther, personal communication, 2017). Operational information for the treatment facility is summarized in **Section 3.1.2** of the 2017 Annual RAPR.

2.2.11 Extraction System Capture

As originally envisioned in the FSRI Work Plan, the influence of the extraction system would be characterized by turning the treatment system off until water levels in extraction wells and monitoring wells had recovered to static conditions. Drawdown in response to the extraction system would then be monitored when the system was restarted. Recovery of water levels to static conditions was anticipated to take a few hours for the shallow wells being monitored. The system operator (Arrowhead) deferred approval of the approach to DPNR out of concern that recovery could take longer than anticipated and that the treatment system's operational goals might be negatively impacted. HDR and EPA requested approval from DPNR in late November 2016. Approval had not been obtained from DPNR. However, recovery and drawdown response conditions were captured by the transducers when the treatment system was offline for extended periods of time for repair and maintenance activities. These events were used to perform the capture zone evaluation. System shutdown approval from DPNR was no longer required for the evaluation.

2.3 Elevation/Location Survey

HDR subcontracted BCSC Dospiva, LLC (BCSC), of Christiansted, St. Croix, USVI, to conduct a location and elevation survey for the six monitoring wells and two rock coring boreholes installed during the FSRI. BCSC completed the field portion of the work on March 2, 2017. The survey consisted of measuring the elevations of the ground surface, top of outer casing, top of inner casing and measuring the horizontal coordinates of each well. BCSC provided tabulated well coordinates and elevation data and an AutoCad™ drawing with well locations. Elevation/location survey information is included in **Appendix K**.

2.4 Investigation-Derived Waste

IDW generated during the FSRI included:

1. Monitoring well development and purge water;
2. Groundwater generated during packer groundwater sampling;

3. Soil, rock cuttings, and rock core sections;
4. Residual drilling fluids;
5. Decontamination fluids containing wash/rinse water and decontamination chemicals; and
6. DNAPL.

Arrowhead Contracting, Inc. (Arrowhead) of Lenexa, Kansas, was subcontracted by HDR to provide IDW characterization and disposal services for the FSRI. Arrowhead's services included containing, sampling, analyzing, handling, transporting, and disposing the IDW from the above waste streams.

All liquid IDW generated during drilling operations, including well installation, packer testing and well development, and monitoring well sampling was temporarily stored in lined roll off containers and treated on-site at the Curriculum Center groundwater treatment facility (GWTF #1). Arrowhead also collected and analyzed four liquid IDW waste characterization samples. A total of 6,580 gallons of liquid IDW were treated by Arrowhead and discharged to Turpentine Run along with system discharge from regular system operations.

Solid IDW (rock cores, drill cuttings, and the sediment settled out in the liquid settling roll-off) was collected and stored in lined 20-cubic yard roll-off containers. The roll-off containers were staged in the rear of the Curriculum Center lot in the driller's staging area or along the fence of the groundwater treatment facility. Each container was sampled by Arrowhead and analyzed for the waste characterization parameters required by the Virgin Islands Waste Management Authority (VIWMA). The solid IDW (four roll-off containers in total) was disposed of at VIWMA's Bovoni landfill on St. Thomas following approval by VIWMA. The waste characterization results are presented in **Appendix L**. Disposal documentation was requested from VIWMA by Arrowhead before St. Thomas was impacted by Hurricanes Irma and Maria in September 2017 but had not been received at the time this report was written.

Approximately 15 gallons of water and one gallon of DNAPL were pumped from well OU2-MD2 on June 12, 2017 and temporarily stored in a 55-gallon polyethylene drum. On July 3, 2017, Arrowhead removed the pump and checked the well for DNAPL again and no DNAPL was detected at that time. Arrowhead subsequently conducted waste characterization sampling and analysis on the DNAPL and water. The DNAPL/water mix was secured inside the Curriculum Center treatment system building before Hurricane Irma impacted the USVI in early September 2017. Arrangements for transportation to the disposal facility on the U.S. mainland (the Veolia fuels-blending facility in New Jersey) will be made by Arrowhead once conditions on St. Thomas allow.

3 Physical Characteristics

The Virgin Islands are located at the northwestern end of a chain of small islands that form the Lesser Antilles. St. Thomas, the westernmost of the USVI, lies 44 miles east of Puerto Rico. St. Thomas is 13.5 miles long and 3 miles wide (32 square miles in area). St. Thomas is the second largest of the USVI after St. Croix. The spine of the island is formed by an approximately 800-foot to 1,200-foot high central ridge that slopes steeply to the north and south and is dissected by intermittent streams.

3.1 Demography

According to the U.S. Census, St. Thomas had a population of 51,634 in 2010, of which 7,479 lived in the Town of Anna's Retreat, the area around the Tutu Wells Superfund Site.

The land in Anna's Retreat is used for a variety of institutional and commercial uses. The VIHA property to the northwest of Curriculum Center includes office and maintenance areas and a police station. The VIDE Curriculum Center includes offices, maintenance areas, warehousing, and school bus parking. The area to the southwest of Curriculum Center includes the Metro Motors automobile dealership with car sales and services/repair departments, the Puma (former Texaco) service station, the Tutu fire station, and the Tillett Gardens restaurant/bar. Regional land-use in and around the Site is shown on **Figure 3-1**.

3.2 Meteorology

St. Thomas has a semi-tropical climate with little seasonal variation in temperatures. Average summer temperature ranges from 85 to 90 degrees. The average winter temperature ranges from 72 to 78 degrees. Rainfall averages are highest in September through October (greater than 5 inches per month) and lowest in February and March (less than 1.5 inches per month). Average annual rainfall is about 39.4 inches, with the bulk of the precipitation falling during relatively intense, short-duration and isolated storms. St. Thomas lies in the area of the trade winds; predominantly northeasterly winds that are strongest in winter.

The area of the Tutu Site is in the eastern portion of St. Thomas, which faces the prevailing easterly trade winds and receives higher average rainfalls than the west side. The 2016 climate review for Puerto Rico and the USVI indicated that estimated total rainfall was between 40 and 50 inches towards the western side of St Thomas, and over 60 inches in the area of the Site (NOAA 2017b).

The nearest weather station to the site is at Redhook Bay on the east side of St. Thomas, approximately 2.5 miles east of the site. Precipitation recorded at the Redhook Bay Station during the OU2 investigation is presented on **Figure 3-2**.

3.3 Topography and Drainage

The OU2 investigation area includes the Curriculum Center property and several adjoining properties within the Tutu Valley. The highest elevation near Curriculum Center is located at the VIHA property (approximate elevation 280 feet near Douglas Street), and the lowest elevation is southwest of the Curriculum Center near the intersection of Route 38/Smith Bay Road and Fisher Street (approximate elevation 190 feet). Topographic details of the area are presented in **Figure 3-3**.

At the Curriculum Center, terrain generally slopes from east to west, with a difference of approximately five to ten feet between the highest locations in the east and northeast, and the lowest point near the southwest corner along Smith Bay Road. Two parking areas, a higher paved area facing Smith Bay Road to the south, and a lower gravel area along its western side, are separated by eight feet of elevation. From the Curriculum Center, terrain slopes down hill northwest to the Joseph Gomez Elementary School, west to the Metro Motors car dealership, southwest to the Tutu Fire Station and south to Route 38/Smith Bay Road.

The Metro Motors car dealership and Tutu Fire Station lots generally slope southwest towards the Puma service station (formerly Texaco) at the intersection of Route 38/Smith Bay Road and Fisher Street. The Tillett Gardens property slopes north and west towards Route 38/Smith Bay Road.

The area around Curriculum Center is in the Upper Turpentine Run surface drainage basin of the Tutu Valley. Turpentine Run is an intermittent stream that conveys stormwater runoff after heavy rains. It crosses the adjoining school property to the north of the Curriculum Center, and the car dealership property to the west, where it is channelized in a buried culvert. From there, it follows the Tutu Valley, first to the south and later southeast.

Overland runoff from the OU2 investigation area during precipitation events is directed to Turpentine Run. Surface drainage from the paved areas reaches the culverted section of the creek through paved drainage swales along Smith Bay Road to the south and Fisher Street to the west. A small portion of the northern section of the OU2 area drains directly into the creek channel on the adjoining school property to the north.

3.4 Geology

3.4.1 Regional Geology

Bedrock geology at St. Thomas was formed by volcanism. Rock units that underlie the ridges of St. Thomas consist of lithified lava flows, flow breccias and tuffs, spilitic lava, andesitic breccia and tuff, and minor limestone beds intruded by Cretaceous and early Tertiary dikes and plugs. **Figure 3-4** shows the regional geology of the area (Renken et al 2002). These rocks have been uplifted and faulted, forming northward-dipping volcanic bedding and bedding planes (Donnelly 1966). Unconsolidated alluvial and coastal deposits were deposited within several small stream valleys near the shoreline.

The northward-dipping bedrock of St. Thomas is cut by two strike-slip fault sets that strike in northwest and northeast directions. The northeast trending faults parallel the orientation of the Anegada trough that lies to the south of the island. A third fault set strikes in a north-south direction. The alignment of major stream valleys and their drainage systems with well defined joint sets and major faults is indicative of structurally-controlled selective erosion and weathering of the bedrock (Jordan and Cosner 1973). Alluvium and beach deposits of the Quaternary Period (Holocene and Pleistocene Epochs) occur within some coastal embayments on St. Thomas and are not aerially extensive (**Figure 3-4**).

Bedrock in the upper Turpentine Run basin consists of two volcanic formations, the Water Island Formation and the younger Louisenhoj Formation, separated by a mild angular unconformity. The Water Island Formation consists of keratophyre flows and tuffs, spilite flows, and radiolarian tuffs. Erosional sediments are absent, and the entire volcanic sequence appears to have been extruded on the ocean floor. Overlying the Water Island Formation is the Louisenhoj Formation, which consists of augite andesite tuff and volcanic breccia layered with conglomerate (Cables Point Conglomerate lithofacies). The conglomerate contains pebbles and cobbles of Water Island Formation lithologies. The eruptive center during Louisenhoj time was probably located close to Pillsbury Sound, between St. Thomas and St. John. In western St. John and eastern St. Thomas this formation consists of coarse volcanic cone debris derived largely from a volcanic eruption at land surface (Donnelly 1966).

Alluvium in St. Thomas consists largely of silt, clay, sand and gravel lenses that grade coastward to sandy carbonate beach sands. The thickest alluvial deposits are near the coast and lower reaches of stream valleys. A narrow 200 foot-wide band, no more than 40 feet in thickness is present in the lower reach of Turpentine Run in eastern St. Thomas.

3.4.2 Site-Specific Geology

Surficial deposits consist of unconsolidated, poorly sorted mixtures of clay, silt, sand, gravel, cobbles, and boulders of alluvial origin. The alluvium is generally only two to four feet in thickness, but can locally reach thicknesses of 10-30 feet along the valley axes. Fill material has also been observed beneath paved roads and in the commercially developed central part of the valley (CDM 2001a). Approximately 10 feet of fill, consisting of sand and angular gravel, was observed at boring location OU2-MW5 during the OU2 FSRI, while as little as two feet of fill or soil was observed at other boring locations.

Bedrock at Curriculum Center is comprised of the Louisenhoj Formation. It consists of moderately weathered, fractured and faulted andesitic tuff and breccia. Andesite was encountered at all of the OU2 borings. Locally, the andesite is exposed on hills, steep slopes, and at road and other construction cuts. On gentle slopes of hills and along the valley axes, the bedrock is overlain by thin, unconsolidated alluvial deposits.

Bedrock fracture trace trends in the vicinity of the Site (CDM Federal 1992, Geraghty & Miller 1992) were presented in the Phase II Remedial Investigation (Geraghty & Miller 1995). The inferred fracture traces are shown on **Figure 3-5** along with the fracture

traces identified in the Environmental Photographic Interpretation Center (EPIC) Site Analysis Report (EPIC 1988). The predominant fracture trace orientations trend N68°E and N33°W in the vicinity of the Curriculum Center. An additional fracture, oriented N9°E, aligns with Turpentine Run. These three fracture trace orientations at and in close proximity to Curriculum Center are consistent with the three major regional fault trends discussed in literature.

The surface geophysical survey also identified local features that are consistent with regional fault trends. A northeast-southwest running fracture located on the north side of the Curriculum Center was identified from Aestus' GeoTrax Survey™ data. High-angle fractures, interpreted as a potential deformation zone, extended northwest-southeast along the bottom of the hill on the eastern side of Curriculum Center. A parallel fault runs northwest-southeast along the west side of the Curriculum Center. These structural geologic features and their relationship to fracture traces are shown on **Figure 3-5**.

The bedrock of St. Thomas has been described in literature as consisting of three separate hydrogeologic units; a thin soil zone and saprolite zone capable of absorbing large amounts of rainfall, a weathered bedrock zone (3 to 50 feet thick and rarely as much as 180 feet thick) and unweathered bedrock containing joints that are more numerous and more open at shallower depths (Cosner 1972). Bedrock fractures and joint weakness are best expressed in valleys and provide the greatest opportunity for additional groundwater supplies, particularly in the lower part of the valley, where overlying alluvium often acts as a source of recharge. Drainage basins and minor valleys have formed by differential weathering along fault and fracture zones and generally function as conduits for groundwater flow in St. Thomas (Jordan 1975).

Groundwater in both the alluvial and bedrock aquifers generally exists under unconfined or water table conditions. The water table depths have been reported as little as 5 feet to more than 100 feet bgs, with the greater depths occurring at higher land elevations. Groundwater is stored and transmitted in fractures in the bedrock. Since the groundwater is transmitted principally through fractures and the rock is more fractured along major lineaments, the bedrock aquifer demonstrates vertical, as well as horizontal anisotropy.

Recharge to the aquifers results from precipitation, and is therefore dependent on the frequency and intensity/volume of rainfall. The bedrock aquifer is infrequently recharged and usually only after heavy rainfalls or a series of storms that generate two or more inches of rainfall (Jordan 1975).

3.4.3 Site-Specific Hydrogeology

Hydrogeologic Units

An alluvial aquifer does not exist at the Curriculum Center. The thin deposits of alluvium and fill material are unsaturated with respect to groundwater. The relatively coarse grained deposits serve to transmit local recharge from rainfall to the underlying water table.

The water table is present at an approximate depth of 30 feet bgs at Curriculum Center. However, it ranges throughout the OU2 study area from approximately 65 feet bgs at

higher elevations northeast of Curriculum Center (i.e., the VIHA property) to approximately 15 feet bgs in topographically lower areas to the west and south of the center (i.e., the Metro Motors property).

The bedrock aquifer at Curriculum Center can be divided into two zones:

1. Shallow (<90 feet bgs) zone with water bearing fractures with a moderate permeability extend in a west-southwest direction on the north side of Curriculum Center. A few low permeability fractures extend north-south in front and behind Curriculum Center and extend in a west-southwest direction in front of Curriculum Center.
2. Deep (90 to 140 feet bgs) zone with very few water bearing bedrock fractures and low permeability.

The bedrock aquifer has both primary (matrix) and secondary (fracture) porosity. The primary or matrix porosity was estimated to be approximately 2 percent during the matrix diffusion investigation. In general, it has limited interconnectivity and therefore groundwater movement through these pore spaces is minimal. Typical values for secondary or fracture porosity ranges between 0.001 and 0.1 percent. However, due to relatively high interconnectivity (high permeability), groundwater flow in fractured rock is largely through the secondary system of joints and fractures. Groundwater flow rates in the shallow zone are relatively higher than in the deep zone due to relatively higher fracture frequency and hydraulic conductivity. The degree and orientation of fracturing combined with heat pulse flow measurements and packer testing performed during the FSRI indicate that only limited groundwater flow is occurring in the deep water-bearing zone. However, water-bearing fractures exhibiting weak inflow were observed to depths approaching 200 feet bgs during the FSRI.

Borehole and surface geophysical surveys indicated the presence of numerous fractures, both high and low angle, and conductive, water-bearing features that provide hydraulic connection between monitoring well locations in the shallow zone of the bedrock aquifer. The high-angle fractures and water-bearing features also extended into the lower zone but with less frequency. The strike of these fractures generally trended to the northwest and northeast, consistent with regional trends. Fractures dipped to the northwest and southeast and southwest. However they most commonly dipped to the northwest.

Rock core also showed evidence of weathering in the fracture zone on the north side of the Curriculum Center. The shallow rock observed in this area was more friable and generally showed a higher frequency of fractures. Intermediate stages of weathering like this (i.e. not completely weathered to clay minerals) can enhance the hydraulic conductivity of the material and create a preferential pathway for contaminant migration. The transmissivity of the shallow and deep water-bearing zones was not characterized in the FSRI. Previous investigations indicated that the transmissivity of the shallow zone ranged from 1,662 to 2,991 square feet per day, based on a pumping test conducted at extraction well RW-7. Although anticipated to be relatively lower, the transmissivity of the lower water-bearing zone has not been estimated.

Groundwater Flow

Water level measurements and calculated elevations for the two synoptic groundwater level monitoring events are provided in **Table 3-1**. Shallow and deep zone groundwater flow contour maps were produced for both events (**Figures 3-6 to 3-9**). Pumping activity, structural features (i.e., locations/trends of fracture zones/lineaments) and regional groundwater flow were considered when constructing the maps. Groundwater elevations for wells that were considered to be either significantly influenced by pumping at the Curriculum Center GWTF (RD-11 for the June 2017 event, IW-1 for both events) and wells that do not appear to be representative of the groundwater zone (e.g., deep wells OU2-MW4, OU2-MW5, and RD-5) were not used to construct the contour maps. The low productivity of these wells demonstrates the non-homogenous nature of fractured rock and indicates that there are areas of the occurrence and movement of groundwater is minimal.

Shallow water-bearing zone groundwater elevations and flow directions for the February and June 2017 events were very similar (**Figures 3-6 and 3-8**). Because of limited well control, groundwater contours and flow direction beneath most of the Curriculum Center building and extending to Route 38 were inferred. The contour maps indicate that shallow groundwater flow is generally to the south-southwest at the Curriculum Center property. The contours also show a slight convergence of flow along an axis approximately centered on Turpentine Run valley. The flow convergence implies the presence of a more hydraulically conductive pathway. The general direction of groundwater flow shown by the contour maps is consistent with ground surface topography and the regional flow of groundwater identified in previous investigations.

The area covered by the deep zone monitoring wells during the OU2 investigation was not as extensive as in the shallow zone, due to limited well control, but was sufficient to evaluate groundwater flow at the Curriculum Center property (**Figures 3-7 and 3-9**). Groundwater flow in the lower zone during both events was generally to the southwest, towards the axis of the north-south running portion of the Tutu Valley. February contours showed a stronger southwestward flow and June contours showed a stronger southward trend. The difference is a result of lower groundwater levels at wells RD-11 and RD-9 located in the area of the extraction system during the June event. Because of limited well control in the lower water-bearing zone, groundwater contours and flow direction beneath most of the Curriculum Center building and extending to Route 38 were also inferred.

In addition to flow direction, the contour maps were used to estimate the magnitude of horizontal and vertical hydraulic gradients at the Site. Average horizontal gradients observed in the shallow zone were reasonably consistent between the February and June monitoring events. Average horizontal hydraulic gradients in the general direction of plume migration were 0.011 ft/ft for the February event and, 0.013 ft/ft for the June event.

Average horizontal hydraulic gradients for the deep zone were also relatively consistent between the February and June events and were slightly higher than the shallow zone; possibly a result of the lower hydraulic conductivity in the deeper zone. Average deep

zone horizontal hydraulic gradients in the general direction of plume migration were 0.019 ft/ft for the February event and, 0.016 ft/ft for the June event.

The shallow hydraulic gradients are relatively high and would be indicative of a low hydraulic conductivity in porous media. However, in fractured rock the calculated gradient is more reflective of the effective or net hydraulic conductivity in the direction of the hydraulic gradient. Groundwater flow is limited to the secondary system of joints and fractures. In general this results in a longer pathway and a slower net velocity in the direction of the hydraulic gradient. Groundwater flow at the Curriculum Center can be expected to move most readily in a southwest direction because the conductive pathway and hydraulic gradient align reasonably well. In other areas of the Site, where conductive pathways are sub-parallel or perpendicular to the gradient, the longer pathway will result in a slower net movement in the direction of the hydraulic gradient.

Vertical hydraulic gradients were generally upward as was observed in previous investigations. Vertical gradients were calculated for the area of the treatment system and for the downgradient portion of OU2, in the area of monitoring well OU2-MW3. Upward gradients were generally stronger during the February event ranging from 0.08 ft/ft near the treatment system to 0.011 ft/ft near OU2-MW3. Upward gradients in June were estimated to be 0.025 ft/ft near the treatment system and 0.005 ft/ft in the downgradient area near OU2-MW3.

The difference in the magnitude of vertical gradients is largely due to the head differences in the lower water-bearing zone. Hydraulic head in the lower zone, in the area of the extraction system, was approximately 3.5 feet lower during the June event, when the system was in operation. Groundwater levels in the shallow zone were very similar between the February and June events.

The upward gradients are consistent with the results of previous investigations and with the Site's location in the discharge zone of the Turpentine Run drainage basin. Groundwater recharge zones in topographically high areas are present both to the west and east of the Site and ground surface topography drops steeply to the valley in the area of the Site. Historical groundwater withdrawals from the more conductive shallow water-bearing zone for water supply may have contributed to the upward gradient.

Based on the direction of plume migration, the location of stream valleys and the general trend of faults in the area, the movement of groundwater within the Turpentine Run valley is expected to be controlled by a regional north-south trending fracture. Differential weathering has most likely increased the secondary fracture density and hydraulic conductivity along the valley. The plume migration pathway also indicates that a second northwest trending fault may be impacting groundwater flow in the area of the former O'Henry Dry Cleaners facility. Both fracture trends are consistent with regional fracture trends in the St. Thomas area.

Local Groundwater Recharge and Withdrawal

Groundwater level data collected during the long-term groundwater level monitoring event are presented in hydrograph format in **Figure 3-10**. The figure includes a graph of

rainfall data recorded at the Redhook Bay weather station during the same period. Raw transducer data for water levels over time are included in **Appendix M**.

The graph of BP-2 provides a record of ambient groundwater level fluctuations without the influence of RW-7. The overall fluctuations in the baselines are on the order of 10 feet over the course of the monitoring period. Larger scale fluctuations are consistent with general trends in precipitation and are interpreted to represent ambient fluctuations in the potentiometric surface of the shallow zone resulting from direct recharge at the Site. Precipitation data for this investigation period were obtained from the National Weather Service's National Climatic Data Center for the Redhook Bay station, located approximately 2.5 miles east of the Site (NOAA 2017a).

Individual rain events totaling 0.5 inches or more appear to correspond with increases in groundwater levels within two to four days of the rain event. Rain events on the order of an inch or more appear to temporarily increase groundwater levels in the range of one to two feet and for a period of one to two weeks. The short term response to local rain events indicate that the shallow water-bearing unit is recharged locally.

A number of small scale fluctuations that do not clearly show the characteristic shape of a recovery or drawdown curve correlate with smaller scale rain events and may be a result of leakage into the well casings from stormwater runoff.

3.5 Extraction System Capture

Long term water level monitoring data show clear responses to pumping at RW-7 in five of the six wells that were monitored (BP-1, BP-3, IW-1S, IW-2S and MW-16), while little to no response was observed at well BP-2. A comparison of the hydrographs of BP-2 and the other wells shows a similar response to recharge, but a very different response to pumping. This indicates that the pumping influence of RW-7 is limited to the fracture, fault or interconnected set of fractures that encounter the other wells, but not BP-2. Contaminant concentrations provide further evidence that BP-2 is not in direct communication with the extraction system. Total CVOC concentrations in well BP-2 were more than an order of magnitude higher than in wells BP-1 and BP-3 although they are completed at the same depth and located in the same general area. A tracer study performed as part of the EAB pilot study similarly concluded that BP-2 had a limited connection to RW-7 (CDM 2004b).

The smaller scale recovery and drawdown events, ranging between 0.2 and 1.4 feet, generally correlate with periods of treatment facility downtime due to intermittent power outages, or electrical phase loss, and system maintenance periods. Power outages commonly occur on St. Thomas. The dates of these events are shown on **Figure 3-10** as individual points along the 178-foot horizontal gridline. It is these drawdown and recovery events that were used to evaluate the impact of extraction system pumping.

Drawdown and recovery in response to pumping at RW-7 is more evident in late December through February when groundwater levels are lower. The more obvious response during this period may be related to the lower transmissivity of the aquifer during drier months of the year. These data suggest that the lower pumping rates

currently employed at Treatment Facility #1 may result in a more limited capture of the plume during the rainy season.

Review of two individual drawdown and recovery events during the long-term monitoring event indicates that drawdown observed at MW-16 and IW-1S, located 10 feet and 45 feet from the operating recovery wells, was similar in magnitude, whereas wells located between these locations, such as BP-2 located at a distance of 26 feet, showed little to no response.

The magnitude of drawdown data observed both in the FSRI and the original aquifer test indicates an anisotropic response to pumping, common in fractured rock settings. The trend of more clear responses to pumping is roughly northeast-southwest, based on the responses at MW-16, BP-1, BP-3, IW-1S and IW-2S during this study, and at MW-16, MW-14 and MW-1 during the original aquifer test. Response to pumping appeared to be very limited along an east-west trend, based on the original aquifer test. However, more than a foot of drawdown was observed north-northeast of RW-7 during the FSRI (BP-1, BP-3, IW-1S, and IW-2S), and several tenths of a foot of drawdown were observed southwest of the pumping well at wells MW-1, MW-14 during the original aquifer test (CDM 2001a). Evaluations of the capture zone for Treatment Facility #1 were conducted previously in 1999 and 2004. In 1999, RW-7 was used as the pumping well during pre-design investigation aquifer testing. The well was pumped at a rate of 50 gpm for a period of 34 hours and 12 observation wells were monitored. The observation wells were completed in both the shallow and deep zones. A maximum drawdown of 3.25 feet was observed in the pumping well. Drawdown in response to pumping at RW-7 was observed in shallow zone wells MW-16 (2.58'), MW-14 (0.41'), MW-1 (0.33') and MW13D (0.05'). Among the wells with observed drawdown, MW-1 was the farthest from pumping well RW-7 (approximately 285 feet southwest). The report concluded that the long-term pumping response was consistent with radial flow to a well, although they indicated that there appeared to be evidence of non-radial flow in early stages of the test at short distances from the pumping well (i.e., fracture dewatering). The predicted theoretical radius of influence projected to 72-hours, using the Cooper-Jacob solution for aquifer parameters, was 750 feet from RW-7. However, the Cooper-Jacob solution does not take into consideration boundary effects or the potentiometric surface of the groundwater table (CDM 2001a). In 2004, as part of startup testing for the GWTF at the Curriculum Center, CDM conducted an aquifer test that consisted of pumping at extraction well RW-7 and monitoring of water levels and drawdown at nearby monitoring wells BP-1, BP-2, BP-3, IW-1S, IW-2S, and MW-16. Pumping rates varied during the test from around 22 gpm to approximately 48 gpm. Drawdowns ranging between three and 6.5 feet were observed at all wells. It was reported that, at the applied pumping rates, the system was effective in maintaining hydraulic control (CDM 2004a).

RW-7 is currently operated at a constant head of 148 feet above mean sea level (amsl), using a variable speed pump. Static groundwater levels measured at the six wells with transducers during the long-term monitoring study ranged from approximately 182 feet amsl to 172 feet amsl, indicating that drawdown at RW-7 was on the order of 34 to 24 feet. Information from the system operator indicates that the average pumping rate for this recovery well was approximately 10 to 11 gpm for the period from May 1, 2016 to April 30, 2017 (Arrowhead 2017).

The lower pumping rates and greater drawdown associated with the target pumping elevation suggest a significant drop in the well's specific capacity from pre-design testing levels, and indicates that the well might benefit from reconditioning. Assuming that RW-7 was a 100 percent efficient well at the time of installation, the drawdown observed in the aquifer appeared to be consistent with original specific capacity observed during pre-design testing. Based on the original specific capacity of approximately 15 gallons per minute per foot of drawdown, a maximum drawdown of 1.4 to 1.5 feet can be expected in the formation adjacent to RW-7. Under the hydraulic gradients measured in the shallow water-bearing zone during the February and June synoptic water level monitoring events, the limit of drawdown from RW-7 in a downgradient direction can be expected to be on the order of 150 feet.

A theoretical extent of drawdown cannot be estimated because of the variable response to pumping and there does not appear to be sufficient well control in the shallow water-bearing unit to define a capture zone using a potentiometric surface map. However, based on the responses to pumping observed in the long-term water level monitoring study and in the original RW-7 aquifer test, some general conclusions can be drawn. The influence of the pumping well appears to extend to distances on the order of tens of feet in an east-west direction and potentially a few hundreds of feet in the northeast-southwest direction in the shallow monitoring zone. Drawdown in the downgradient direction could be more limited as discussed in the previous paragraph.

Drawdown is limited to secondary porosity features such as faults and fractures with a direct connection to RW-7. As evidenced by the lack of response at BP-2, the drawdown is independent of distance where the fracture interconnection does not exist. The extent of capture in hydraulically upgradient areas, to the north-northeast of RW-7, is likely to approach the full distance of drawdown and the full extent of the contaminant plume in the shallow zone. Capture to the south (downgradient) and to the east and west will be limited to a zone where the ambient hydraulic gradient is overcome by drawdown from the extraction well. Capture in the shallow zone is unlikely to extend to the limits of the plume in these directions.

Based on the results of the surface geophysical survey, capture along conductive pathways associated with the lineament along the north side of the Curriculum Center, the fault along the west side of the Center and the deformation zone along the east side of the Center, could extend to greater relative distances. However, these areas were not part of the long-term monitoring study and the anticipated influence of the extraction system in these areas cannot be verified at this time. There has been no conclusive evidence to date that the influence of the extraction system extends measurably into the deep zone. The lower water levels in RW-11 and RW-9 measured in the June event suggest that the possibility exists. However, without continuous monitoring data a direction connection with extraction system cannot be made. Therefore, based on the results of the FSRI, contaminants that migrate to the deep zone are unlikely to be captured by the current extraction system.

4 Cultural Resources Survey

HDR conducted a Phase Ia archaeological site review and sensitivity assessment based on site literature review, site visitation, and boring log review for the Tutu Wells Superfund Site OU2 area (the Project area). The Phase Ia investigation was carried out in response to the potential impact of the installation of monitoring wells for FSRI/FS activities. The purpose of the site review and sensitivity assessment was to identify archaeological and historical resources within one mile of the proposed area of potential effects (APE) and determine, through site literature consultation and a visit to the proposed Project APE, any potential subsurface archaeological and historical resources that may be affected by project activities. The review was prepared in compliance with Section 106 of the National Historic Preservation Act of 1966, as amended, and adhered to Department of the Interior and USVI State Historic Preservation Office (USVISHPO) Standards for Cultural Resource Investigations.

HDR's archaeologist conducted background research at the USVISHPO, located in the St. Thomas regional library, on all archaeological sites and listed, eligible, or inventoried architectural structures within one mile of the proposed Project location in December of 2016. A Site visit was performed on December 10, 2016. The report for the Phase Ia archaeological site review and sensitivity assessment (HDR 2017) was submitted under separate cover and the findings and recommendations are summarized below.

4.1 Results of the Archaeological Survey

Both the investigation and assessments from the USVISHPO revealed no concerns regarding subsurface archaeological deposits within the proposed APE. The investigation consisted of literature review and physical inspection of the proposed well locations by the archaeologist. Observations during the investigation indicated that the APE, which is situated on rocky slopes with exposed bedrock at or near surface, has been subject to extensive modification caused by modern anthropogenic fill deposition, grading, and asphalt paving.

4.2 Results of the Architectural Survey

The investigation revealed no concerns regarding impacts on buildings or structures from the Tutu Wells Project area. Well placement activities, consisting of drilling within the area, posed no impact, physical or visual, on any listed or eligible structure within a 0.5-mile (0.8-km) radius of the Project area.

4.3 Recommendations

No archaeological remains were identified within the Project's direct APE (ground disturbance footprint). The APE lacks the potential for intact archaeological deposits owing to shallow sediments overlying bedrock and the extensive modification of the area caused by modern activity such as fill deposition, road grading, and paving. The APE of exposed bedrock is characteristic of the Project area landform noted in soil characterizations and corroborated by borehole profiles and field observation. Document

review and geomorphologic assessment demonstrates that there has been extensive fill and paving throughout the APE that would have heavily impacted and likely eradicated any shallow cultural deposits. Furthermore, USVISHPO has determined that activities within the APE would not adversely affect historical or archeological resources listed in or eligible for inclusion in the National Register of Historic Places (NRHP) nor would they adversely affect any potential subsurface archeological deposits, historic buildings, or historic structures.

The Cultural Resources Survey report is included in **Appendix O**.

5 Nature and Extent of Contamination

This section describes the nature and extent of chemical constituents detected in groundwater and the rock matrix during the OU3 FSRI. The sampling and analytical methods are discussed in detail in **Section 2**. Applicable or Relevant and Appropriate Requirements (ARARs) and To Be Considered (TBCs) materials are presented in **Section 5.1**. Contaminants of Concern (COCs) are discussed in **Section 5.2**. Data sources are discussed in **Section 5.3**. A summary of existing groundwater data is discussed in **Section 5.4**. The results of the OU2 FSRI investigation and their evaluation are presented in **Section 5.5**.

5.1 Applicable and Relevant and Appropriate Requirements (ARARs)

Section 121 (d) of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) states that remedial actions must attain a degree of cleanup of hazardous substances, pollutants, and contaminants which will assure protection of human health and the environment. Section 121 (d)(2)(A) provides that the cleanup must meet certain standards, requirements, criteria and limitations derived from specified Federal environmental laws. This section also provides that the cleanup must meet certain standards, requirements, criteria and limitations derived from State or territory environmental or facility siting laws if these are more stringent than the Federal standards or criteria, if these State or territory standards come from an approved, delegated program and have been identified by the State in a timely manner.

To determine whether a standard, requirement, criterion or limitation is to be met, EPA must first determine whether that standard, requirement, criterion, or limitation is legally applicable to the hazardous substance or pollutant or contaminant of concern, or is relevant and appropriate under the circumstances of the release, or threatened release, at the site. A standard, requirement, criterion, or limitation that is legally applicable or has been determined by EPA to be relevant and appropriate for a particular cleanup is an ARAR.

In addition to ARARs, EPA and the State or territory may, as appropriate, identify other Federal, State, or territory advisories, criteria, guidance, or proposed but non-promulgated standards to be considered in developing the remedy for a particular site. Although not sources of potential ARARs, because they are neither promulgated nor enforceable, the information in these sources is TBC in developing a protective site remedy.

Potential groundwater ARARs include relevant standards from the Safe Drinking Water Act MCLs (40 CFR 141). The USVI do not have groundwater protection standards or guidance values. Potential cleanup standards (PCS) have been identified at the Federal MCLs listed in **Table 5-1**. The potential cleanup standards have been selected here for the purpose of identifying COCs and delineating the nature and extent of COCs in groundwater. EPA will select the final cleanup standards for OU2 in the ROD.

5.2 Contaminants of Concern

Six CVOCs were identified as contaminants of concern (COCs) during the OU2 FSRI, based on the site history, frequency of detection, and the exceedance of potential cleanup standards: PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, 1,1-DCE, and VC. The COCs are listed in **Table 5-2**, along with their potential cleanup standard values.

5.3 Sources of Analytical Results

The LTRA groundwater sampling results (Arrowhead 2017) summary is presented as **Table 5-3**. The LTRA extraction well RW-6 influent results for the 2016 to 2017 monitoring period are summarized in **Table 5-4**. The FSRI rock matrix sampling results summary is presented in **Table 5-5**, with the complete analytical results and rock matrix sampling report presented as **Appendix B**. The OU2 FSRI packer test screening sample range of detected contaminants is summarized in **Table 5-6**. Complete analytical results of the packer test and OU2-MD2 vertical profile groundwater samples are presented in **Table 5-7**. Groundwater screening analytical reports are in **Appendix P**. The FSRI Groundwater sampling analytical results are presented in **Table 5-8**. Groundwater sampling analytical reports are in **Appendix Q**. There is an adequate amount of data of known quality to define the nature and extent of contamination for the purposes of moving forward to the FS; however the extent (aerial and vertical) of contamination has not been defined to the MCLs.

In addition, analytical results for the potable water used during drilling were provided by the driller. The driller used potable groundwater from the Mohogany Run Golf Course. Water was delivered to the site and stored in a temporary water tank for use during the subsurface investigation. A water sample from the temporary water tank was also tested by the Cascade lab for verification purposes. No chlorinated VOCs, including all of the COCs, and BTEX compounds analyzed were detected. The results for this sample is included in the analytical results section of the Matrix Diffusion report (**Appendix B**)

5.4 Summary of Existing Groundwater Data

A large amount of historical and recent groundwater data exists for the Tutu Wells Superfund Site. As part of the LTRA for the Tutu Wells Superfund Site, groundwater samples were collected from 30 groundwater monitoring wells and residential wells on a quarterly basis from 2004 to 2007. Since 2007, samples have been collected on an annual basis. The sampling results from 2004 to 2013 were reported in RAPRs prepared by CDM. Since 2014, RAPRs have been prepared by the treatment system O&M contractor Arrowhead and submitted to DPNR.

Of the 30 wells sampled annually, nine wells (MW-1D, MW-2, MW-13D, MW-14, MW-15, RD-5, RD-9, RD-13, and the former Tillett supply well) are in or near the OU2 investigation area. In addition, two extraction wells for the groundwater treatment system at the Curriculum Center, RW-6 completed in the deep zone and RW-7 completed in the shallow zone, are sampled monthly. A summary of the ranges of individual COC concentrations for the nine annually monitored wells, frequency of detection and

comparison to potential cleanup standards for the most recent sampling event in **Table 5-3**. These data are presented in the most recent available RAPR (Arrowhead 2017) for the period of May 1, 2016 through April 30, 2017.

Of the five COCs detected during the most recent annual sampling event (PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and VC), one or more exceeded the respective potential cleanup standard in five of the nine wells. The COC 1,1-DCE was not detected above the reporting limit in any of the samples. The highest concentrations of PCE, the two DCE isomers and VC were detected at downgradient wells MW-1D and RD-13, located in the southwest portion of the Curriculum Center property. The highest concentration for TCE was detected at source area well RD-9.

The results of monthly extraction well sampling during the May 1, 2016 through April 30, 2017 reporting period, indicated that total COC concentrations ranged from 26.8 to 134.36 µg/l at RW-7 and from 4,235 to 34,210 µg/l at RW-6. Shallow extraction well RW-7 is the primary pumping well for the remediation system. Deep extraction well RW-6 is pumped once per week. Shallow extraction well RW-9, which is completed across the same interval as RW-7, is not sampled during monthly extraction well sampling. A summary of COC concentrations at deep extraction well RW-6 is provided in **Table 5-4**.

5.5 OU2 Analytical Results

5.5.1 Rock Matrix Diffusion Testing

This section describes the nature and extent of VOCs found in the rock matrix during the core drilling in the fractured rock aquifer at two locations well locations. Rock matrix samples were collected from OU2-MD1 and OU2-MD2 by methods described in **Section 2.0**. The VOC analyses were conducted in an on-Site and off-Site laboratory, and the results were used to guide real-time decision making during the field investigation of this FSRI. The rock matrix results were converted to porewater results as described in Appendix B. These pore water values are considered screening values only.

No COCs were detected in 167 rock core samples collected from 33 to 200 feet bgs at OU2-MD1. No open bedrock fractures were identified in borehole geophysics completed in OU2-MD1. OU2-MD-1 is not located near any photo-linear features or bedrock lineaments during fracture trace analysis completed during OU2.

COCs were detected in 15 of 157 rock core samples collected from OU2-MD2. The detection of COCs in rock core samples collected from OU2-MD2 correlate to fractures at 49 feet, 67 feet, 106 feet, 108 feet, 132 feet, 165 feet and 166 feet bgs at location OU2-MD2. PCE was detected in 14 samples (29.9 to 14,300 µg/kg), TCE in 7 samples (28.5 J to 457 µg/kg), and cis-1,2-DCE in 11 samples (25.8 J to 654 µg/kg). **Figure 5-1** presents a graph of the calculated porewater concentrations with borehole images. Porewater values were calculated from rock matrix values using the following equation:

$$C_w = \frac{C_t P_{b(wet)}}{(dry) + \Phi}$$

Where: C_w = matrix pore water concentration

C_t = matrix or bulk rock concentration

$P_{b(wet)}$ = wet bulk porosity

(dry) = dry bulk porosity

K_d = distribution coefficient ($K_{oc} \times f_{oc}$)

Φ = matrix porosity

Analysis for the presence of chlorinated solvents was performed on rock matrix samples using a methanol extraction procedure. While the detection limits for this method are higher than typical CLP reporting limits for soil, they are in the range of 5 to 10 times those reporting limits. The detection limits for rock matrix analysis typically ranged between 25 and 45 ug/kg.

PCE (29.9 µg/kg) was detected in a rock core sample collected from 0.3 ft above a fracture at 49.95 feet bgs, which coincides with a nearby conductive fracture identified by borehole geophysics. PCE was the only COC detected at this depth.

PCE (14,300 µg/kg) was detected in a rock core sample collected from 66.95 feet bgs. This concentration is more than two orders of magnitude greater than any other result. The calculated porewater concentration for this sample was 48,000 µg/l, which is approximately 24 percent of the solubility value for PCE and indicative of the potential presence of NAPL. A concentration equivalent to 1 percent of a compound's solubility limit in water is generally accepted as an indicator of the presence of free phase or residual saturation levels of NAPL. Cis-1,2-DCE and TCE were also detected at this depth (144 µg/kg and 229 µg/kg respectively). This sample was collected near a calcite-filled fracture, but since no samples were collected at incremental distances from the fracture, it could not be determined how far into the matrix the contaminant mass may have diffused at this location.

PCE (152 µg/kg) was detected in a rock core sample collected from 169.85 feet bgs. Cis-1,2-DCE and TCE were also detected at this depth (144 µg/kg and 86.1 µg/kg respectively). Conductive fractures were also identified by the borehole geophysical investigation at this approximate depth. The COCs detected in the OU2-MD2 rock core are summarized in **Table 5-5**.

Rock core data indicate that contaminants have diffused at least 0.3 to 0.6 ft into the matrix and that the highest concentration is not at the fracture face. These data show there are concentration gradients both outward toward the fracture and inward diffusing further into the rock from the fracture face. This suggests that the peak concentration in the fracture occurred in the past and contaminant diffusion is both out of the matrix into fracture water (back diffusion) and diffusion further into the rock from the fracture face.

Because the rock matrix diffusion investigation was limited to these two locations, the full horizontal and vertical extent of COC contamination of the rock matrix cannot be determined. However, the data indicate that contamination of the rock matrix can be expected in areas where high levels of COCs are detected in groundwater and that compounds are currently and will likely continue to back-diffuse from the rock matrix and impact groundwater in the OU2 area.

The matrix diffusion report prepared by Cascade (**Appendix B**) includes results of the rock core chemical analyses, estimates of porewater concentrations, and total VOC mass as well as a discussion of the methods used to estimate porewater concentrations.

5.5.2 Packer Groundwater Sampling

Groundwater packer samples were collected from four boreholes. Three packer groundwater samples were collected at OU2-MW1 at the upgradient VIHA property (60 to 70 feet bgs, 64 to 73 feet bgs, and 75 to 85 feet bgs). Groundwater packer samples were also collected from OU2-MW2, OU2-MW3, and OU2-MW-6 at Curriculum Center. One packer groundwater sample was collected at OU2-MW2 (47 to 55 feet bgs). Three packer groundwater samples were collected at OU2-MW3 (85-95 feet bgs, 122 to 132 feet bgs, and 135 to 149 feet bgs). Two packer groundwater samples were collected at OU2-MW6 (60 to 70 feet bgs and 115 to 125 feet bgs).

COCs were detected in all of the packer groundwater samples. Concentrations of all COC were below potential cleanup standards in groundwater collected from upgradient borehole OU2-MW1. Concentrations of two to four COCs exceeded potential cleanup standards in all packer test intervals from the three boreholes located at the Curriculum Center. Specifically:

- OU2-MW1: COCs were detected in groundwater collected from 75-85 feet bgs. The concentration of COCs was below the potential cleanup standard.
- OU2-MW2: PCE, TCE, cis-1,2-DCE, and VC were detected in groundwater collected from 47-55 feet bgs at concentrations that exceeded potential cleanup standards.
- OU2-MW3: PCE, TCE, and cis-1,2-DCE were detected in groundwater samples collected from 85-95, 122-132 and 135-149 feet bgs at concentrations that exceeded potential cleanup standards.
- At OU3-MW6: PCE and TCE were detected in groundwater samples collected from 60-70 and 115-125 feet bgs at concentrations that exceeded potential cleanup standards. Cis-1,2-DCE was detected in groundwater collected both intervals but only exceeded potential cleanup standards in the deeper interval.

Concentration of COCs in packer groundwater samples are summarized in **Table 5-6** and the complete analytical results for packer groundwater samples are presented in **Table 5-7**.

Packer groundwater samples were collected to determine the highest concentration of COCs in each borehole. These data were used to determine the depth to install the well

screen for wells OU2-MW1 and OU2-MW2. These data were used to identify the proper pump depth in future groundwater sampling events as wells OU2-MW3 and OU2-MW6 were completed as open hole wells (**Figure 1-4**). Packer groundwater sampling data are presented in **Appendix P**.

5.5.3 OU2-MD2 Vertical Profile Sampling

Groundwater samples were collected from seven targeted depths within rock matrix diffusion borehole OU2-MD2 using low flow sampling methods because the borehole diameter was too small to permit the use of the packer assembly. Several of the samples appeared to be impacted by DNAPL based on PCE concentrations that equate to 1 to 14.5 percent of the PCE solubility limit. Results of borehole geophysical logging indicated that the DNAPL may have entered the open borehole through a fracture at a depth of approximately 67 feet then accumulated in the bottom of the borehole. The analytical data are summarized with the packer groundwater sampling data in **Table 5-7**.

5.5.4 Monitoring Well Groundwater Samples

This section describes the nature and extent of VOCs in groundwater collected from monitoring wells completed in the fractured bedrock. Groundwater samples were collected from conventional shallow bedrock wells and from open-hole wells.

COCs were detected in all groundwater samples collected from the 26 monitoring wells and three treatment system extraction wells during the February/March 2017 sampling event. Up to six COCs were detected, including (in order of frequency), PCE, TCE, VC, cis-1,2-DCE, trans-1,2-DCE, and 1,1-DCE. These compounds exceeded potential cleanup standards in 25 of the 29 well samples. The analytical data are summarized in **Table 5-8**. The locations of the exceedances are shown in **Figure 5-2**.

The highest concentration of VOCs in the shallow (<90 feet bgs) portion of bedrock was detected in groundwater collected from IW-1 (depth of 85 feet bgs). Groundwater collected from this well contained cis-1,2-DCE (33,000 µg/l), VC (12,000 µg/l), TCE (5,800 µg/l), PCE (4,100 µg/l), trans-1,2-DCE (1,400 µg/l) and 1,1-DCE (170 µg/l). These data show reductive dechlorination has degraded the PCE so that the highest concentrations are cis-1,2-DCE and VC. An evaluation of complete reductive dechlorination to ethene could not be performed because samples were not analyzed for dissolved gases (methane, ethane, ethene). However, an EAB pilot study completed in 2004, did analyze for dissolved gases and concluded that complete significant reductive dechlorination to ethene was not occurring in the shallow zone and that it was occurring in the deep zone (IW-1, IW-2 and RW-6). There was also a strong correlation between mg/l concentrations of vinyl chloride and ethene. Based on that correlation, it is likely that complete degradation to ethene continues at IW-1, IW-2 and RW-6 and may also be occurring at RD-9. The reductive dechlorination is likely driven by co-located petroleum hydrocarbons and/or septic waste.

The spatial variation in the concentrations of CVOCs in the shallow water bearing zone shown on **Figure 5-2** show the heterogeneous nature of the fractured bedrock aquifer.

Groundwater in the shallow water-bearing zone generally flows to the west-southwest to OU2-MW2 and then more to the southwest towards OU2-MW3.

PCE (2,500 µg/l) detected in OU2-MW4 with relatively low concentrations of TCE (130 µg/l) and cis-1,2-DCE (140 µg/l) and VC (2.2 µg/l) shows that some PCE from the source area or an unknown location of DNAPL is contributing PCE to this well. These data show very little reductive dechlorination in this portion of bedrock. Groundwater containing mostly PCE migrates to the southwest OU2-MW4 towards OU2-MW5.

Very high concentrations of CVOCs were detected in groundwater collected from RD-9 (depth 97.5 feet bgs) located north of Curriculum Center near IW1-85. Groundwater collected from RD-9 contained; cis-1,2-DCE (160,000 µg/l), PCE (92,000 µg/l), VC (38,000 µg/l), TCE (29,000 µg/l), trans-1,2-DCE (2,300 µg/l) and 1,1-DCE (400 µg/l). The concentration of PCE (92,000 µg/l) detected in the sample from RD-9 was equivalent to 46 percent of its solubility limit, indicating the potential presence of PCE product. Bedrock at these depths contains very few fractures and has a correspondingly low permeability. Groundwater containing high concentrations of CVOCs in the deep portion of bedrock is not migrating very fast or very far. However, the high concentrations of CVOCs could be diffusing into the porewater in bedrock matrix creating a secondary source in this area. These data are shown on Figure 5-2. The distribution of CVOCs is consistent with groundwater flow.

The percent of total ethenes (PCE, TCE, DCE, cis-1,2-DCE + trans-1,2-DCE, and VC) is shown as pie diagrams for each well in **Figures 5-3** and **5-4**. The size of the pie is proportional to the concentration of total CVOCs in the groundwater sample. The data presented on **Figures 5-3** and **5-4** show the portion of the PCE that has been reductively dechlorinated on the north side of Curriculum center and the portion of the PCE that has not been reductively dechlorinated on the south side of Curriculum Center. These data show the heterogeneous nature of the groundwater flow system and the possibility that there are multiple source areas that may contain DNAPL.

Groundwater collected from four wells on the perimeter of Curriculum Center did not exceed potential cleanup standards. Two of the wells (MW-13 and OU2-MW1) are located upgradient of the Curriculum Center with total depths of 80.5 and 85 feet bgs, respectively and two (MW-14 and MW-17) are located to the west and cross-gradient to the plume. MW-14 and MW-17 are shallow wells with total depths of 45 and 13.5 feet bgs, respectively.

The depth relationship between the CVOCs detected during the OU2 FSRI and the downgradient plume is shown in cross section on Figure 5-5. The cross section is located along the approximate center line of the plume. Analytical results are posted at sample collection depths converted to elevation. January 2017 LTRA analytical results were used for the downgradient portion of the plume. Results of the surface resistivity survey and fracture projections from the borehole televiewer survey were included to support the distribution of contamination in the OU2 study area.

In general, the cross section shows that contamination detected in the OU2 FSRI is consistent with the offsite plume in terms of elevation, with the possible exception of

deep contamination found at OU2-MW3. However, when the upward hydraulic gradients, measured during synoptic water levels monitoring events, are considered The cross section shows that the deeper contamination detected at OU2-MW3 is reasonably consistent with the depth of the offsite plume when upward vertical hydraulic gradients are considered.

Toluene was detected at low concentrations, ranging from 0.82 to 4.7 µg/l, in eight groundwater samples (Table 5-8). Several chlorobenzenes were also present in these samples at low concentrations. Light non-aqueous phase liquid (LNAPL) was observed at monitoring well IW-1 during borehole geophysical logging. LNAPL has reportedly been observed at IW-1. LNAPL was not present when groundwater samples were collected from this well. The groundwater collected from this well did not contain high concentrations of toluene (1.5 µg/l), chlorobenzenes (totaling 39.4 µg/l), or other compounds with specific gravities less than one that would indicate the presence of LNAPL.

Groundwater samples were also analyzed for total and fecal coliform bacteria. Fecal coliform bacteria were not present in any of the samples, while total coliform bacteria were detected in samples from five of the seven wells (MW-13, MW-14, MW-16, OU2-MW1, and RD-9). Total coliform bacteria were not detected in groundwater collected from wells MW-1D and OU2-MW6. The data indicate that an upgradient septic system was not the most likely source of the bacteria, as the signature fecal coliform was not present. Total coliform bacteria are commonly present in soil and contribute to soil development. The laboratory report for the bacteria samples are appended to the Aestus geophysical report, included in Appendix C.

6 Fate and Transport

6.1.1 DNAPL

DNAPL was discovered at the bottom of rock matrix borehole OU2-MD2. Repeated measurements with an oil-water interface probe conducted between January and early March 2017, and again in June 2017, indicated that the depth to the top of the DNAPL did not significantly change, with measurements ranging between 198.05 feet to 198.10 feet bgs. DNAPL was pumped from OU2-MD2 borehole on June 12, 2017 (**Section 2.4**). Follow-up gauging of the borehole with an oil-water interface probe on July 3, 2017 indicating that additional detectable quantities of DNAPL had not accumulated at the bottom of the borehole.

Following the discovery of the DNAPL in borehole OU2-MD2, nearby wells were gauged for the presence of DNAPL (OU2-MW2 and RD-9). The oil-water interface probe did not indicate measureable thicknesses of DNAPL at these wells. However, very small brown oil-like droplets and staining were observed on paper towels wrapped around the probe at well OU2-MW2, after the initial gauging had not indicated the presence of a measurable DNAPL thickness.

The presence of DNAPL in the saturated or unsaturated portion of site bedrock had been suspected in prior investigations, going back to the 1995 RI (Geraghty & Miller 1995). In addition to the physical presence of DNAPL, dissolved-phase concentrations of PCE, TCE, cis-1,2-DCE and VC were present at 1 percent or more of their aqueous solubility limits.

PCE detected in a sample and duplicate sample at RW-6 (8,800 µg/l and 12,000 µg/l respectively) indicate 3.4 and 9.5 percent of the PCE solubility limit. PCE detected in the sample from RD-9 (92,000 µg/l) indicate 46 percent of the PCE solubility limit. In addition to samples from these two wells, concentrations of cis-1,2-DCE and PCE either approached or slightly exceeded 1 percent of their solubility limits in samples from wells IW-1, IW-2, OU2-MW3, OU2-MW4 and RW-8. The completion depths of these wells were either in the deep monitoring zone or extended from lower elevations of the shallow zone into the deep zone.

Wells RW-6 and RD-9 are both completed in the deep monitoring zone. RD-9 is approximately 15 feet from the northern wall of the Curriculum Center and within close proximity of the original source areas. The presence of concentrations representing more than 1 percent of the solubility limits for PCE, TCE and VC in the deep monitoring zone indicates that a preferential pathway to depth, such as a high-angle joint, fracture or fault may exist in this area. The presence of this type of feature along the northern wall of the Curriculum Center is consistent with both the location of fracture traces identified in previous investigations and the lineament identified in the surface geophysical survey performed as part of the FSRI.

Wells IW-1, IW-2 and RW-6 are located to the north and northwest of both the source area and extraction well RW-7. The presence of high PCE concentrations at these locations indicates either the presence of a different source area local to these wells or

that DNAPL has moved independent of both the extraction wells and the hydraulic head distribution at the Site. The location of a former drum storage area and the orientation of open fractures observed in the borehole geophysical investigation indicate that both of these scenarios are possible. Well RW-6 is located at the northwestern edge of the lineament, approximately 50 feet from the building. Wells IW-1 and IW-2 are located further to the north and approximately 70 feet from the building.

PCE, detected at approximately 1 percent of its solubility limit, in monitoring wells OU2-MW3 and OU2-MW-4, is not consistent with previously identified source areas. These wells are located near the northwestern and southeastern corners of the Curriculum Center. The presence of PCE at these levels could be explained by separate unknown sources, or they could indicate that these wells are located along fractures that directly connect them to locations where DNAPL has migrated to depth. The locations of these wells both appear to be hydraulically downgradient of known sources based on the current understanding of secondary porosity features and the distribution of hydraulic head in the area. The relative concentrations of individual compounds detected at OU2-MW-3 is generally consistent with results from OU2-MW-2 and the relative concentrations at OU2-MW-4 are consistent with OU2-MW-6 results providing further evidence of direct connections between these well locations.

6.2 Introduction

This section discusses the migration potential and probable environmental fate of COCs identified at the Curriculum Center (OU2). First, probable contaminant transport and attenuation mechanisms are discussed in the context of a fractured sedimentary bedrock environment, where contaminant transport is dominated by advection with minor dispersion and molecular diffusion effects. Next, the transformation processes are discussed. This information is synthesized to form the site conceptual model presented in **Section 7**.

6.3 Contaminant Transport and Attenuation Mechanisms

This section provides an overview of fluid flow mechanisms relevant to dissolved contaminant transport in fractured sedimentary rock.

6.3.1 Advection

Advection is the movement of dissolved or suspended chemicals by the displacement of the fluid (i.e., groundwater). As such, advection moves dissolved or suspended chemicals along, not across, groundwater flow paths. Advection is often the dominant transport process in the movement of chemicals in groundwater, especially where the aquifer material is composed of coarse granular material. Studies of contaminant migration in granular material generally estimate the advance of the leading edge of the aqueous mass by dividing the average linear groundwater velocity by the effective porosity of the formation (Freeze and Cherry 1979).

When this concept is applied to a fractured rock setting in which the advective transport is occurring in a network of fractures, the effective porosity of the fracture network is

generally several orders of magnitude lower than in granular media (rock matrix). The net effect is that the calculated linear groundwater velocity in the fractured media is very high. However, several field studies have shown that the actual rate of advance of the leading edge of the aqueous mass in fractured sedimentary rock can be lower than the calculated (predicted) value. The ratio between the calculated average linear velocity and the observed advance rate of the leading edge of the aqueous mass is referred to as plume front retardation (Lipson et al, 2005), and is generally thought to be a result of the net effect of diffusion (into a porous rock matrix), sorption, facilitated transport, dispersion, volatilization, and transformational processes. These processes are further described below.

6.3.2 Diffusion

The traditional understanding of groundwater systems pre-supposed that mass transport due to diffusion is negligible relative to transport due to advection and dispersion. However, studies conducted over the past two decades have increasingly focused on the importance of matrix diffusion of dissolved contaminants as a transport process in fractured sedimentary rock environments.

The driving force for diffusion of dissolved contaminant mass into the sedimentary rock matrix is the concentration gradient between the aqueous phase present at the fracture surface and the immobile pore water in the matrix. Parker et al. (1994) investigated DNAPL dissolution and subsequent diffusion in fractured porous media, and presented a detailed conceptual model for solute transport in fractured sedimentary bedrock. In this model, flow of immiscible-phase liquids in fractured rock is expected to occur almost exclusively in the fractures. The immiscible-phase liquids will migrate through the fractures and eventually diffuse into the primary porosity of the bedrock depending on the concentration gradient and the primary porosity of the bedrock.

In the early stages, diffusion into the rock matrix can be considered an attenuation process (Lipson et al., 2005). After an extended period of time, as clean water is flushed through the fractures, the concentration gradients adjacent to the fractures reverse, resulting in contaminant removal from the rock matrix at a rate controlled by diffusion and desorption from the matrix. This process is termed “back-diffusion”. Removal of mass due to back-diffusion takes longer than the time period for inward diffusion due to much lower concentration gradients in the reverse direction. In this scenario, the impacted matrix rock becomes a source of contamination to groundwater, and can be the source of contaminant mass for decades to centuries.

6.3.3 Sorption

Sorption, a general class of surface reactions, is the process by which dissolved substances in groundwater bind chemically and/or physically to the surface of aquifer material (in this case a fracture surface or surface of rock matrix following diffusion into the rock). Although sorption is reversible, its effect is to reduce a compound’s mobility in groundwater and retard the compound’s rate of migration in an aquifer. Sorption does not alter the total mass of a contaminant, but the associated reduction in mobility may lead to substantial reduction in risk to human and ecological health. The specific mechanisms of

sorption for organic compounds may differ from that of inorganics. Ion exchange is one type of surface reaction in which the specific binding mechanism is the electrolytic attraction between the charged ion in solution and the charged surface of a particle, usually clay minerals or other oxides. Another mechanism by which dissolved cations bind with particles is isomorphous substitution, where a dissolved cation replaces another cation in the crystal lattice of clay minerals. Except under extreme conditions or during clay mineral formation, isomorphous substitution is not expected to be an important attenuation mechanism in most groundwater environments. Since the specific binding mechanism is not always explicitly known, the term sorption is generally applied to all forms of chemical and physical binding with aquifer material.

6.3.4 Facilitated Transport

In certain cases, a compound may sorb to a colloid or other mobile solid within an aquifer. Alternatively, the presence of surfactants or co-solvents may serve to reduce the compound's actual sorption potential by the mechanisms described below. In either case, the theoretical compound mobility (based on advective flow and chemical sorption potential with a particular aquifer material) is less than transport facilitated by the mobile colloids.

The co-solvent effect occurs when a miscible organic compound such as a chlorinated solvent DNAPL is present in sufficient concentration to reduce the sorption coefficient of a hydrophobic organic compound so that it is more soluble in solution. Since many sites often have multiple sources, it is common to find strongly sorbing organic compounds and metals along with miscible organic compounds.

Surfactants are another class of compounds that act to alter the sorption coefficient of a surface. This may lead to an increase in concentration of a chemical in solution that is typically sorbed. Surfactants may be naturally occurring or introduced into the environment.

Facilitated transport occurs most often because organic and inorganic compounds sorb onto colloids. Colloids are defined as particles of less than 10 micrometers (μm) in diameter. Colloids may be organic or inorganic in composition. Organic colloids are further characterized as biocolloids such as bacteria or spores, macromolecules such as humic substances and organic fibers, and NAPL, such as oil droplets and surfactants. Inorganic colloids include clays, metal oxides, and inorganic precipitates which may or may not be naturally occurring.

6.3.5 Dispersion

Dispersion is the mechanical mixing of dissolved chemicals resulting from differences in groundwater velocity (magnitude and direction) between pores or fractures of varying size and shape. As such, dispersion results in the spreading of dissolved constituents both parallel and perpendicular to groundwater flow.

6.3.6 Volatilization

Volatilization is the process by which mass of a certain compound is transferred from the aqueous phase to the gaseous phase. The aqueous phase may include an immiscible non-aqueous fraction or a compound dissolved in groundwater. The factors that affect a compound's volatilization include the vapor pressure, solubility, and molecular weight. The Henry's Law constant, defined as the vapor pressure divided by the aqueous solubility, characterizes a compound's tendency to volatilize. Compounds with a high Henry's Law constant are more volatile.

6.3.7 Transformation Processes

Contaminant transformation processes are either abiotic or biologically mediated. The most significant abiotic transformation processes for chlorinated ethenes typically occur in the presence of reduced minerals, such as iron sulfide (FeS). These processes are likely limited at Curriculum Center because, based on the groundwater geochemistry, conditions are not sufficiently reducing to support abiotic reductive dechlorination.

Intrinsic biodegradation occurs when indigenous microorganisms work to bring about a reduction in the total mass of contamination in the subsurface without artificial intervention (e.g., the addition of carbon substrate or nutrients). Because of the importance of biodegradation, and to provide a foundation for interpreting Site data, the following subsections review the major biodegradation mechanisms that may act upon chlorinated solvents as well as the other COCs present at Curriculum Center.

6.3.8 Biodegradation of Chlorinated Ethenes

The mechanisms of chlorinated solvent biodegradation are described in detail in the "Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Groundwater" (EPA 1998) and in "Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents" (AFCEE et al. 2004). The following sections provide a summary of the discussions in these documents.

Chlorinated solvents can be transformed, directly or indirectly, by three fundamentally different biological pathways. These pathways include use of the solvent as an electron acceptor, use of the solvent as an electron donor, and cometabolism. At a given site, one or all of these processes may be operating, although the use of chlorinated solvents as electron acceptors appears to be the most important degradation mechanism.

6.3.9 Reductive Dechlorination

The most important process for the natural biodegradation of the more highly chlorinated solvents is reductive dechlorination. During this process, the chlorinated compound is used as an electron acceptor, not as a source of carbon, and a chlorine atom is removed and replaced with a hydrogen atom. In general, reductive dechlorination of chlorinated ethenes occurs by sequential dechlorination from PCE to TCE to DCE (primarily the cis-1,2-DCE isomer) to VC to ethene. Depending upon environmental conditions, these sequences may be interrupted, with other processes such as aerobic or abiotic degradation. Reductive dechlorination of chlorinated solvents is associated with the

accumulation of daughter products and an increase in metabolic byproducts such as chloride.

Reductive dechlorination affects chlorinated compounds differently. Of the ethenes, PCE is the most susceptible to reductive dechlorination because it is the most oxidized. Conversely, VC is the least susceptible to reductive dechlorination because it is the least oxidized of these compounds. In general, the rate of reductive dechlorination of chlorinated solvents has been observed to decrease as the degree of chlorination decreases. It has been postulated that this rate decrease may explain the accumulation of VC and cis-1,2-DCE mass relative to PCE and TCE mass where reductive dechlorination is occurring.

In addition to being affected by the degree of chlorination of the compound, reductive dechlorination also can be affected by the redox conditions of the groundwater system. For example, dechlorination of PCE and TCE to DCE can proceed under mildly reducing conditions such as nitrate reduction or iron (III) reduction, while the transformation of DCE to VC, or the transformation of VC to ethene requires more strongly reducing conditions.

Reductive dechlorination of some compounds also has been shown to preferentially produce specific daughter compounds. For example, during reductive dechlorination of TCE or PCE, all three isomers of DCE can theoretically be produced. However, it has been found that during biodegradation, cis-1,2-DCE is a more common intermediate than trans-1,2-DCE, and that 1,1-DCE is the least prevalent intermediate of the three DCE isomers. EPA (1998a) proposes that if cis-1,2-DCE makes up more than 80 percent of the total DCE in a delineated aqueous mass, then the DCE is likely the product of reductive dechlorination of TCE.

When chlorinated compounds are used as electron acceptors, there must be an appropriate source of organic carbon to be used as electron donors for microbial growth. Potential carbon sources/electron donors can include natural organic matter, fuel hydrocarbons, or other anthropogenic organic compounds. Current literature suggests that anaerobic reductive dechlorination of chlorinated ethenes is carried out by relatively few metabolic classifications of bacteria. These groups, which may behave very differently from one another, include methanogens, sulfate-reducing bacteria, and dechlorinating bacteria. The bacteria that can reduce PCE and TCE to cis-1,2-DCE appear to be ubiquitous in the subsurface environment. However, complete dechlorination of PCE or TCE to ethene by a single species has been demonstrated in the laboratory only for *Dehalococcoides Ethenogenes* (DHE). DHE appear to be common, but not ubiquitous, in the environment.

6.3.10 Electron Donor Reactions

Under aerobic conditions or weakly reducing conditions, some chlorinated solvents can be used as an electron donor in biologically mediated redox reactions. In contrast to reactions in which the chlorinated compound is used as an electron acceptor, only the least oxidized chlorinated solvents (e.g., VC and DCE) may be utilized as electron donors in biologically mediated redox reactions.

6.3.11 Cometabolism

When a chlorinated solvent is biodegraded through cometabolism, it serves as neither an electron acceptor nor a primary substrate in a biologically mediated redox reaction. Instead, the degradation of the chlorinated solvent is catalyzed by an enzyme or cofactor that is fortuitously produced by organisms for other purposes. The organism receives no known benefit from the degradation of the chlorinated solvent; rather, the cometabolic degradation of the chlorinated solvent may in fact be harmful to the microorganism responsible for the production of the enzyme or cofactor. Cometabolism is best documented in aerobic environments. It has been reported that under aerobic conditions chlorinated ethenes, with the exception of PCE, are susceptible to cometabolic degradation, and that the rate of cometabolism may increase as the degree of halogenation decreases.

6.4 Fate and Transport of COCs Identified at the Curriculum Center

6.4.1 Chlorinated Ethenes

DNAPL present on the surface of bedrock either beneath the building, at the suspected waste pit or in the former drum storage area. DNAPL likely entered and migrated through bedrock fractures such as the fracture bisected by boring OU2-MD2. This is evidenced by the high concentration of PCE (48 mg/l) in porewater at the face of a bedrock fracture at 66.9-67 feet bgs in rock matrix diffusion borehole OU2-MD2. DNAPL migrating through this fracture pooled at the bottom of OU2-MD2. DNAPL has not been confirmed in any other boring at the Curriculum Center.

DNAPL dissolution produced a dissolved-phase plume in the andesitic tuff sedimentary bedrock at and downgradient of the Curriculum Center. The main transport mechanism of the aqueous COCs is advective groundwater flow through fractures. Some limited matrix diffusion is occurring that slightly retards the advective movement of COCs in fractured sedimentary bedrock. The amount of matrix diffusion is relatively small as the primary porosity of the andesitic tuff is 1-2 percent and the diffusive penetration of COCs into bedrock from the fracture faces is limited creating diffusion halos based on matrix diffusion sampling. For example, the concentration of PCE in porewater in bedrock at a fracture face at 66.9 feet below ground surface of OU2-MD2 is 48,000 µg/l which is about 24 percent of the solubility of PCE. A matrix diffusion sample collected at 67.5-67.6 feet (0.6 feet from the fracture face) was non-detect for PCE. Matrix diffusion of PCE into porewater was detected at four additional fractures at concentrations ranging from 100 to 2,700 µg/l. These data show that no other fracture likely contained DNAPL as the highest porewater sample was less than 2 percent (2,700 µg/l) the solubility of PCE. These data also show that the CVOCs only penetrated the bedrock by 0.6 feet.

Dissolved-phase CVOCs continue to migrate through bedrock fractures and creating additional dissolved-phase plume. Dissolved-phase PCE is biologically transforming to TCE, cis-1,2-DCE, and VC through reductive dechlorination in only portions of the shallow and deep groundwater. This is likely due to either petroleum or septic waste locally driving the shallow portions of bedrock groundwater into an anaerobic condition

which is supporting the reductive dechlorination of PCE. This is occurring in the shallow northwestern portion of the plume. Shallow groundwater is migrating into the deep portions of the bedrock aquifer in this area. The result is groundwater containing PCE, TCE, cis-1,2-DCE, and VC in both the shallow and deep portions of the aquifer on the north and northwestern portion of the Curriculum Center. The chlorinated compounds are used as an electron acceptor not as a source of carbon, and a chlorine atom is removed and replaced with a hydrogen atom generated through biological activity.

Groundwater on the eastern and southeastern portion of the Curriculum Center contains mostly PCE as the potential effects of the petroleum or septic waste is less and the aquifer remains mostly aerobic resulting in less reductive dechlorination. Groundwater contamination in this portion of the aquifer (both shallow and deep) is mainly PCE with much lower concentrations of TCE, cis-1,2-DCE, and VC than groundwater to the north-northwest.

7 Conceptual Site Model

7.1 Purpose

The conceptual site model synthesizes data acquired from historical research, site characterization, and remediation system operation. The model is based on, and supported by, interpretive graphics, reduced and analyzed data, subsurface investigation logs, and other pertinent characterization information. The site conceptual model is not a mathematical or computer model, although these may be used to assist in developing and testing the validity of the conceptual model or evaluating the restoration potential of the site. The conceptual model, like any other theory or hypothesis, is a dynamic tool that should be tested and refined throughout the life of the project. The model should evolve in stages as information is gathered during the various phases of site remediation. The iterative process allows data collection efforts to be designed so that key model hypotheses may be tested and revised to reflect new information.

7.2 Elements of the Conceptual Site Model

The CSM is presented below in a summary and on **Figure 7-1**. The CSM is arranged in a logical sequence, building on concepts and information presented in this RI report. This CSM integrates information collected during historical investigations and this FSRI, including site background, setting, geology, hydrogeology, and the type and extent of contamination. The CSM provides the current understanding of the interaction between the shallow and deep aquifer zones with respect to contaminants and the mechanism of transport in relation to the Tutu Wells Site, specifically the Curriculum Center.

7.3 Conceptual Site Model

The Curriculum Center building and property were previously occupied by LAGA Industries, Ltd., who owned and operated a textile manufacturing plant at this location from 1971 to 1978. The plant included an industrial size dry cleaning process that used PCE as the dry cleaning solvent. The historic discharge point or discharge points at the LAGA facility were never definitively identified. Spent PCE and residue from the dry cleaning process were reportedly disposed in an outdoor pit located to the north of the building. However, no waste pit was identified during the 1995 RI or subsequent investigations. A drum disposal area located less than 100 feet to the northwest of the LAGA building, where 22 drums had been deposited in an uncontrolled manner was identified in a 1989 Preliminary Assessment. Additional potential discharge areas identified in the 1995 RI included a former discharge pipe and sink on the northeast side of the building, facility floor drains and sub slab piping that contained oil and 30 percent PCE solvent. EPA was able to trace the piping to a room that apparently held the PCE reclamation still and further on to the former dry cleaning room. While no evidence of leakage in the section of investigated pipe was found, the full extent of the piping and its integrity remained unknown.

There are no water saturated soils at the Curriculum Center. The water table is within the andesitic tuff sedimentary bedrock at approximately 15-30 feet bgs. Bedrock

fractures at Curriculum Center and Tutu Valley are the result of regional faulting that has resulted in structurally controlled erosion and weathering of bedrock forming river valleys such as Turpentine Run on St. Thomas. Most of the andesitic tuff at Curriculum Center contains few water bearing fractures. Shallow (<90 feet bgs) water bearing fractures with a moderate permeability extend in a west-southwest direction on the north side of Curriculum Center. A few low permeability fractures extend north-south east and west of Curriculum Center and extend in a west-southwest direction in front of Curriculum Center. The andesitic tuff between 90 and 140 feet bgs contains very few water bearing bedrock fractures and has a low permeability.

Groundwater flow occurs primarily through the bedrock fractures. Where present, permeability weathered zones, faults and high-angle fractures provide hydraulic connection between the shallow and deep zones. Fractures are both open and calcite-filled. The permeability zones are horizontally and vertically-oriented. The fracture and weathered zone porosity is relatively low as compared to the porosity of the matrix rock (1 to 3.5 percent with an average of 2 percent). However, where present the fracture interconnectedness allows for both vertical and horizontal groundwater flow through the bedrock.

Water levels measured during the RI indicate that the water table in the shallow water bearing zone and potentiometric surface in the deep water bearing zones are generally controlled by recharge zones at higher elevation and local surface drainage patterns. Groundwater flow in both zones moves south and west from Curriculum Center toward the Tutu Valley.

DNAPL from suspected source areas had likely collected on the surface of bedrock and migrated through fractures to the water table. DNAPL dissolution produces a dissolved-phase plume in bedrock at and downgradient of the Curriculum Center. The main transport mechanism of the aqueous COCs is advective groundwater flow through fractures. Some limited matrix diffusion is occurring that likely only slightly retards the advective movement of COCs in fractured sedimentary bedrock. The amount of matrix diffusion is relatively small as the primary porosity of the andesitic tuff is 1-3 percent. Based on matrix diffusion sampling the diffusive penetration of COCs into bedrock from the fracture faces is limited, creating diffusion halos around fractures. DNAPL measured through one fracture as the porewater sample associated with this fracture is 48 mg/l (24 percent the solubility of PCE). These data also show that the CVOCs only penetrated the bedrock up to 0.6 feet. Although not prevalent, back diffusion out of the matrix (pore water) is occurring in areas where the concentration gradient between the rock matrix and the aqueous phase in fractures supports the process, which may contribute to ongoing groundwater contamination.

Dissolved-phase CVOCs migrated through bedrock fractures and creating a dissolved-phase plume. Dissolved-phase PCE is biologically transforming to TCE, cis-1,2-DCE, and VC through reductive dechlorination in only portions of the shallow and deep groundwater. This is likely due to either petroleum or sewer waste locally driving the shallow portions of bedrock groundwater into an anaerobic condition which is supporting the reductive dechlorination of PCE. This is occurring in the shallow northwestern portion of the plume. Shallow groundwater is migrating into the deep portions of the

bedrock aquifer in this area. The result is groundwater containing PCE, TCE, cis-1,2-DCE, and VC in both the shallow and deep portions of the aquifer on the north and northwestern portion of the Curriculum Center (**Figures 5-3 and 5-4**).

Groundwater on the eastern and southeastern portion of the Curriculum Center contains mostly PCE as the potential effects of the petroleum or sewer waste are less and the aquifer remains mostly aerobic resulting in less reductive dechlorination. Groundwater in this portion of the aquifer (both shallow and deep) is mainly PCE with much lower concentrations of TCE, cis-1,2-DCE, and VC than groundwater to the north-northwest. (**Figures 5-3 and 5-4**).

Groundwater flow in the shallow fractured zone is relatively fast as compared to the zones with lower hydraulic conductivity. The degree and orientation of fractures observed below 140 feet bgs suggested limited potential for vertical contaminant migration below this depth. Vertical hydraulic gradients at the Site are upward, likely due to strong hydrologic gradient to the west.

The influence of the GWTF #1 extraction system appears to extend tens of feet cross gradient in an east-west direction and potentially a few hundreds of feet up and down gradient in the northeast-southwest direction in the shallow monitoring zone. RW-7 is the only well operated on a continuous basis of the three GWTF #1 extraction wells, RW-6, WR-7 and RW-9. Drawdown is limited to bedrock features and faults with a direct connection to pumping well RW-7. GWTF #1 does not capture the full width of aqueous CVOC's in the shallow zone. There has been no evidence to date that the influence of the extraction system extends measurably into the deep zone below 90 feet bgs. Therefore, contaminants that migrate to the deep zone are unlikely to be captured by the current extraction system. DNAPL is also outside the capture zone of GWTF #1.

Major trends in open fracture orientation were observed along a northeast-southwest trending strike with dip angles generally between 25° to 35° and 13° to 15° to the northwest, and along a northwest-southeast strike with dip angles of approximately 35° and 70° to 85° to the southwest. Projections of northeast-southwest fracture sets to the ground surface subcrop beneath the Curriculum Center building. An open fracture dipping approximately 35° along the northeast-southwest strike generally encountered the OU2 boreholes in the shallow monitoring zone (between the ground surface and a depth of 90 feet), and project into the screen zones of existing wells IW-1 and IW-2. This fracture also correlates within 10 feet of the interval where mg/kg levels of PCE were identified by the matrix diffusion survey at boring OU2-MD2. Higher-angle fractures encountered boreholes in the deep zones.

The general trends of open fractures observed in the RI boreholes coincide with historical fracture traces and the orientation of major geologic features identified by surface and borehole geophysics. High-angle fractures along the northwest-southeast strike correspond with the deformation zone identified by the surface geophysical investigation. The general trend aligns with fracture traces further to the east of the site. The high-angle fractures observed in the deep monitoring zone at OU2-MW6 may provide a direct pathway to OU2-MW4, where a similar distribution of chlorinated compounds was observed (**Figures 5-3 and 5-4**).

Groundwater moves most freely in a hydraulically downgradient direction along the strike of the fractures as this direction offers the least resistance by physical barriers to flow. Response to pumping from the GWTS #1 extraction wells will also be greatest along the strike of these fractures. Fracture orientation will also control the downward migration of chlorinated solvents introduced to the subsurface in non-aqueous phase. Downward migration of DNAPL can be expected to move from source area downward along the dip of fractures and encounter boreholes at different depths depending on the distance from the source areas. Direct evidence of DNAPL migrating through a bedrock fracture bisected by boring OU2-MD2 was observed during the RI. DNAPL has not been confirmed in any other boring at the Curriculum Center, although its presence has been inferred based on observations at borehole OU2-MW2 and monitoring well RD-9. These wells are approximately 25 and 40 feet respectively from OU2-MD2 in the direction of the Curriculum Center building and contaminant concentrations suggests DNAPL presence.

The horizontal and vertical extent of the source area at the Curriculum Center is greater than indicated by previous investigations, as evidenced by PCE concentrations greater than 1 percent of its solubility limit at the southeast corner of the Curriculum Center (OU2-MW4) and at depths of 140 to 150 feet bgs (OU2-MW3). The greater extent of the source area is still consistent with horizontal and vertical extent of the offsite plume in terms of the overall contaminant migration pathway. While the preferential pathways in the OU2 study area may control local groundwater movement, the net flow is to the south southwest toward the axis of the Turpentine Run drainage basin. Groundwater coming in contact with source material at the Curriculum Center continues to migrate offsite as a dissolve phase contaminant plume.

8 Summary of the Baseline Human Health Risk Assessment

This section provides a summary of the BHHRA prepared by HDR (February 2018) based on the FSRI findings for the Curriculum Center. The BHHRA was prepared to evaluate potential baseline health risks for future receptor exposure to contaminants of potential concern (COPCs) present in groundwater. The COPC screening of the BHHRA identified 13 COPCs, as shown in Table 3-4 of the BHHRA.

The potential exposure scenarios considered in the BHHRA include drinking water ingestion, dermal contact and inhalation of groundwater by residents, drinking water ingestion and dermal contact by indoor and outdoor workers as well as incidental ingestion, contact and inhalation with groundwater by a construction worker while working in a trench.

The evaluation of potential cancer risks and noncancer hazards to future receptors on-site from exposure to COPCs in environmental media indicates that there are several primary COPCs, now identified as COCs, whose concentrations in environmental media contribute to the hazard and risk estimates, and exposure to these COCs may result in potential adverse health effects. The results of the hazard identification and risk characterization are presented in Attachment A, EPA Risk Assessment Guidance for Superfund Part D Tables 7.1 through 7.3 of the HHRA. COCs are identified for only exposure pathways that have an excess lifetime cancer risk (ELCR) greater than 1×10^{-6} and a hazard index (HI) greater than one, as these constituents are considered to be primary contributors to the risk estimates.

- The evaluation for on-site future construction workers indicates that VC, TCE, PCE, cis-1,2-DCE and 1,1,2-trichloroethane have been identified as COCs for groundwater exposure, based on an ELCR exceeding 1×10^{-6} or resulting in an HI greater than or equal to one, as summarized in Table 6-1 of the BHHRA.
- The evaluation for on-site future workers indicates that VC, TCE, PCE and cis-1,2-DCE have been identified as COCs for groundwater exposure, based on an ELCR exceeding 1×10^{-6} or resulting in an HI greater than or equal to one, as summarized in Table 6-2. PCE and TCE volatilizing into buildings are also of potential concern to workers based on groundwater, indoor air and sub-slab soil gas data. Volatilizing of VC into buildings may be of potential concern based on groundwater concentrations; however, VC was non-detect in the sub-slab soil gas and indoor air during two sampling events in 2007 and 2011 as provided in Tables 6-4 and 6-5 of the BHHRA.
- The evaluation of potential cancer risks and noncancer hazards to future residents indicates VC, TCE, PCE, cis-1,2-DCE, trans-1,2-DCE, bromodichloromethane, 1,2-dichloroethane, 1,4-dichlorobenzene, 1,2,4-trichlorobenzene and 1,1,2-trichloroethane have been identified as COCs for groundwater exposure, based on an ELCR of 1×10^{-6} or resulting in an HI greater than or equal to one. PCE, TCE and other VOCs volatilizing into buildings are

also of potential concern to future residents based groundwater, indoor air and sub-slab soil gas data. See Table 6-3 in the BHHRA.

- Note that bromodichloromethane, 1,2-dichloroethane, 1,1,2-trichloroethane, 1,2,4-trichlorobenzene, 1,4-dichlorobenzene are included as COCs, as the calculated cancer risks for these constituents are in the 1×10^{-6} range, contributing to a cumulative ELCR greater than 1×10^{-4} . The COC 1,1,2-trichloroethane contributes to noncancer hazards greater than one for the liver as a target organ via the inhalation pathway. Review of the concentrations of these COCs in groundwater indicates that they do not exceed their respective MCLs; however, they are included in Section 4.5 of the FSRI to document their proposed preliminary remediation goals for consideration in remedy selection. The ELCR for 1,1-DCE is less than 1×10^{-6} , however, its maximum detected concentration exceeds its MCL, and so it too is included as a COC for the FSRI.
- Vapor Intrusion (VI) risks were evaluated using the VISL calculator to develop Site-specific groundwater VISLs for residential and commercial scenarios, using calculator defaults. The VI calculations are presented in Attachment D, Tables D.1 and D.2 of the BHHRA. Table D.3 compares the maximum site-wide groundwater concentrations to the groundwater VISLs.

The results of the BHHRA indicate that site cleanup, engineering controls and/or institutional controls will be necessary to mitigate potential risks associated with existing contamination.

9 Conclusions

Major conclusions are outlined below:

Previous Investigations

1. LAGA, who owned and operated a textile manufacturing plant at this location from 1971 to 1978, reportedly used PCE in an industrial sized dry cleaning process.
2. A drum disposal area was located less than 100 feet to the northwest of the LAGA building at Curriculum Center. Twenty-two drums were in an area of thick brush. Several drums were on their sides, some were corroded, and at least one drum contained an unknown liquid (NUS 1989). EPA and USVI DPNR discovered oil containing 30 percent PCE in sub-slab piping beneath Curriculum Center. The piping was traced from a PCE reclamation still to a pipe that discharges fluids onto land surface on the north-central side of the main building.
3. Soil samples collected near the north-central side of the main building, in the vicinity of the former discharge pipe contained PCE. Although no soil samples were collected from beneath the building, it is suspected that PCE might have leaked from the piping beneath the building.
4. An SVE system was constructed in 2004 to remediate the unsaturated soil contaminated with PCE. The system included two SVE wells (SVE-1 and SVE-7), a moisture knockout tank and a blower, and discharge to the GWTF off-gas treatment system. The SVE system was operated for approximately two years. The system was shut down in April 2006 due to a significant decrease in influent concentrations and achievement of asymptotic conditions. Based on these conditions, it was determined that the SVE system was no longer cost-effective (EPA 2014).
5. Groundwater samples collected from previous investigations show that PCE releases to the unsaturated soil and bedrock at Curriculum Center were the source of PCE detected in underlying groundwater at and downgradient of Curriculum Center.
6. Petroleum Hydrocarbons and/or septic waste are co-located with the release of PCE. Biologic activity associated with the petroleum hydrocarbons or septic waste has consumed the dissolved oxygen in groundwater resulting in a shallow anaerobic water bearing unit. PCE, co-located with the petroleum hydrocarbons or septic waste, reductively dechlorinated to TCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride.
7. Groundwater samples collected from previous investigations show the PCE released at Curriculum Center created a roughly 4,000 foot long plume impacted by PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride. This groundwater plume has been divided into three segments:
 - a. Northern portion of the CVOC plume: Groundwater at Curriculum Center is contaminated with PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl

chloride. The highest concentrations of CVOCs are located on the north side of Curriculum Center. A pump and treat system was installed on the north side of Curriculum Center. The groundwater extraction system includes three wells. The treatment system includes an air stripper, vapor phase carbon and permanganate, with the treated water discharged to Turpentine Run. Use of the off-gas treatment system was discontinued in April 2006 after CVOC concentrations dropped below the air pollution control permit equivalency limits.

- b. Central portion of the CVOC plume: Groundwater that extends from Curriculum Center to the intersection of Smith Bay Road and Palmetto Road is contaminated with PCE, TCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride. This portion of the plume is being remediated by the pump and treat system near the intersection of Smith Bay Road and Palmetto Road. Petroleum hydrocarbons were reportedly released at the Esso and Texaco gas stations located near the intersection of Fisher Street and Smith Bay Road. These potential releases are being regulated by USVI.
- c. Southern portion of the CVOC plume: Groundwater that originally extended over 2,500 feet in a southeastern direction from the pump and treat groundwater remediation system near the intersection of Smith Bay Road and Palmetto Road past Mango Circle to Mariendahl Road. Some chlorinated VOCs detected in the southern plume may have come from the O'Henry Dry Cleaners. This low concentration CVOC plume is being remediated by natural attenuation.

Remedial Action-Groundwater Pump and Treat at Curriculum Center

- 1. RW-7 is the primary shallow extraction well for groundwater remedy at Curriculum Center. RW-7 pumps at roughly 10 gpm on a continual basis at a constant head of 148 feet amsl. The hydraulic influence of RW-7 extends tens of feet in an east-west direction (cross gradient) in the shallow monitoring zone. Comparing the hydraulic containment to the distribution of CVOCs groundwater shows that the full width of CVOCs in the shallow zone are not hydraulically captured by pumping in RW-7. RW-9 is also a shallow extraction well that only operates for short periods of time when the system is restarted after an alarm condition to increase the rate of drawdown and to maintain hydraulic control.
- 2. RW-6 is the deep extraction well at Curriculum center in the less productive zone. RW-6 is pumped once per week for 1-1.5 hours equating to roughly 10 gallons per day. The influent concentration of CVOCs in RW-6 has decreased from 230 mg/l in 2005 to 15 mg/l in 2016. These data show the hydraulic influence of RW-6 in the deep zone is not capable of hydraulically capturing all of the CVOCs in the deep zone.
- 3. These data indicate incomplete hydraulic containment or an additional source of CVOCs are outside of the hydraulic containment system.

OU2 Remedial Investigation Conclusions

1. Bedrock at Curriculum Center is composed of andesitic tuff. The andesitic tuff has a primary porosity of 1.3-5 percent. The andesitic tuff at Curriculum center contained very few, very thin fractures resulting in a fracture porosity that is likely less than 0.001 percent. The primary porosity is likely at least three orders of magnitude greater than the fracture porosity.
2. The fractures in the andesitic tuff at Curriculum Center and Tutu Valley are the result of regional faulting that has resulted in structurally controlled erosion and weathering of bedrock forming river valleys such as Turpentine Run on St. Thomas. Most of the andesitic tuff at Curriculum Center contains few water bearing fractures. Shallow (<90 feet bgs) water bearing fractures with a moderate permeability extend in a west-southwest direction on the north side of Curriculum Center. A few low permeability fractures extend north-south in front and behind Curriculum Center and extend in a west-southwest direction in front of Curriculum Center.
3. The andesitic tuff between 90 and 140 feet bgs contains very few water bearing bedrock fractures and has a low permeability.
4. The degree and orientation of fracturing observed below 140 feet bgs suggested limited potential for vertical contaminant migration below this depth.
5. Whole rock core samples were collected, processed, and analyzed to determine if CVOCs have diffused into porewater in the volcano-sedimentary andesitic tuff bedrock. The results show high concentrations of PCE in porewater that equate to 24 percent of the PCE solubility along one bedrock fracture (67 feet below ground surface) at OU2-MD2. Approximately one gallon of DNAPL migrated through this fracture and pooled at the bottom of OU2-MD2. Based on the strike and dip of the bedrock fracture, the DNAPL likely came from the top of bedrock at the former drum storage area. The drum storage area is outside of the hydraulic containment system.
6. PCE diffused roughly 0.5 feet into porewater in andesitic tuff from the face of the fracture at 67 feet bgs. The PCE matrix diffusion detected in pore water at OU2-MD2 was limited to a few fractures creating 0.5 foot halos of PCE in porewater. OU2-MD2 is located outside of the hydraulic containment of the pump and treat system.
7. Some of the PCE released on the north side of Curriculum Center has been reductively dechlorinated to TCE, cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride by biological activity associated with a co-located petroleum hydrocarbon release. PCE and its degradation by-products migrate to the west-southwest in bedrock fractures on the north side of Curriculum Center. Groundwater in these fractures connects and migrates down Tutu Valley contributing to the central and southern plumes. The concentration of total CVOCs in this zone reaches a historic maximum of 56 mg/l. Groundwater in the deeper (90-140 feet bgs) lower permeability zone north of Curriculum center also contains PCE and its degradation by-products. The concentration of total CVOCs in this zone reaches a historic maximum concentration of 321 mg/l.

8. Some of the PCE released on the north side of Curriculum Center or an unknown source of PCE DNAPL has not been reductively dechlorinated and migrates to the southeast through a bedrock deformation zone along the northeast side of Curriculum Center. Groundwater containing PCE migrates through the deformation zone into bedrock fractures that extend to the west-southwest on the southeast side of the Curriculum Center. Groundwater on the southeast side of Curriculum Center contains PCE at a concentration of 2.5 mg/l. A relatively small fraction of PCE degradation by-products were detected in groundwater in these fractures. This groundwater also migrates in a west-southwest direction down Tutu Valley.
9. A portion of the groundwater containing CVOCs defined during this FSRI is hydraulically captured by the existing hydraulic containment system. A portion of the groundwater containing CVOCs defined during this FSRI is not hydraulically captured by the existing hydraulic containment system.
10. The data collected during this FSRI show DNAPL likely exists in the former drum storage area and potentially under Curriculum Center. These locations are also outside of the current hydraulic containment system.
11. Matrix diffusion data indicate that contamination of the rock matrix can be expected in areas where high levels of COCs are detected in groundwater and that compounds are currently and will likely continue to back-diffuse from the rock matrix and impact groundwater in the OU2 area.

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Table 1-1
2007 and 2011 Subslab Vapor Sampling Summary
Tutu Wells Superfund Site OU2
St. Thomas, U. S. Virgin Islands (USVI)

Compound	Year	Sub-Slab Vapor - Range of Concentrations [$\mu\text{g}/\text{m}^3$]	Sub-Slab Vapor Action Level [$\mu\text{g}/\text{m}^3$]	Sub-Slab Locations >Action Level
PCE	2007	54 - 79,000	100	15/16
	2011	51.6 – 147,000		15/16
TCE	2007	ND - 810	5	7/16
	2011	ND – 688		9/16
cis-1,2-DCE	2007	ND	330	0/16
	2011	ND – 52.2		0/16
trans-1,2-DCE	2007	ND	730	0/16
	2011	ND – 4.0		0/16
VC	2007	ND	7	0/16
	2011	ND		0/16
1,1-DCE	2007	ND – 1,100	2,200	0/16
	2011	ND – 0.646		0/16

Notes:

Data sources: Lockheed Martin 2007; Lockheed Martin 2012.

The source of the Action Levels was not identified in the original documents.

Abbreviations:

$\mu\text{g}/\text{m}^3$ - microgram per cubic meter

Table 1-2
2007 and 2011 Indoor Air Sampling Summary
Tutu Wells Superfund Site OU2
St. Thomas, U. S. Virgin Islands (USVI)

Compound	Year	Sub-Slab Vapor - Range of Concentrations [$\mu\text{g}/\text{m}^3$]	Sub-Slab Vapor Action Level [$\mu\text{g}/\text{m}^3$]	Sub-Slab Locations >Action Level
PCE	2007	0.32 - 58	10	1/29*
	2011	0.806 - 58		1/29*
TCE	2007	ND - 0.47	0.5	0/29
	2011	ND - 0.488		0/29
cis-1,2-DCE	2007	ND - 0.042	33	0/29
	2011	ND - 0.283		0/29
trans-1,2-DCE	2007	ND	73	0/29
	2011	ND - 0.177		0/29
VC	2007	ND	0.7	0/29
	2011	ND		0/29
1,1-DCE	2007	ND - 0.13	220	0/29
	2011	ND		0/29

Notes:

Data sources: Lockheed Martin 2007; Lockheed Martin 2012.

The source of the Action Levels was not identified in the original documents.

Abbreviations:

$\mu\text{g}/\text{m}^3$ - microgram per cubic meter

* - Two co-located samples from a single location in the maintenance area exceeded the indoor air action level.

Table 2-1
Monitoring Well Rock Coring Intervals
Tutu Wells Superfund Site OU2
St. Thomas, U. S. Virgin Islands (USVI)

Monitoring Well	Coring Intervals (bgs)
OU2-2016-MW1	38 - 43, 78 - 83
OU2-2016-MW2	47.5 - 55
OU2-2016-MW3	143 - 149.7
OU2-2016-MW4	35 - 40, 97.5 - 102.5
OU2-2016-MW5	34.5 - 37, 64.5 - 69.5, 79.5 - 84.5
OU2-2016-MW6	no rock coring
OU2-2016-MD1*	33 - 200
OU2-2016-MD2**	43 - 200

Notes:

* Cored for rock matrix diffusion, not completed as a monitoring well.

** Originally cored for rock matrix diffusion; borehole converted to monitoring well.

Abbreviations:

bgs - below ground surface

Table 2-2
Packer Testing Summary
Tutu Wells Superfund Site OU2
St. Thomas, U. S. Virgin Islands (USVI)

Monitoring Well, Interval [feet bgs]	Date	Duration/Volume Purged	Max. Sustained Flow [gpm]	Comments (w/starting Depth to Water in feet below MP)
OU2-MW1, 64-70	01/26/17	25 minutes; ≈45 gallons (gals.)	2 gpm	Sampled; used only the bottom seal/across water table. DTW: 64.4
OU2-MW1, 64-73	01/27/17	60 minutes & > 5 volumes	4 gpm	Sampled; bottom seal only. DTW: 64.7
OU2-MW1, 75-85	01/26/17	60 minutes & > 5 volumes	1 gpm	Sampled; top seal only/ interval open to bottom of hole. DTW: 64.5
OU2-MW2, 47-55	01/25/17	53 minutes, ≈15 gallons	0.25 gpm	Sampled; top seal only/ interval open to bottom of hole. DTW: 28.5
OU2-MW3, 85-95	01/28/17	purged dry; 20 minutes; ≈13 gallons	<1/8 gpm	Sampled after 1 hour recovery. DTW: 25.9
OU2-MW3, 122-132	01/28/17	85 minutes, ≈80 gallons	1 gpm	Sampled. DTW: 25.9
OU2-MW3, 135-149'	01/29/17	60 minutes, ≈50 gallons	0.75 gpm	Sampled; top seal only/ interval open to bottom of hole.
OU2-MW6, 50-60	01/23/17	purged dry in <5 minutes, 2 gallons	0.5 gpm	Not sampled.
OU2-MW6, 60-70	01/23/17	25 minutes, 85 gallons	4 gpm	Sampled.
OU2-MW6, 75-85	01/23/17	dry after 7 gallons	none	Recovery: 2 feet in 30 minutes. Not sampled.
OU2-MW6, 115-125	01/24/17	purged dry in 30 minutes, 35 gallons	<0.5 gpm	Sampled.

Abbreviations:

bgs - below ground surface

DTW - depth to water

gpm - gallon per minute

MP - measuring point

Table 2-3
Monitoring Well Construction Details
Tutu Wells Superfund Site
St. Thomas, U.S. Virgin Islands (USVI)

WELL ID	Date Installed	Stickup or Flush Mount	Survey Coordinates (NAD83)		Ground Surface Elevation (ft, amsl)	Top of Casing Elevation (ft, amsl)	Total Well Depth (ft, bgs)	Inside Well Diameter (inches)	Screened Interval (ft, amsl)		Screened Interval (ft, bgs)	
			Northing	Easting					Top	Bottom	Top	Bottom
SHALLOW GROUNDWATER MONITORING WELLS												
BP-1	10/29/2003	Flush Mount	842953.563	1192568.469	202.67	202.67	58.8	4	162.67	143.87	40	58.8
BP-2	10/23/2003	Flush Mount	842942.834	1192565.908	202.64	202.64	60.3	4	162.64	142.34	40	60.3
BP-3	10/25/2003	Flush Mount	842933.267	1192565.178	202.71	202.71	59.68	2	162.71	143.03	40	59.68
IW-1	9/22/2003	Flush Mount	842955.637	1192563.366	202.79	202.79	95.1	6	127.79	107.69	75	95.1
IW-1S	11/7/2003	Flush Mount	842960.101	1192557.167	202.85	202.85	56.62	4	162.85	146.23	40	56.62
IW-2	9/25/2003	Flush Mount	842958.563	1192573.469	202.94	202.94	90.77	6	127.94	112.17	75	90.77
IW-2S	11/3/2003	Flush Mount	842963.564	1192573.469	203.77	203.77	60.55	4	163.77	143.22	40	60.55
MW-1D	7/8/1992	Flush Mount	842621.762	1192525.118	195.14	195.14	90	6	125.14	105.14	70	90
MW-2	8/25/1992	Flush Mount	842615.545	1192135.475	178.31	178.15	27	4	171.15	151.15	7	27
MW-5	8/25/1992	Flush Mount	842363.532	1192279.473	187.24	187.09	39	4	168.09	148.09	19	39
MW-13	4/28/1994	Flush Mount	842917.999	1192785.722	237.00	236.31	80.5	6	176.01	155.81	60.3	80.5
MW-14	7/2/1992	Flush Mount	842789.493	1192424.808	196.04	196.12	45.2	4	170.92	150.92	25.2	45.2
MW-15	3/31/1994	Flush Mount	842713.550	1192297.473	178.95	178.95	36.2	6	163.95	142.75	15	36.2
MW-16	5/2/1994	Flush Mount	842918.759	1192556.306	203.00	202.33	44.6	6	177.73	157.73	24.6	44.6
MW-17	3/30/1994	Flush Mount	842702.550	1192237.474	177.18	177.18	13.5	4	168.68	163.68	8.5	13.5
OU2-MD-2	1/21/2017	Flush Mount	842904.159	1192524.467	202.02	201.47	200	4.8	161.47	1.47	40	200
OU2-MW-1	1/3/2017	Flush Mount	843025.405	1192822.647	237.83	237.83	85	2	172.83	152.83	65	85
OU2-MW-2	1/25/2017	Flush Mount	842890.294	1192537.527	203.19	202.72	54	2	158.72	148.72	44	54
OU2-MW-6	1/25/2017	Flush Mount	842962.344	1192651.489	205.56	204.95	130	6	152.95	74.95	52	130
RD-5	11/12/1998	Flush Mount	842401.534	1192470.471	189.91	189.91	43	4	156.91	146.91	33	43
RW-8	9/14/2003	Flush Mount	842920.079	1192563.463	202.75	202.75	105.23	6	152.75	97.52	50	105.23
Tillett	1963	Flush Mount	842224.525	1192282.473	186.00	186.00	98.4	6	177.00	88.00	9	98
DEEP GROUNDWATER MONITORING WELLS												
MW-13D	7/15/1992	Flush Mount	842928.816	1192784.793	236.67	236.60	120	6	136.60	116.60	100	120
OU2-MW-3	1/14/2017	Flush Mount	842783.092	1192445.815	195.94	196.43	149.7	6	106.43	46.73	90	149.7
OU2-MW-4	1/14/2017	Flush Mount	842717.860	1192798.280	204.08	203.73	102.5	6	113.73	101.23	90	102.5
OU2-MW-5	1/14/2017	Flush Mount	842632.993	1192662.122	204.12	203.80	140	6	113.80	63.80	90	140
RD-10	6/23/1999	Stickup	843009.566	1192459.470	196.15	199.18	105	4	119.18	94.18	80	105
RD-9	6/16/1999	Flush Mount	842911.561	1192587.469	203.79	203.79	110	4	118.79	93.79	85	110
RD-11	6/8/1999	Flush Mount	842955.519	1192547.266	202.45	202.46	110	4	117.46	92.46	85	110
RD-12	8/17/1999	Flush Mount	842907.654	1192787.869	235.46	236.71	155	4	106.71	81.71	130	155
RD-13	7/13/1999	Flush Mount	842618.670	1192542.966	195.62	196.41	125	4	96.41	71.41	100	125

Notes:

The 2/21/17 depth to water measurement for MW-13 is considered erroneous and was contributed to equipment malfunction.

(compared with recent and historic monthly readings and nearby wells, DTW should have been approx. 65 feet).

Abbreviations:

amsl - above mean sea level

bgs - below ground surface

btoc - below top of casing

DTW - Depth to water

ft - feet

Table 2-4
Packer Testing Groundwater Screening Samples Summary
Tutu Wells Superfund Site OU2
St. Thomas, U. S. Virgin Islands (USVI)

Well	Pump Intake [feet bgs]	Sample ID	Sampling Date	Notes
OU2-MD2	37.5	OU2-MD2-37.5-20170122	01/22/17	
OU2-MD2	40.5	OU2-MD2-40.5-20170122	01/22/17	
OU2-MD2	66	OU2-MD2-66-20170122	01/22/17	
OU2-MD2	76.5	OU2-MD2-76.5-20170122	01/22/17	
OU2-MD2	96	OU2-MD2-96-20170123	01/23/17	MS/MSD
OU2-MD2	131	OU2-MD2-131-20170124	01/24/17	
OU2-MD2	131	OU2-MD2-131-20170124-1	01/24/17	Duplicate
OU2-MD2	164	OU2-MD2-164-20170124	01/24/17	
OU2-MW1	60-70	OU2-MW1-60-70-20170126	01/26/17	
OU2-MW1	75 - 85	OU2-MW1-75-85-20170126	01/26/17	
OU2-MW1	64 - 73	OU2-MW1-64-73-20170127	01/27/17	
OU2-MW2	47 - 55	OU2-MW2-47-55-20170125	01/25/17	
OU2-MW3	85 - 95	OU2-MW3-85-95-20170128	01/28/17	
OU2-MW3	122 - 132	OU2-MW3-122-132-20170128	01/28/17	
OU2-MW3	135 - 149	OU2-MW3-135-149-20170129	01/29/17	
OU2-MW6	60 - 70	OU2-MW6-60-70-20170123	01/23/17	
OU2-MW6	115 - 125	OU2-MW6-115-125-20170124	01/24/17	

Abbreviations:

bgs - below ground surface

MS/MSD - Matrix Spike/Matrix Spike Duplicate

Table 2-5
Groundwater Monitoring Well Samples Summary
Tutu Wells Superfund Site OU2
St. Thomas, U. S. Virgin Islands (USVI)

Well	Pump Intake [feet bgs]	Sample ID	Sampling Date	Notes
BP1	49.5	BP1-49.5-20170222	02/22/17	
BP1	49.5	BP1-49.5-20170222-1	02/22/17	Duplicate
BP2	50	BP2-50-20170222	02/22/17	
BP3	50	BP3-50-20170222	02/22/17	
IW1	85	IW1-85-20170302	03/02/17	
IW1S	48.5	IW1S-48.5-20170227	02/27/17	
IW2	82.9	IW2-82.9-20170302	03/02/17	
IW2S	50.3	IW2S-50.3-20170302	03/02/17	
MW1D	80	MW1D-80-20170228	02/28/17	
MW13	70.5	MW13-70.5-20170301	03/01/17	
MW13D	110	MW13D-110-20170221	02/21/17	
MW14	35.2	MW14-35.2-20170227	02/27/17	
MW15	26	MW15-26-20170223	02/23/17	
MW16	34.6	MW16-34.6-20170301	03/01/17	
MW17	11	MW17-11-20170223	02/23/17	
OU2-MW1	75	OU2-MW1-75-20170301	03/01/17	
OU2-MW2	49	OU2-MW2-49-20170224	02/24/17	
OU2-MW3	90.5	OU2-MW3-90.5-20170306	03/06/17	
OU2-MW3	140	OU2-MW3-140-20170306	03/06/17	
OU2-MW4	95	OU2-MW4-95-20170222	02/22/17	
OU2-MW5	135	OU2-MW5-135-20170224	02/24/17	
OU2-MW6	120	OU2-MW6-120-20170228	02/28/17	
RD9	97.5	RD9-97.5-20170228	02/28/17	
RD10	90	RD10-90-20170223	02/23/17	
RD11	97.5	RD11-97.5-20170227	02/27/17	
RD12	142.5	RD12-142.5-20170222	02/22/17	
RD13	112.5	RD13-112.5-20170224	02/24/17	
RW6	125	RW6-125-20170301	03/01/17	
RW6	125	RW6-125-20170301-1	03/01/17	Duplicate
RW7	75	RW7-75-20170301	03/01/17	
RW8	80	RW8-80-20170228	02/28/17	
RW9	55	RW9-55-20170301	03/01/17	

Abbreviations:

bgs - below ground surface

Table 3-1
Monitoring Well Construction and Synoptic Groundwater Elevations
Tutu Wells Superfund Site
St. Thomas, U.S. Virgin Islands (USVI)

WELL ID	Date Installed	Stickup or Flush Mount	Survey Coordinates (NAD83)		Ground Surface Elevation (ft, amsl)	Top of Casing Elevation (ft, amsl)	Total Well Depth (ft, bgs)	Inside Well Diameter (inches)	Screened Interval (ft, amsl)		Screened Interval (ft, bgs)		February 21, 2017		June 13, 2017	
			Northing	Easting					Top	Bottom	Top	Bottom	DTW [ft btoc]	Water Level Elevation [ft amsl]	DTW [ft btoc]	Water Level Elevation [ft amsl]
SHALLOW GROUNDWATER MONITORING WELLS																
BP-1	10/29/2003	Flush Mount	842953.563	1192568.469	202.67	202.67	58.8	4	162.67	143.87	40	58.8	31.16	171.51	31.49	171.18
BP-2	10/23/2003	Flush Mount	842942.834	1192565.908	202.64	202.64	60.3	4	162.64	142.34	40	60.3	31.07	171.57	31.58	171.06
BP-3	10/25/2003	Flush Mount	842933.267	1192565.178	202.71	202.71	59.68	2	162.71	143.03	40	59.68	31.93	170.78	32.02	170.69
IW-1	9/22/2003	Flush Mount	842955.637	1192563.366	202.79	202.79	95.1	6	127.79	107.69	75	95.1	35.56	167.23	35.83	166.96
IW-1S	11/7/2003	Flush Mount	842960.101	1192557.167	202.85	202.85	56.62	4	162.85	146.23	40	56.62	31.73	171.12	31.82	171.03
IW-2	9/25/2003	Flush Mount	842958.563	1192573.469	202.94	202.94	90.77	6	127.94	112.17	75	90.77	26.57	176.37	31.76	171.18
IW-2S	11/3/2003	Flush Mount	842963.564	1192573.469	203.77	203.77	60.55	4	163.77	143.22	40	60.55	32.10	171.67	32.15	171.62
MW-1D	7/8/1992	Flush Mount	842621.762	1192525.118	195.14	195.14	90	6	125.14	105.14	70	90	28.68	166.46	29.23	165.91
MW-2	8/25/1992	Flush Mount	842615.545	1192135.475	178.31	178.15	27	4	171.15	151.15	7	27	13.41	164.74	13.36	164.79
MW-5	8/25/1992	Flush Mount	842363.532	1192279.473	187.24	187.09	39	4	168.09	148.09	19	39	24.02	163.07	23.88	163.21
MW-13	4/28/1994	Flush Mount	842917.999	1192785.722	237.00	236.31	80.5	6	176.01	155.81	60.3	80.5	49.78	186.53	64.21	172.10
MW-14	7/2/1992	Flush Mount	842789.493	1192424.808	196.04	196.12	45.2	4	170.92	150.92	25.2	45.2	26.51	169.61	26.30	169.82
MW-15	3/31/1994	Flush Mount	842713.550	1192297.473	178.95	178.95	36.2	6	163.95	142.75	15	36.2	9.82	169.13	9.71	169.24
MW-16	5/2/1994	Flush Mount	842918.759	1192556.306	203.00	202.33	44.6	6	177.73	157.73	24.6	44.6	31.57	170.76	31.75	170.58
MW-17	3/30/1994	Flush Mount	842702.550	1192237.474	177.18	177.18	13.5	4	168.68	163.68	8.5	13.5	9.11	168.07	8.90	168.28
OU2-MD-2	1/21/2017	Flush Mount	842904.159	1192524.467	202.02	201.47	200	4.8	161.47	1.47	40	200	31.39	170.08	31.66	169.81
OU2-MW-1	1/3/2017	Flush Mount	843025.405	1192822.647	237.83	237.83	85	2	172.83	152.83	65	85	66.19	171.64	65.98	171.85
OU2-MW-2	1/25/2017	Flush Mount	842890.294	1192537.527	203.19	202.72	54	2	158.72	148.72	44	54	32.63	170.09	32.94	169.78
OU2-MW-6	1/25/2017	Flush Mount	842962.344	1192651.489	205.56	204.95	130	6	152.95	74.95	52	130	34.31	170.64	34.65	170.30
RD-5	11/12/1998	Flush Mount	842401.534	1192470.471	189.91	189.91	43	4	156.91	146.91	33	43	30.55	159.36	30.37	159.54
RW-8	9/14/2003	Flush Mount	842920.079	1192563.463	202.75	202.75	105.23	6	152.75	97.52	50	105.23	29.26	173.49	33.61	169.14
Tillett	1963	Flush Mount	842224.525	1192282.473	186.00	186.00	98.4	6	177.00	88.00	9	98	24.08	161.92	NA	NA
DEEP GROUNDWATER MONITORING WELLS																
MW-13D	7/15/1992	Flush Mount	842928.816	1192784.793	236.67	236.60	120	6	136.60	116.60	100	120	67.57	169.03	68.85	167.75
OU2-MW-3	1/14/2017	Flush Mount	842783.092	1192445.815	195.94	196.43	149.7	6	106.43	46.73	90	149.7	26.91	169.52	26.90	169.53
OU2-MW-4	1/14/2017	Flush Mount	842717.860	1192798.280	204.08	203.73	102.5	6	113.73	101.23	90	102.5	63.70	140.03	43.90	159.83
OU2-MW-5	1/14/2017	Flush Mount	842632.993	1192662.122	204.12	203.80	140	6	113.80	63.80	90	140	133.87	69.93	127.72	76.08
RD-10	6/23/1999	Stickup	843009.566	1192459.470	196.15	199.18	105	4	119.18	94.18	80	105	24.43	174.75	24.30	174.88
RD-9	6/16/1999	Flush Mount	842911.561	1192587.469	203.79	203.79	110	4	118.79	93.79	85	110	29.48	174.31	33.80	169.99
RD-11	6/8/1999	Flush Mount	842955.519	1192547.266	202.45	202.46	110	4	117.46	92.46	85	110	28.12	174.34	36.27	166.19
RD-12	8/17/1999	Flush Mount	842907.654	1192787.869	235.46	236.71	155	4	106.71	81.71	130	155	60.55	176.16	64.55	172.16
RD-13	7/13/1999	Flush Mount	842618.670	1192542.966	195.62	196.41	125	4	96.41	71.41	100	125	26.74	169.67	27.98	168.43

Notes:

The 2/21/17 depth to water measurement for MW-13 is considered erroneous and was contributed to equipment malfunction. (compared with recent and historic monthly readings and nearby wells, DTW should have been approx. 65 feet).

Abbreviations:

amsl - above mean sea level

bgs - below ground surface

btoc - below top of casing

DTW - Depth to water

ft - feet



Table 5-1
Site-Specific Screening Concentrations - Groundwater
Tutu Wells Superfund Site OU2
St. Thomas, U.S. Virgin Islands

Compound	CAS Number	Original Project Action Limits (QAPP Worksheet #15) [µg/l]	Federal MCL [µg/l]	Potential Cleanup Standards [µg/l]
Acetone	67-64-1	NA	NA	NA
Benzene	71-43-2	5	5	5
Bromochloromethane	74-97-5	NA	NA	NA
Bromodichloromethane	75-27-4	NA	80*	80
Bromoform	75-25-2	NA	80*	80
Bromomethane (Methyl bromide)	74-83-9	NA	NA	NA
2-Butanone (Methyl ethyl ketone)	78-93-3	NA	NA	NA
Carbon Disulfide	75-15-0	NA	NA	NA
Carbon Tetrachloride	56-23-5	5	5	5
Chlorobenzene	108-90-7	100	100	100
Chloroethane	75-00-3	NA	NA	NA
Chloroform	67-66-3	NA	80*	80
Chloromethane	74-87-3	NA	NA	NA
Cyclohexane	110-82-7	NA	NA	NA
Dibromochloromethane	124-48-1	NA	80*	80
1,2-Dibromo-3-Chloropropane	96-12-8	NA	0.2*	0.2
1,2-Dibromoethane (Ethylene dibromide)	106-93-4	NA	0.05*	0.05
1,2-Dichlorobenzene (ortho)	95-50-1	NA	600*	600
1,3-Dichlorobenzene (meta)	541-73-1	NA	NA	NA
1,4-Dichlorobenzene (para)	106-46-7	NA	75*	75
Dichlorodifluoromethane	75-71-8	NA	NA	NA
1,1-Dichloroethane	75-34-3	NA	NA	NA
1,2-Dichloroethane	107-06-2	5	5	5
1,1-Dichloroethene	75-35-4	7	7	7
cis-1,2-Dichloroethene	156-59-2	70	70	70
trans-1,2-Dichloroethene	156-60-5	100	100	100
1,2-Dichloropropane	78-87-5	5	5	5
cis-1,3-Dichloropropene	10061-01-5	NA	NA	NA
trans-1,3-Dichloropropene	10061-02-6	NA	NA	NA
Ethylbenzene	100-41-4	700	700	700
2-Hexanone	591-78-6	NA	NA	NA
Isopropylbenzene (Cumene)	98-82-8	NA	NA	NA
4-Methyl-2-Pentanone	108-10-1	NA	NA	NA
Methylcyclohexane	108-87-2	NA	NA	NA
Methylene Chloride	75-09-2	NA	NA	NA
Methyl Acetate	79-20-9	NA	NA	NA
Methyl tert-Butyl Ether	1634-04-4	NA	NA	NA
Styrene	100-42-5	100	100	100
1,1,2,2-Tetrachloroethane	79-34-5	NA	NA	NA
Tetrachloroethene	127-18-4	5	5	5
Toluene	108-88-3	1000	1,000	1,000
1,2,3-Trichlorobenzene	87-61-6	NA	NA	NA
1,2,4-Trichlorobenzene	120-82-1	70	70	70

Table 5-1
Site-Specific Screening Concentrations - Groundwater
Tutu Wells Superfund Site OU2
St. Thomas, U.S. Virgin Islands

Compound	CAS Number	Original Project Action Limits (QAPP Worksheet #15) [µg/l]	Federal MCL [µg/l]	Potential Cleanup Standards [µg/l]
1,1,2-Trichloro-1,2,2-trifluoroethane	76-13-1	NA	NA	NA
1,1,1-Trichloroethane	71-55-6	200	200	200
1,1,2-Trichloroethane	79-00-5	5	5	5
Trichloroethene	79-01-6	5	5	5
Trichlorofluoromethane	75-69-4	NA	NA	NA
Vinyl Chloride	75-01-4	2	2	2
m,p-Xylene	179601-23-1	10,000	10,000	10,000
o-Xylene	95-47-6	10,000	10,000	10,000

Notes:

* - Different from value in QAPP. Updated value used.

Updated project action limits are shaded

Abbreviations:

MCL - Maximum Contaminant Level

µg/l - Microgram per liter

Table 5-2
Contaminants of Concern
Tutu Wells Superfund Site OU2
St. Thomas, U. S. Virgin Islands (USVI)

COC	Potential Cleanup Standards [µg/l]
PCE	5
TCE	5
cis-1,2-DCE	70
trans-1,2-DCE	100
Vinyl chloride	2
1,1-DCE	7

Abbreviations:

COC - Contaminant of Concern

µg/l - Microgram per liter

Table 5-3
COC Concentrations at OU2 Area Wells, 2017 LTRA Sampling
Tutu Wells Superfund Site OU2
St. Thomas, U. S. Virgin Islands (USVI)

Compound	Range of Detected Concentrations [µg/l]	Frequency of Detection	Potential Cleanup Standards [µg/l]
PCE	0.43 - 42	8/9	5
TCE	0.26 – 48	8/9	5
cis-1,2-DCE	3.3 – 120	7/9	70
trans-1,2-DCE	0.26 – 120	5/9	100
VC	2.8 – 100	3/9	2
1,1-DCE	ND	0/9	7

Abbreviations:

ND - Not Detected

µg/l - Microgram per liter

Table 5-4
COC Concentrations In Extraction Well RW-6, 2016 - 2017
Tutu Wells Superfund Site OU2
St. Thomas, U. S. Virgin Islands (USVI)

Compound	Range of Concentrations [µg/l]	Frequency of Detection	Potential Cleanup Standards [µg/l]
PCE	1,800 – 9,200	12/12	5
TCE	2,300 – 6,300	12/12	5
cis-1,2-DCE	23 – 25,000	12/12	70
trans-1,2-DCE	1.3 – 500	12/12	100
VC	<0.5 - 700	10/12	2
1,1-DCE	ND	0/12	7

Abbreviations:

PCS - Potential Cleanup Standards

ND - Not detected

µg/l - Microgram per liter

Table 5-5
CVOC Detections In Rock Core OU2-2016-MD2
Tutu Wells Superfund Site OU2
St. Thomas, U. S. Virgin Islands (USVI)

Depth [feet bgs]	cis-1,2-DCE [µg/kg]	PCE [µg/kg]	TCE [µg/kg]	Location relative to Feature
49.95	ND	29.9	ND	~0.3 feet above fracture
66.95	144	14,300	229	Above a calcite-filled fracture
105.95	ND	37.9	ND	Bottom of a core run
106.85	ND	47.9	ND	Above horizontal fracture between two calcite-filled fractures at intersection with high-angle fracture)
107.75	ND	59.3	ND	Below the bottom of the high-angle fracture noted above
131.55	113	133	ND	Below a calcite-filled fracture
131.75	99.7	466	ND	0.2 feet into matrix from fracture noted above
132.15	90.9	106	ND	0.6 feet into matrix from fracture noted above
132.45	25.8 J	95.7	28.5 J	~0.3 feet above mechanical break. Below intersection of a thin low-angle calcite-filled crack and thin high-angle calcite-filled crack
165.05	37.3 J	ND	ND	In rock matrix (~0.2 ft at thin low angle calcite filled crack
166.15	390	399	257	Below a low-angle fracture
166.45	654	745	457	0.3 feet into the matrix from fracture noted above. Possibly a high-angle fracture running past this zone past this portion of the core
169.25	351	420	254	Below fracture surface. Fracture surface appears unweathered but is at the intersection of several weathered calcite-filled zones.
169.55	281	330	195	Approximately 0.3 ft into matrix from fracture noted above
169.85	144	152	86.1	Approximately 0.6 feet into the matrix from the fracture noted above. Also at bottom face of calcite-filled fracture (thin, low angle, weathered)

Notes:

Multiple detections that the matrix diffusion contractor considered to be associated with a single fracture are indicated by gray shading.

Abbreviations:

bgs - below ground surface

DCE - Dichloroethene

J - the reported value is an estimate

ND - Not Detected

PCE - Tetrachloroethene

TCE - Trichloroethene

µg/kg - Microgram per kilogram

Table 5-6
COC Range of Concentrations in Packer Testing Screening Samples
Tutu Wells Superfund Site OU2
St. Thomas, U. S. Virgin Islands (USVI)

Compound	Range of Detected Concentrations [µg/l]	Potential Cleanup Standards [µg/l]
PCE	2.9 - 5,000	5
TCE	0.21 J – 250	5
cis-1,2-DCE	0.54 – 750	70
trans-1,2-DCE	5.5 J – 10	100
1,1-DCE	ND	7
VC	170	2

Abbreviations:

ND - Not Detected

µg/l - Microgram per liter

Table 5-7
Groundwater Screening Analytical Results Summary
Tutu Wells Superfund Site OU2
St. Thomas, U.S. Virgin Islands (USVI)

Sample ID Sample Date Sample Depth (feet bgs) Unit			OU2-MD2-37.5- 20170122 1/22/2017 37.5 µg/l	OU2-MD2-40.5- 20170122 1/22/2017 40.5 µg/l	OU2-MD2-66- 20170122 1/22/2017 66 µg/l	OU2-MD2-76.5- 20170122 1/22/2017 76.5 µg/l	OU2-MD2-96- 20170123 1/23/2017 96 µg/l	OU2-MD2-131- 20170124 1/24/2017 131 µg/l	OU2-MD2-131- 20170124-1 1/24/2017 131 µg/l	OU2-MD2-164- 20170124 1/24/2017 164 µg/l	OU2-MW1-60-70- 20170126 1/26/2017 60 µg/l	OU2-MW1-64-73- 20170127 1/27/2017 64 µg/l
Analyte	CAS RN	PCS (µg/l)										
1,1,1-Trichloroethane	71-55-6	200	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,1,2,2-Tetrachloroethane	79-34-5	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,1,2-Trichloro-1,2,2-	76-13-1	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,1,2-Trichloroethane	79-00-5	5	25 UJ	25 U	25 UJ	25 U	25 UJ	50 U	50 U	100 U	0.5 U	0.5 U
1,1-Dichloroethane	75-34-3	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,1-Dichloroethene	75-35-4	7	25 U	25 UJ	25 U	25 UJ	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,2,3-Trichlorobenzene	87-61-6	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,2,4-Trichlorobenzene	120-82-1	70	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,2-Dibromo-3-Chloropropane	96-12-8	0.2	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,2-Dibromoethane	106-93-4	0.05	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,2-Dichlorobenzene	95-50-1	600	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,2-Dichloroethane	107-06-2	5	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,2-Dichloropropane	78-87-5	5	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,3-Dichlorobenzene	541-73-1	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
1,4-Dichlorobenzene	106-46-7	75	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
2-Butanone	78-93-3	--	250 U	250 U	250 U	250 U	250 U	500 U	500 U	1000 U	5 U	5 U
2-Hexanone	591-78-6	--	250 U	250 U	250 U	250 U	250 U	500 U	500 U	1000 U	5 U	5 U
4-Methyl-2-Pentanone	108-10-1	--	250 U	250 U	250 U	250 U	250 U	500 U	500 U	1000 U	5 U	5 U
Acetone	67-64-1	--	250 U	250 U	250 U	250 U	250 U	500 U	500 U	1000 U	5 U	5 U
Benzene	71-43-2	5	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Bromochloromethane	74-97-5	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Bromodichloromethane	75-27-4	80	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Bromoform	75-25-2	80	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Bromomethane	74-83-9	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Carbon Disulfide	75-15-0	--	25 U	25 UJ	25 U	25 UJ	25 U	50 UJ	50 UJ	100 UJ	0.5 U	0.5 U
Carbon Tetrachloride	56-23-5	5	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Chlorobenzene	108-90-7	100	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Chloroethane	75-00-3	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Chloroform	67-66-3	80	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Chloromethane	74-87-3	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
cis-1,2-Dichloroethylene	156-59-2	70	110	50	42	20 J	730	1,200	1,300	2,000	0.5 U	0.5 U
cis-1,3-Dichloropropene	10061-01-5	--	25 UJ	25 U	25 UJ	25 U	25 UJ	50 U	50 U	100 U	0.5 U	0.5 U
Cyclohexane	110-82-7	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Dibromochloromethane	124-48-1	80	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Dichlorodifluoromethane	75-71-8	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Ethylbenzene	100-41-4	700	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Isopropylbenzene	98-82-8	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
M, P Xylenes	179601-23-1	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Methyl Acetate	79-20-9	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Methyl tert-Butyl Ether	1634-04-4	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Methylcyclohexane	108-87-2	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Methylene Chloride	75-09-2	5	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
o-Xylene	95-47-6	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Styrene	100-42-5	100	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Tetrachloroethylene (PCE)	127-18-4	5	1,400	1,100	2,000	1,000	10,000	18,000	18,000	29,000	0.5 U	0.5 U
Toluene	108-88-3	1000	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	2.8	3.6
trans-1,2-Dichloroethene	156-60-5	100	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
trans-1,3-Dichloropropene	10061-02-6	--	25 UJ	25 U	25 UJ	25 U	25 UJ	50 U	50 U	100 U	0.5 U	0.5 U
Trichloroethene (TCE)	79-01-6	5	49	39	86	55	920	2,000	1,900	3,400	0.5 U	0.5 U
Trichlorofluoromethane	75-69-4	--	25 U	25 U	25 U	25 U	25 U	50 U	50 U	100 U	0.5 U	0.5 U
Vinyl Chloride	75-01-4	2	25 U	25 U	25 U	25 U	34	50 U	50 U	100 U	0.5 U	0.5 U
1-Pentanol, 4-amino-	927-55-9	NS										
Acetamide, N-(aminocarbonyl)-	4791-21-3	NS										0.52 J
Benzeneethanamine, N-methyl-	589-08-2	NS										
N-Methyltaurine	107-68-6	NS									0.64 J	
Total Alkane Tics	E966796	NS	5.6	5.6	5.6	5.6	5.6	11	11	22	0.11	0.11
Unknown-01	UNKNOWN-01	NS									0.55 J	2.1 J

Notes:
Values in bold and shaded exceed Potential Cleanup Standards (PCS).

Abbreviations:

bgs - below ground surface

J - the reported value is an estimate

NS - no standard; these are tentatively identified compounds (TICs)

U - not detected at or above the Reporting Limit

µg/l - micrograms per liter



Table 5-7
Groundwater Screening Analytical Results Summary
Tutu Wells Superfund Site OU2
St. Thomas, U.S. Virgin Islands (USVI)

Sample ID			OU2-MW1-75-85- 20170126 1/26/2017 75 µg/l	OU2-MW2-47-55- 20170125 1/25/2017 47 µg/l	OU2-MW3-85-95- 20170128 1/28/2017 85 µg/l	OU2-MW3-122-132- 20170128 1/28/2017 122 µg/l	OU2-MW3-135-149- 20170129 1/29/2017 135 µg/l	OU2-MW6-60-70- 20170123 1/23/2017 60 µg/l	OU2-MW6-115-125- 20170124 1/24/2017 115 µg/l
Analyte	CAS RN	PCS (µg/l)							
1,1,1-Trichloroethane	71-55-6	200	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,1,2,2-Tetrachloroethane	79-34-5	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,1,2-Trichloro-1,2,2-	76-13-1	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,1,2-Trichloroethane	79-00-5	5	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,1-Dichloroethane	75-34-3	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,1-Dichloroethene	75-35-4	7	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,2,3-Trichlorobenzene	87-61-6	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,2,4-Trichlorobenzene	120-82-1	70	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,2-Dibromo-3-Chloropropane	96-12-8	0.2	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,2-Dibromoethane	106-93-4	0.05	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,2-Dichlorobenzene	95-50-1	600	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,2-Dichloroethane	107-06-2	5	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,2-Dichloropropane	78-87-5	5	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,3-Dichlorobenzene	541-73-1	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
1,4-Dichlorobenzene	106-46-7	75	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
2-Butanone	78-93-3	--	5.6	250 U	250 U	1000 U	1000 U	50 U	500 U
2-Hexanone	591-78-6	--	5 U	250 U	250 U	1000 U	1000 U	50 U	500 U
4-Methyl-2-Pentanone	108-10-1	--	5 U	250 U	250 U	1000 U	1000 U	50 U	500 U
Acetone	67-64-1	--	5 U	250 U	250 U	1000 U	1000 U	50 U	500 U
Benzene	71-43-2	5	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Bromochloromethane	74-97-5	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Bromodichloromethane	75-27-4	80	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Bromoform	75-25-2	80	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Bromomethane	74-83-9	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Carbon Disulfide	75-15-0	--	0.5 U	25 U	25 U	100 U	100 U	5 UJ	50 UJ
Carbon Tetrachloride	56-23-5	5	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Chlorobenzene	108-90-7	100	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Chloroethane	75-00-3	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Chloroform	67-66-3	80	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Chloromethane	74-87-3	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
cis-1,2-Dichloroethylene	156-59-2	70	0.54	750	160	140	250	11	150
cis-1,3-Dichloropropene	10061-01-5	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Cyclohexane	110-82-7	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Dibromochloromethane	124-48-1	80	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Dichlorodifluoromethane	75-71-8	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Ethylbenzene	100-41-4	700	0.13 J	25 U	25 U	100 U	100 U	5 U	50 U
Isopropylbenzene	98-82-8	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
M, P Xylenes	179601-23-1	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Methyl Acetate	79-20-9	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Methyl tert-Butyl Ether	1634-04-4	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Methylcyclohexane	108-87-2	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Methylene Chloride	75-09-2	5	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
o-Xylene	95-47-6	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Styrene	100-42-5	100	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Tetrachloroethylene (PCE)	127-18-4	5	2.9	930	840	2,100	3,400	180	5,000
Toluene	108-88-3	1000	21	25 U	25 U	100 U	100 U	5 U	50 U
trans-1,2-Dichloroethene	156-60-5	100	0.5 U	10 J	5.5 J	100 U	100 U	5 U	50 U
trans-1,3-Dichloropropene	10061-02-6	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Trichloroethene (TCE)	79-01-6	5	0.21 J	250	33	84 J	58 J	9	57
Trichlorofluoromethane	75-69-4	--	0.5 U	25 U	25 U	100 U	100 U	5 U	50 U
Vinyl Chloride	75-01-4	2	0.5 U	170	25 U	100 U	100 U	5 U	50 U
1-Pentanol, 4-amino-	927-55-9	NS				110 J			
Acetamide, N-(aminocarbonyl)-	4791-21-3	NS							
Benzeneethanamine, N-methyl-	589-08-2	NS					120 J		
N-Methyltaurine	107-68-6	NS							
Total Alkane Tics	E966796	NS	0.11	5.6	5.6	22	22	1.1	11
Unknown-01	UNKNOWN-01	NS	0.74 J			340 J			

Notes:

Values in bold and shaded exceed Potential Cleanup Standards (PCS).

Abbreviations:

bgs - below ground surface

J - the reported value is an estimate

NS - no standard; these are tentatively identified compounds (TICs)

NS - no standard; these are tentatively identified compounds (TICs)

U - not detected at or above the Reporting Limit

µg/l - micrograms per liter



Table 5-8
Groundwater Analytical Results Summary - OU2 FSRI Sampling, February/March 2017
Tutu Wells Superfund Site OU2
St. Thomas, U.S. Virgin Islands (USVI)

Sample ID Sample Date Sample Depth (feet bgs) Unit			BP1-49.5-20170222 2/22/2017 49.5 µg/l	BP1-49.5-20170222-1 2/22/2017 49.5 µg/l	BP2-50-20170222 2/22/2017 50 µg/l	BP3-50-20170222 2/22/2017 50 µg/l	IW1-85-20170302 3/2/2017 85 µg/l	IW1S-48.5-20170227 2/27/2017 48.5 µg/l	IW2-82.9-20170302 3/2/2017 82.9 µg/l	IW2S-50.3-20170302 3/2/2017 50.3 µg/l	MW13-70.5-20170301 3/1/2017 70.5 µg/l
Analyte	CAS RN	PCS (µg/l)									
1,1,1-Trichloroethane	71-55-6	200	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2,2-Tetrachloroethane	79-34-5	--	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 UL
1,1,2-Trichloro-1,2,2-	76-13-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2-Trichloroethane	79-00-5	5	0.5 U	0.5 U	0.5 U	0.5 U	1.6	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethane	75-34-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethene	75-35-4	7	0.5 UL	0.5 U	1.5	0.5 U	170	0.5 U	98	0.5 U	0.5 U
1,2,3-Trichlorobenzene	87-61-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2,4-Trichlorobenzene	120-82-1	70	0.5 U	0.5 U	0.5 U	0.5 U	4	0.5 U	1	0.5 U	0.5 U
1,2-Dibromo-3-	96-12-8	0.2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 UL
1,2-Dibromoethane	106-93-4	0.05	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichlorobenzene	95-50-1	600	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloroethane	107-06-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.65	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloropropane	78-87-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,3-Dichlorobenzene	541-73-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.6	0.5 U	0.64	0.5 U	0.5 U
1,4-Dichlorobenzene	106-46-7	75	0.5 U	0.5 U	0.5 U	0.5 U	2.8	0.5 U	0.62	0.5 U	0.5 U
2-Butanone	78-93-3	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-Hexanone	591-78-6	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	108-10-1	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Acetone	67-64-1	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Benzene	71-43-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromochloromethane	74-97-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromodichloromethane	75-27-4	80	0.5 U	0.5 U	2.7	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromoform	75-25-2	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromomethane	74-83-9	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Carbon Disulfide	75-15-0	--	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 UL
Carbon Tetrachloride	56-23-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chlorobenzene	108-90-7	100	0.5 U	0.5 U	0.5 U	0.5 U	30	0.5 U	11	0.5 U	0.5 U
Chloroethane	75-00-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroform	67-66-3	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloromethane	74-87-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,2-Dichloroethylene	156-59-2	70	34 L	36	760	44	33,000	190	28,000	94	0.5 U
cis-1,3-Dichloropropene	10061-01-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Cyclohexane	110-82-7	--	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Dibromochloromethane	124-48-1	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Dichlorodifluoromethane	75-71-8	--	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 UL	0.5 U	0.5 UL	0.5 UL	0.5 U
Ethylbenzene	100-41-4	700	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Isopropylbenzene	98-82-8	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
M, P Xylenes	179601-23-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl Acetate	79-20-9	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl tert-Butyl Ether	1634-04-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylcyclohexane	108-87-2	--	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylene Chloride	75-09-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	3	0.5 U	0.5 U
o-Xylene	95-47-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Styrene	100-42-5	100	0.5 UL	0.5 U	0.5 U	0.5 U	2.1	0.5 U	0.5 U	0.5 U	0.5 U
Tetrachloroethylene (PCE)	127-18-4	5	13 L	13	340	16	4,100	290	12	16	0.97
Toluene	108-88-3	1,000	0.5 U	0.5 U	0.5 U	0.5 U	1.5	0.5 U	0.82	0.5 U	0.5 U
trans-1,2-Dichloroethene	156-60-5	100	0.67	0.68	19	1.2	1,400	1.5	2,100	1.8	0.5 U
trans-1,3-Dichloropropene	10061-02-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Trichloroethene (TCE)	79-01-6	5	2.3	2.3	310	6	5,800	14	1,300	5	0.5 U
Trichlorofluoromethane	75-69-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Vinyl Chloride	75-01-4	2	15 L	15	79	4.7	12,000	0.5 U	16,000	4.6	0.5 U
Azulene	275-51-4	NS					0.98 NJ				
Methyl Sulfide	75-18-3	NS									
Unknown Aromatics	UNKAROMATIC1	NS									

Notes:

Values in bold and shaded exceed Potential Cleanup Standards (PCS).

Abbreviations:

bgs - below ground surface
J - the reported value is an estimate
K - the reported value may be biased high

L - the reported value may be biased low
NA - not applicable
NJ - There is presumptive evidence that the analyte is present; the analyte is reported as a tentative identification.

NS - no standard; these are tentatively identified compounds (TICs)
PCS - Potential Cleanup Standards
U - not detected at or above the Reporting Limit
µg/l - micrograms per liter



Table 5-8
Groundwater Analytical Results Summary - OU2 FSRI Sampling, February/March 2017
Tutu Wells Superfund Site OU2
St. Thomas, U.S. Virgin Islands (USVI)

Sample ID Sample Date Sample Depth (feet bgs) Unit			MW13D-110-20170221 2/21/2017 110 µg/l	MW14-35.2-20170227 2/27/2017 35.2 µg/l	MW15-26-20170223 2/23/2017 26 µg/l	MW16-34.6-20170301 3/1/2017 34.6 µg/l	MW17-11-20170223 2/23/2017 11 µg/l	MW1D-80-20170228 2/28/2017 80 µg/l	OU2-MW1-75-20170301 3/1/2017 75 µg/l	OU2-MW2-49-20170224 2/24/2017 49 µg/l	OU2-MW3-140-20170306 3/6/2017 140 µg/l
Analyte	CAS RN	PCS (µg/l)									
1,1,1-Trichloroethane	71-55-6	200	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2,2-Tetrachloroethane	79-34-5	--	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 U	0.5 UL	0.5 U
1,1,2-Trichloro-1,2,2-	76-13-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2-Trichloroethane	79-00-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethane	75-34-3	--	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethene	75-35-4	7	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1.2	0.5 U
1,2,3-Trichlorobenzene	87-61-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2,4-Trichlorobenzene	120-82-1	70	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1.8	0.5 U
1,2-Dibromo-3-	96-12-8	0.2	0.5 U	0.5 UL	0.5 UL	0.5 UL	0.5 U	0.5 UL	0.5 U	0.5 UL	0.5 U
1,2-Dibromoethane	106-93-4	0.05	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichlorobenzene	95-50-1	600	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloroethane	107-06-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloropropane	78-87-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,3-Dichlorobenzene	541-73-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.74	0.5 U
1,4-Dichlorobenzene	106-46-7	75	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1.2	0.5 U
2-Butanone	78-93-3	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-Hexanone	591-78-6	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	108-10-1	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Acetone	67-64-1	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Benzene	71-43-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromochloromethane	74-97-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromodichloromethane	75-27-4	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromoform	75-25-2	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromomethane	74-83-9	--	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Carbon Disulfide	75-15-0	--	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 U
Carbon Tetrachloride	56-23-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chlorobenzene	108-90-7	100	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroethane	75-00-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroform	67-66-3	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloromethane	74-87-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,2-Dichloroethylene	156-59-2	70	0.5 U	0.67 L	7.1	1.7	0.72	49	2.8	410	1,700
cis-1,3-Dichloropropene	10061-01-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Cyclohexane	110-82-7	--	0.5 UL	0.5 UL	0.5 U	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U
Dibromochloromethane	124-48-1	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Dichlorodifluoromethane	75-71-8	--	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 UL
Ethylbenzene	100-41-4	700	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Isopropylbenzene	98-82-8	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
M, P Xylenes	179601-23-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl Acetate	79-20-9	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl tert-Butyl Ether	1634-04-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylcyclohexane	108-87-2	--	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylene Chloride	75-09-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
o-Xylene	95-47-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Styrene	100-42-5	100	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tetrachloroethylene (PCE)	127-18-4	5	5.4	1.1	33	7.9	3.2	84	3.5	1,100	3,500
Toluene	108-88-3	1,000	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	2.3
trans-1,2-Dichloroethene	156-60-5	100	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	3.5	0.5 U	7	2.5
trans-1,3-Dichloropropene	10061-02-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Trichloroethene (TCE)	79-01-6	5	0.51	0.7 L	2.1	0.5 U	0.5 U	11	0.82	270	50
Trichlorofluoromethane	75-69-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Vinyl Chloride	75-01-4	2	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U	8.4	0.5 U	180	6.2
Azulene	275-51-4	NS									
Methyl Sulfide	75-18-3	NS									
Unknown Aromatics	UNKAROMATIC1	NS									

Notes:

Values in bold and shaded exceed Potential Cleanup Standards (PCS).

Abbreviations:

bgs - below ground surface

J - the reported value is an estimate

K - the reported value may be biased high

L - the reported value may be biased low

NA - not applicable

NJ - There is presumptive evidence that the analyte is present; the analyte is reported as a tentative identification.

NS - no standard; these are tentatively identified compounds (TICs)

PCS - Potential Cleanup Standards

U - not detected at or above the Reporting Limit

µg/l - micrograms per liter



Table 5-8
Groundwater Analytical Results Summary - OU2 FSRI Sampling, February/March 2017
Tutu Wells Superfund Site OU2
St. Thomas, U.S. Virgin Islands (USVI)

Sample ID Sample Date Sample Depth (feet bgs) Unit			OU2-MW3-90.5-20170306 3/6/2017 90.5 µg/l	OU2-MW4-95-20170222 2/22/2017 95 µg/l	OU2-MW5-135-20170224 2/24/2017 135 µg/l	OU2-MW6-120-20170228 2/28/2017 120 µg/l	RD10-90-20170223 2/23/2017 90 µg/l	RD11-97.5-20170227 2/27/2017 97.5 µg/l	RD12-142.5-20170222 2/22/2017 142.5 µg/l	RD13-112.5-20170224 2/24/2017 112.5 µg/l	RD9-97.5-20170228 2/28/2017 97.5 µg/L
Analyte	CAS RN	PCS (µg/l)									
1,1,1-Trichloroethane	71-55-6	200	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2,2-Tetrachloroethane	79-34-5	--	0.5 U	0.5 UL	0.5 UL	0.5 U	0.5 UL	0.5 UL	0.5 UL	0.5 U	0.5 U
1,1,2-Trichloro-1,2,2-	76-13-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2-Trichloroethane	79-00-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1.3
1,1-Dichloroethane	75-34-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethene	75-35-4	7	0.5 U	0.74	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	400
1,2,3-Trichlorobenzene	87-61-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2,4-Trichlorobenzene	120-82-1	70	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	4.1
1,2-Dibromo-3-	96-12-8	0.2	0.5 U	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U
1,2-Dibromoethane	106-93-4	0.05	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichlorobenzene	95-50-1	600	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloroethane	107-06-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.8
1,2-Dichloropropane	78-87-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,3-Dichlorobenzene	541-73-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,4-Dichlorobenzene	106-46-7	75	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.53	0.5 U	0.5 U	2.1
2-Butanone	78-93-3	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-Hexanone	591-78-6	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	108-10-1	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Acetone	67-64-1	--	5 U	5 U	5.8	5 U	5 U	5 U	5 U	5 U	13
Benzene	71-43-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromochloromethane	74-97-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromodichloromethane	75-27-4	80	0.5 U	1.2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromoform	75-25-2	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromomethane	74-83-9	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Carbon Disulfide	75-15-0	--	0.5 U	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	6.6 L
Carbon Tetrachloride	56-23-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chlorobenzene	108-90-7	100	0.5 U	0.5 U	0.5 U	1.9	0.5 U	3.2	0.5 U	0.5 U	48
Chloroethane	75-00-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroform	67-66-3	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloromethane	74-87-3	--	0.51	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,2-Dichloroethylene	156-59-2	70	380	140 K	20	150	47	12	2.1	140	160,000
cis-1,3-Dichloropropene	10061-01-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Cyclohexane	110-82-7	--	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 UL	0.5 U	0.5 UL	0.5 U	0.5 U
Dibromochloromethane	124-48-1	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Dichlorodifluoromethane	75-71-8	--	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Ethylbenzene	100-41-4	700	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Isopropylbenzene	98-82-8	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
M, P Xylenes	179601-23-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl Acetate	79-20-9	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl tert-Butyl Ether	1634-04-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylcyclohexane	108-87-2	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylene Chloride	75-09-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
o-Xylene	95-47-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.52	0.5 U	0.5 U	0.5 U
Styrene	100-42-5	100	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tetrachloroethylene (PCE)	127-18-4	5	2,100	2,500	86	19,000	110	0.98	2.3	15	92,000
Toluene	108-88-3	1,000	4	0.5 U	0.5 U	2.6	0.5 U	0.5 U	0.5 U	0.5 U	4.7
trans-1,2-Dichloroethene	156-60-5	100	4.7	1.6	0.5 U	2.1	0.5 U	17	0.5 U	240	2,300
trans-1,3-Dichloropropene	10061-02-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Trichloroethene (TCE)	79-01-6	5	200	130	9.3	140	10	2.9	0.5 U	50	29,000
Trichlorofluoromethane	75-69-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Vinyl Chloride	75-01-4	2	9.2	2.2	0.5 U	2.6	0.5 U	7.8	4.3	74	38,000
Azulene	275-51-4	NS									
Methyl Sulfide	75-18-3	NS			2.7 NJ						
Unknown Aromatics	UNKAROMATIC1	NS							1.4 NJ		

Notes:

Values in bold and shaded exceed Potential Cleanup Standards (PCS).

Abbreviations:

bgs - below ground surface

J - the reported value is an estimate

K - the reported value may be biased high

L - the reported value may be biased low

NA - not applicable

NJ - There is presumptive evidence that the analyte is present; the analyte is reported as a tentative identification.

NS - no standard; these are tentatively identified compounds (TICs)

PCS - Potential Cleanup Standards

U - not detected at or above the Reporting Limit

µg/l - micrograms per liter



Table 5-8
Groundwater Analytical Results Summary - OU2 FSRI Sampling, February/March 2017
Tutu Wells Superfund Site OU2
St. Thomas, U.S. Virgin Islands (USVI)

Sample ID Sample Date Sample Depth (feet bgs) Unit			RW6-125-20170301 3/1/2017 125 µg/l	RW6-125-20170301-1 3/1/2017 125 µg/l	RW7-75-20170301 3/1/2017 75 µg/l	RW8-80-20170228 2/28/2017 80 µg/l	RW9-55-20170301 3/1/2017 55 µg/l	EB-20170221 2/21/2017 NA µg/l	EB-20170222 2/21/2017 NA µg/l	EB-20170223 2/23/2017 NA µg/l	EB-20170224 2/24/2017 NA µg/l
Analyte	CAS RN	PCS (µg/l)									
1,1,1-Trichloroethane	71-55-6	200	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2,2-Tetrachloroethane	79-34-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 UL	0.5 UL	0.5 UL	0.5 UL
1,1,2-Trichloro-1,2,2-	76-13-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2-Trichloroethane	79-00-5	5	0.5 U	0.76	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethane	75-34-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethene	75-35-4	7	41	37	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2,3-Trichlorobenzene	87-61-6	--	0.67	0.61	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2,4-Trichlorobenzene	120-82-1	70	2.8	2.7	0.5 U	0.63	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dibromo-3-	96-12-8	0.2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dibromoethane	106-93-4	0.05	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichlorobenzene	95-50-1	600	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloroethane	107-06-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloropropane	78-87-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,3-Dichlorobenzene	541-73-1	--	0.5 U	0.5 U	0.5 U	1.3	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,4-Dichlorobenzene	106-46-7	75	1.1	1	0.5 U	1.5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
2-Butanone	78-93-3	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-Hexanone	591-78-6	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	108-10-1	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Acetone	67-64-1	--	5 U	5 U	5 U	5 U	5 U	5.3	5 U	5.1	5.8
Benzene	71-43-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromochloromethane	74-97-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromodichloromethane	75-27-4	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromoform	75-25-2	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromomethane	74-83-9	--	0.5 UL	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Carbon Disulfide	75-15-0	--	0.5 U	0.5 U	0.5 U	43 L	0.5 U	0.5 UL	0.5 UL	0.5 UL	0.5 UL
Carbon Tetrachloride	56-23-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chlorobenzene	108-90-7	100	9.7	9.5	0.5 U	29	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroethane	75-00-3	--	1	1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroform	67-66-3	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloromethane	74-87-3	--	0.5 U	1.2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,2-Dichloroethylene	156-59-2	70	7,100	4,400	19	870	18	0.51	0.5 U	0.5 U	0.5 U
cis-1,3-Dichloropropene	10061-01-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Cyclohexane	110-82-7	--	0.5 U	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 UL	0.5 UL	0.5 UL	0.5 UL
Dibromochloromethane	124-48-1	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Dichlorodifluoromethane	75-71-8	--	0.5 U	0.5 U	0.5 UL	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U
Ethylbenzene	100-41-4	700	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Isopropylbenzene	98-82-8	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
M, P Xylenes	179601-23-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl Acetate	79-20-9	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl tert-Butyl Ether	1634-04-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylcyclohexane	108-87-2	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylene Chloride	75-09-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
o-Xylene	95-47-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Styrene	100-42-5	100	0.5 U	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tetrachloroethylene (PCE)	127-18-4	5	6,800	12,000	56	2,100	110	0.5 U	0.5 U	0.5 U	1
Toluene	108-88-3	1,000	0.98	0.98	0.5 U	1.3	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
trans-1,2-Dichloroethene	156-60-5	100	190	61	0.5 U	1,500	0.6	0.5 U	0.5 U	0.5 U	0.5 U
trans-1,3-Dichloropropene	10061-02-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Trichloroethene (TCE)	79-01-6	5	6,600	5,700	4.5	27	10	0.5 U	0.5 U	0.5 U	0.5 U
Trichlorofluoromethane	75-69-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Vinyl Chloride	75-01-4	2	3,500	180	0.5 U	2,600	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Azulene	275-51-4	NS									
Methyl Sulfide	75-18-3	NS									
Unknown Aromatics	UNKAROMATIC1	NS									

Notes:

Values in bold and shaded exceed Potential Cleanup Standards (PCS).

Abbreviations:

bgs - below ground surface
J - the reported value is an estimate
K - the reported value may be biased high

L - the reported value may be biased low
NA - not applicable
NJ - There is presumptive evidence that the analyte is present; the analyte is reported as a tentative identification.

NS - no standard; these are tentatively identified compounds (TICs)
PCS - Potential Cleanup Standards
U - not detected at or above the Reporting Limit
µg/l - micrograms per liter



Table 5-8
Groundwater Analytical Results Summary - OU2 FSRI Sampling, February/March 2017
Tutu Wells Superfund Site OU2
St. Thomas, U.S. Virgin Islands (USVI)

Sample ID Sample Date Sample Depth (feet bgs) Unit			EB-20170227 2/27/2017 NA µg/l	EB-20170228 2/28/2017 NA µg/l	EB-20170301 3/1/2017 NA µg/l	EB-20170302 3/2/2017 NA µg/l	EB-20170306 3/6/2017 NA µg/l	FB-20170221 2/21/2017 NA µg/l	FB-20170222 2/22/2017 NA µg/l	FB-20170223 2/23/2017 NA µg/l	FB-20170224 2/24/2017 NA µg/l	FB-20170227 2/27/2017 NA µg/l
Analyte	CAS RN	PCS (µg/l)										
1,1,1-Trichloroethane	71-55-6	200	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2,2-Tetrachloroethane	79-34-5	--	0.5 UL	0.5 UL	0.5 UL	0.5 U	0.5 U	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL
1,1,2-Trichloro-1,2,2-	76-13-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2-Trichloroethane	79-00-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethane	75-34-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethene	75-35-4	7	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2,3-Trichlorobenzene	87-61-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2,4-Trichlorobenzene	120-82-1	70	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dibromo-3-	96-12-8	0.2	0.5 U	0.5 UL	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dibromoethane	106-93-4	0.05	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichlorobenzene	95-50-1	600	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloroethane	107-06-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloropropane	78-87-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,3-Dichlorobenzene	541-73-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,4-Dichlorobenzene	106-46-7	75	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
2-Butanone	78-93-3	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-Hexanone	591-78-6	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	108-10-1	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Acetone	67-64-1	--	11	11	11	5 U	5 U	5	5.5	6.2	5.2	11
Benzene	71-43-2	5	1.2	1	0.79	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	1.4
Bromochloromethane	74-97-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromodichloromethane	75-27-4	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromoform	75-25-2	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromomethane	74-83-9	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Carbon Disulfide	75-15-0	--	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL
Carbon Tetrachloride	56-23-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chlorobenzene	108-90-7	100	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroethane	75-00-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroform	67-66-3	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloromethane	74-87-3	--	0.5 U	0.5 U	0.5 U	1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,2-Dichloroethylene	156-59-2	70	0.5 U	0.5 U	0.5 U	0.81	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,3-Dichloropropene	10061-01-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Cyclohexane	110-82-7	--	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL
Dibromochloromethane	124-48-1	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Dichlorodifluoromethane	75-71-8	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Ethylbenzene	100-41-4	700	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Isopropylbenzene	98-82-8	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
M, P Xylenes	179601-23-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl Acetate	79-20-9	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl tert-Butyl Ether	1634-04-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylcyclohexane	108-87-2	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylene Chloride	75-09-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
o-Xylene	95-47-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Styrene	100-42-5	100	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tetrachloroethylene (PCE)	127-18-4	5	0.5 U	0.5 U	0.59	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Toluene	108-88-3	1,000	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
trans-1,2-Dichloroethene	156-60-5	100	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
trans-1,3-Dichloropropene	10061-02-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Trichloroethene (TCE)	79-01-6	5	0.5 U	0.5 U	0.5 U	1	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Trichlorofluoromethane	75-69-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Vinyl Chloride	75-01-4	2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Azulene	275-51-4	NS										
Methyl Sulfide	75-18-3	NS										
Unknown Aromatics	UNKAROMATIC1	NS										

Notes:

Values in bold and shaded exceed Potential Cleanup Standards (PCS).

Abbreviations:

bgs - below ground surface
J - the reported value is an estimate
K - the reported value may be biased high

L - the reported value may be biased low

NA - not applicable

NJ - There is presumptive evidence that the analyte is present; the analyte is reported as a tentative identification.

NS - no standard; these are tentatively identified compounds (TICs)

PCS - Potential Cleanup Standards

U - not detected at or above the Reporting Limit

µg/l - micrograms per liter



Table 5-8
Groundwater Analytical Results Summary - OU2 FSRI Sampling, February/March 2017
Tutu Wells Superfund Site OU2
St. Thomas, U.S. Virgin Islands (USVI)

Sample ID Sample Date Sample Depth (feet bgs) Unit			FB-20170228 2/28/2017 NA µg/l	FB-20170301 3/1/2017 NA µg/l	FB-20170302 3/2/2017 NA µg/l	FB-20170306 3/6/2017 NA µg/l	TB-20170223 2/23/2017 NA µg/l	TB-20170227 2/27/2017 NA µg/l	TB-20170301 3/1/2017 NA µg/l	TB-20170302 3/2/2017 NA µg/l	TB-20170306 3/6/2017 NA µg/l
Analyte	CAS RN	PCS (µg/l)									
1,1,1-Trichloroethane	71-55-6	200	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2,2-Tetrachloroethane	79-34-5	--	0.5 UL	0.5 UL	0.5 U	0.5 U	0.5 UL	0.5 UL	0.5 UL	0.5 U	0.5 U
1,1,2-Trichloro-1,2,2-	76-13-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1,2-Trichloroethane	79-00-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethane	75-34-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,1-Dichloroethene	75-35-4	7	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2,3-Trichlorobenzene	87-61-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2,4-Trichlorobenzene	120-82-1	70	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dibromo-3-	96-12-8	0.2	0.5 UL	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 UL	0.5 UL	0.5 U	0.5 U
1,2-Dibromoethane	106-93-4	0.05	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichlorobenzene	95-50-1	600	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloroethane	107-06-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,2-Dichloropropane	78-87-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,3-Dichlorobenzene	541-73-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
1,4-Dichlorobenzene	106-46-7	75	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
2-Butanone	78-93-3	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
2-Hexanone	591-78-6	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
4-Methyl-2-Pentanone	108-10-1	--	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Acetone	67-64-1	--	12	12	5 U	5 U	5 U	5 U	5 U	5 U	5 U
Benzene	71-43-2	5	1.2	0.99	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromochloromethane	74-97-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromodichloromethane	75-27-4	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromoform	75-25-2	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Bromomethane	74-83-9	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Carbon Disulfide	75-15-0	--	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL	0.5 UL
Carbon Tetrachloride	56-23-5	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chlorobenzene	108-90-7	100	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroethane	75-00-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloroform	67-66-3	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Chloromethane	74-87-3	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,2-Dichloroethylene	156-59-2	70	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
cis-1,3-Dichloropropene	10061-01-5	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Cyclohexane	110-82-7	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 UL	0.5 U	0.5 U	0.5 U	0.5 U
Dibromochloromethane	124-48-1	80	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Dichlorodifluoromethane	75-71-8	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Ethylbenzene	100-41-4	700	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Isopropylbenzene	98-82-8	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
M, P Xylenes	179601-23-1	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl Acetate	79-20-9	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methyl tert-Butyl Ether	1634-04-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylcyclohexane	108-87-2	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Methylene Chloride	75-09-2	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
o-Xylene	95-47-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Styrene	100-42-5	100	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Tetrachloroethylene (PCE)	127-18-4	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.91	0.5 U	0.5 U	0.5 U
Toluene	108-88-3	1,000	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
trans-1,2-Dichloroethene	156-60-5	100	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
trans-1,3-Dichloropropene	10061-02-6	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Trichloroethene (TCE)	79-01-6	5	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U		0.5 U
Trichlorofluoromethane	75-69-4	--	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Vinyl Chloride	75-01-4	2	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U	0.5 U
Azulene	275-51-4	NS									
Methyl Sulfide	75-18-3	NS									
Unknown Aromatics	UNKAROMATIC1	NS									

Notes:

Values in bold and shaded exceed Potential Cleanup Standards (PCS).

Abbreviations:

bgs - below ground surface

J - the reported value is an estimate

K - the reported value may be biased high

L - the reported value may be biased low

NA - not applicable

NJ - There is presumptive evidence that the analyte is present; the analyte is reported as a tentative identification.

NS - no standard; these are tentatively identified compounds (TICs)

PCS - Potential Cleanup Standards

U - not detected at or above the Reporting Limit

µg/l - micrograms per liter



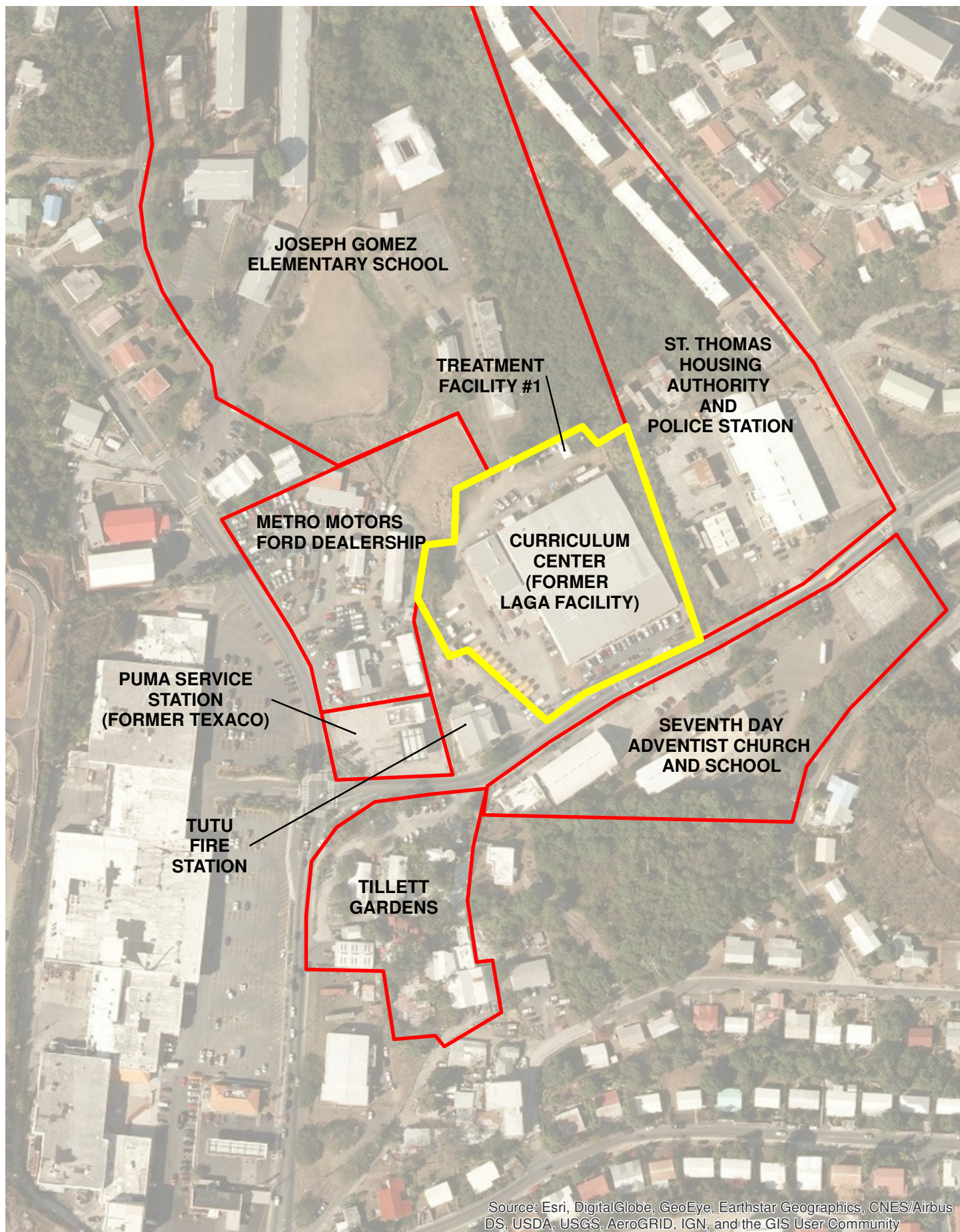


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 Source: US National Park Service

SITE LOCATION MAP ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 1-1





OU2 SITE VICINITY MAP ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 1-3



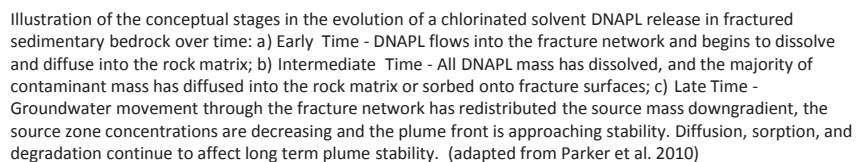
Data Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

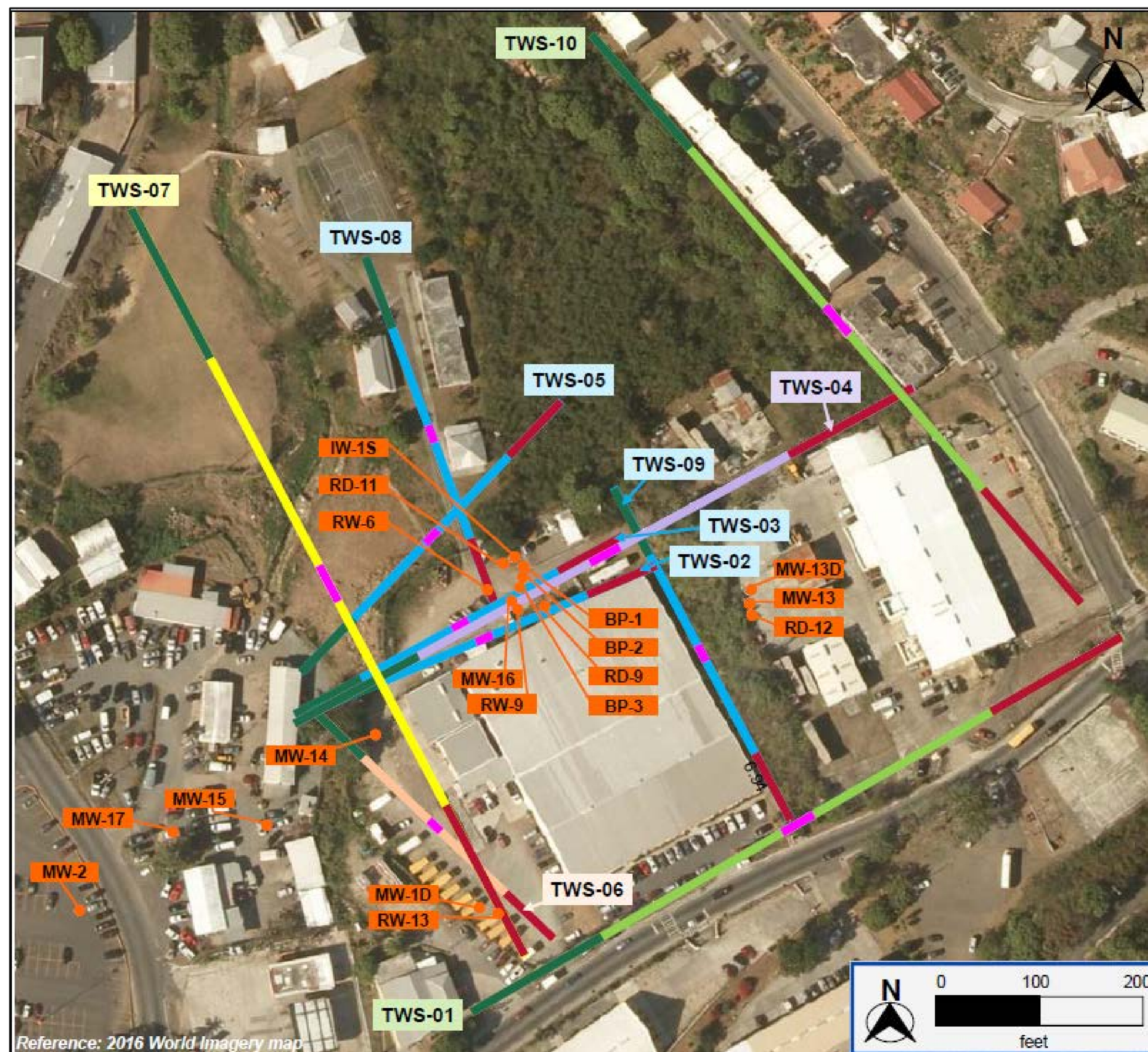


United States
Environmental Protection
Agency

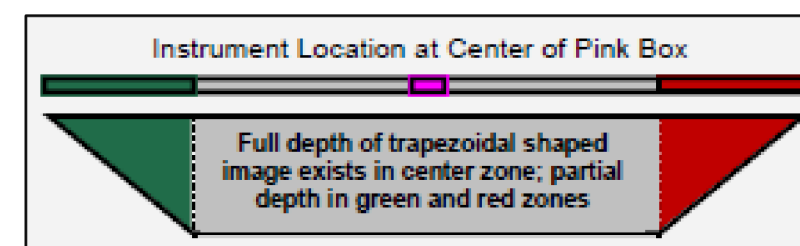
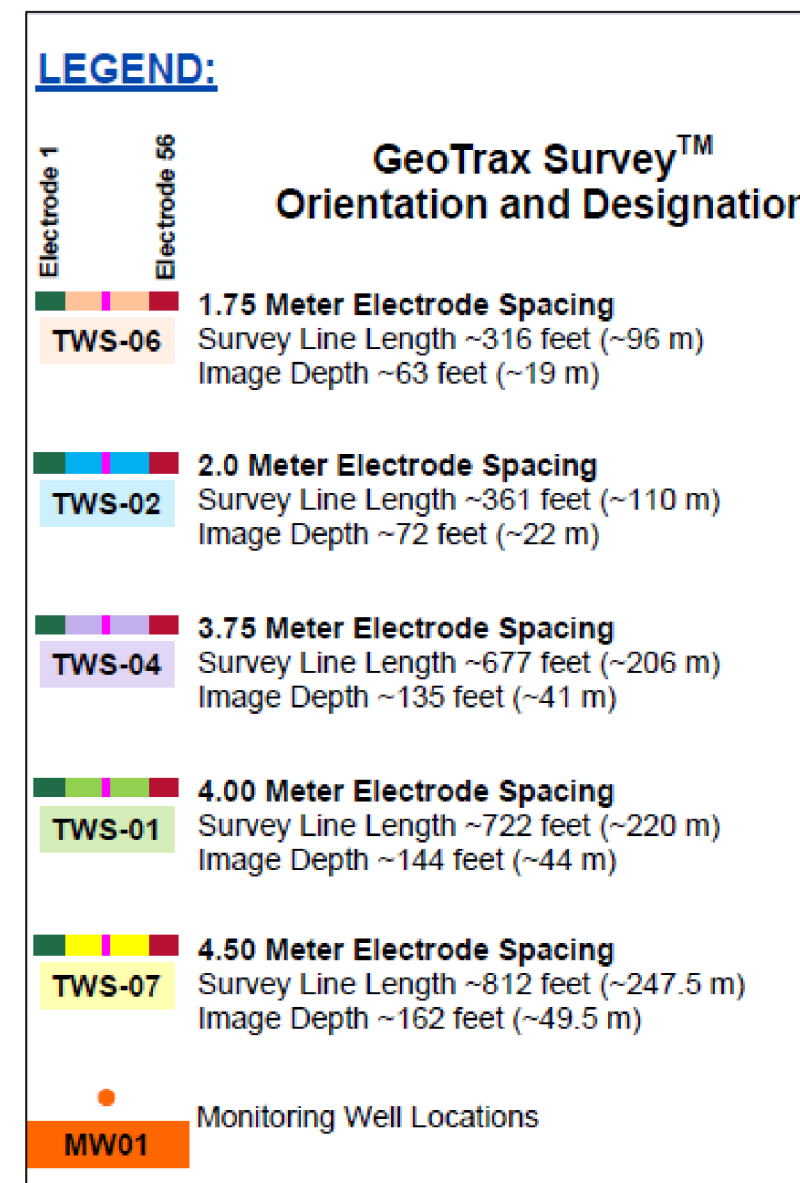
OU2 SITE PLAN
ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 1-4





Source: Aestus LLC, 2017

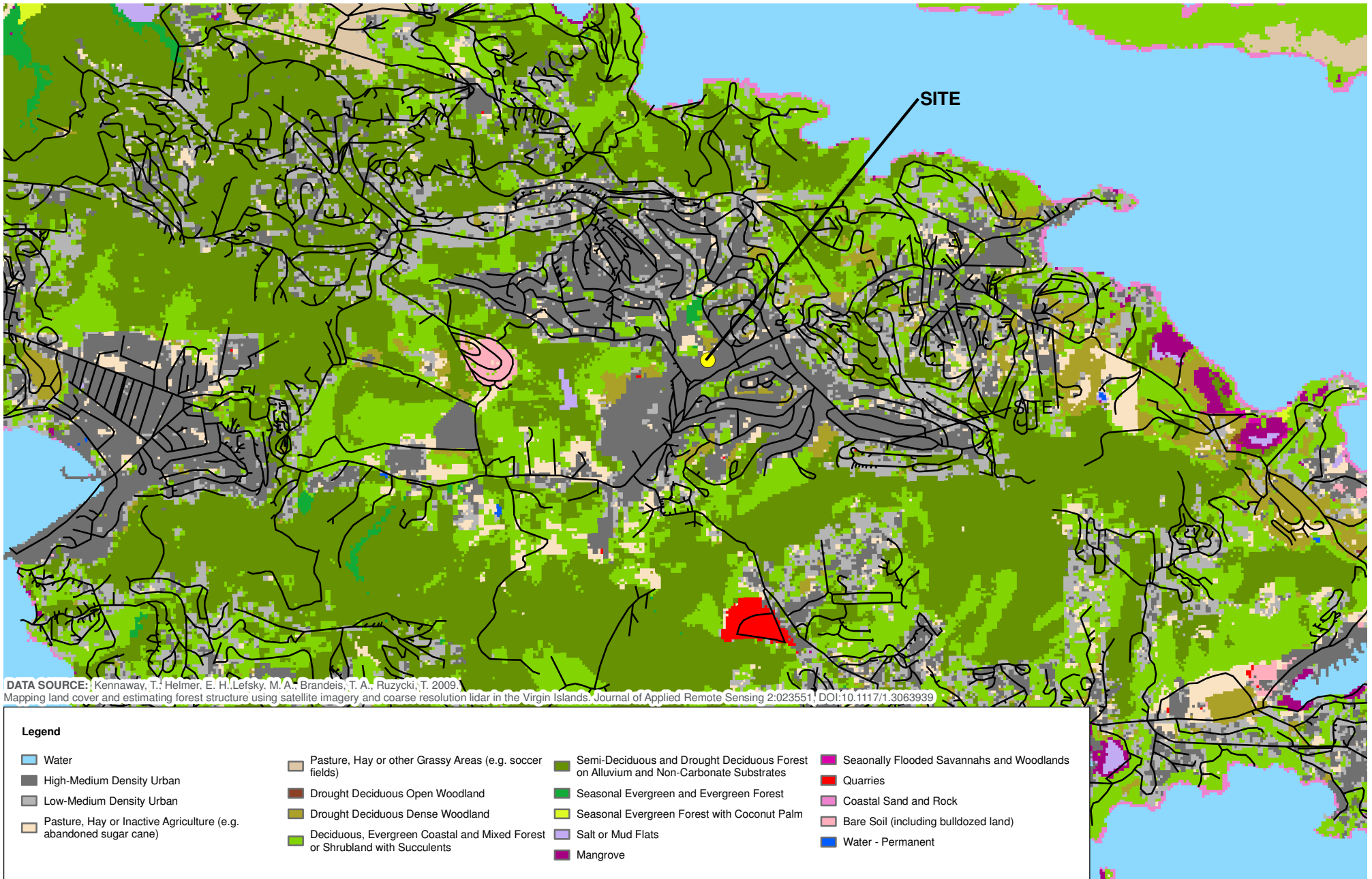


SURFACE GEOPHYSICS (GeoTrax™) LAYOUT

ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 2-1

TUTU WELLS SUPERFUND SITE FOCUSED SOURCE RI/FS OU2



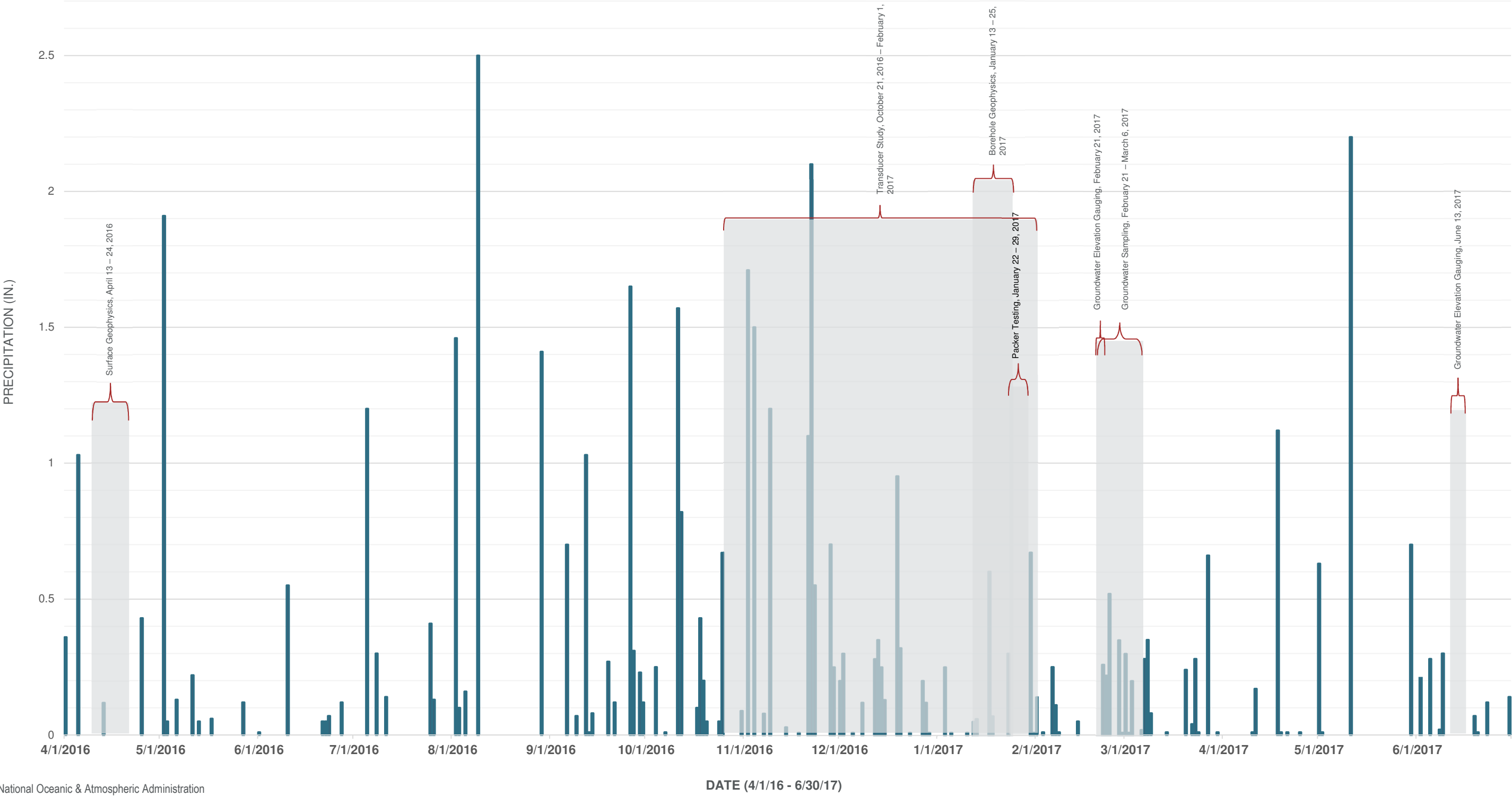
DATA SOURCE: Kennaway, T.; Helmer, E. H.; Lefsky, M. A.; Brandeis, T. A.; Ruzicki, T. 2009. Mapping land cover and estimating forest structure using satellite imagery and coarse resolution lidar in the Virgin Islands. *Journal of Applied Remote Sensing* 2:023551, DOI:10.1117/1.3063939



LAND USE
ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 3-1

Daily Precipitation in Redhook Bay, St. Thomas, USVI

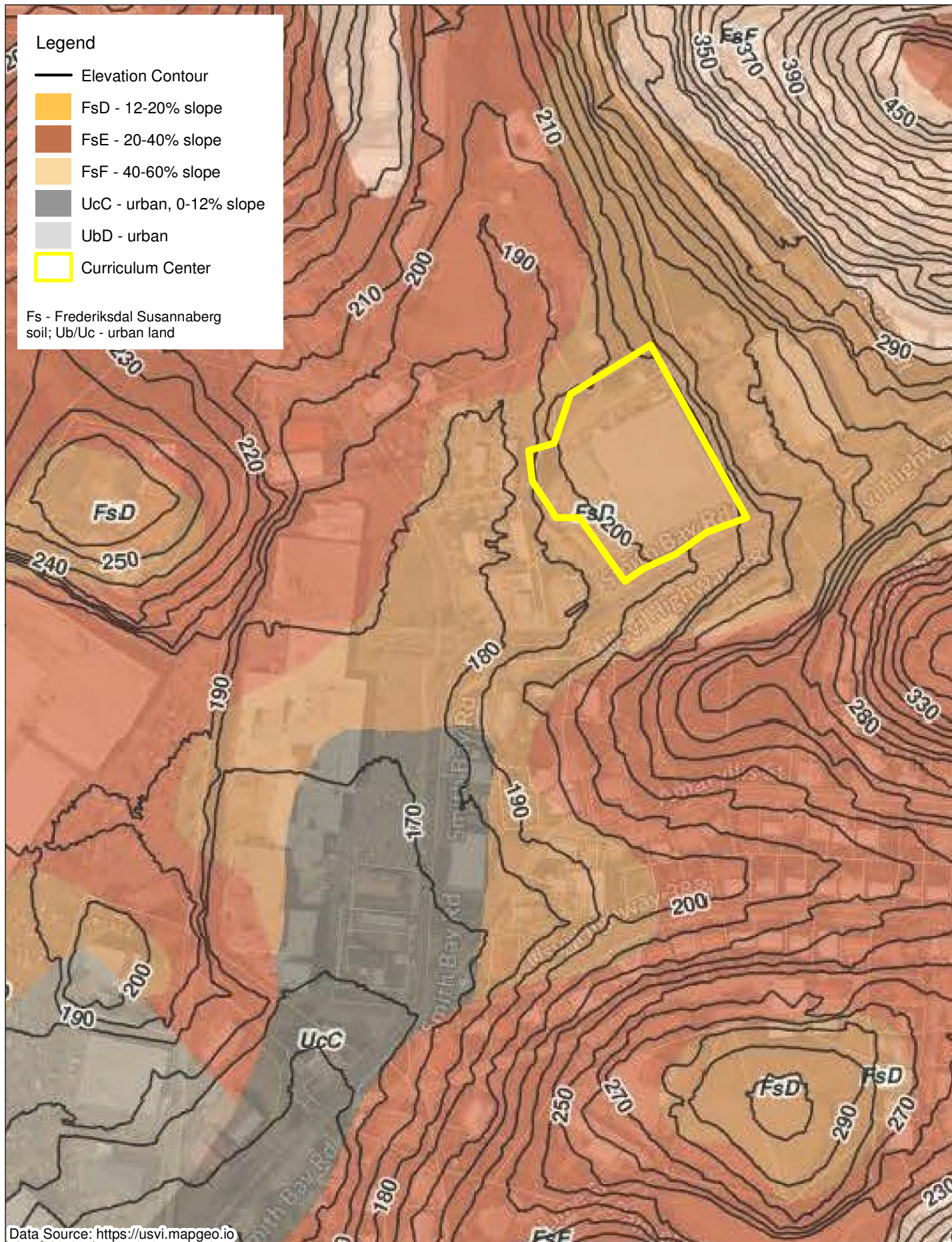


Source: National Oceanic & Atmospheric Administration

Legend

- Elevation Contour
- FsD - 12-20% slope
- FsE - 20-40% slope
- FsF - 40-60% slope
- UcC - urban, 0-12% slope
- UbD - urban
- Curriculum Center

Fs - Frederiksdal Susannaberg soil; Ub/Uc - urban land

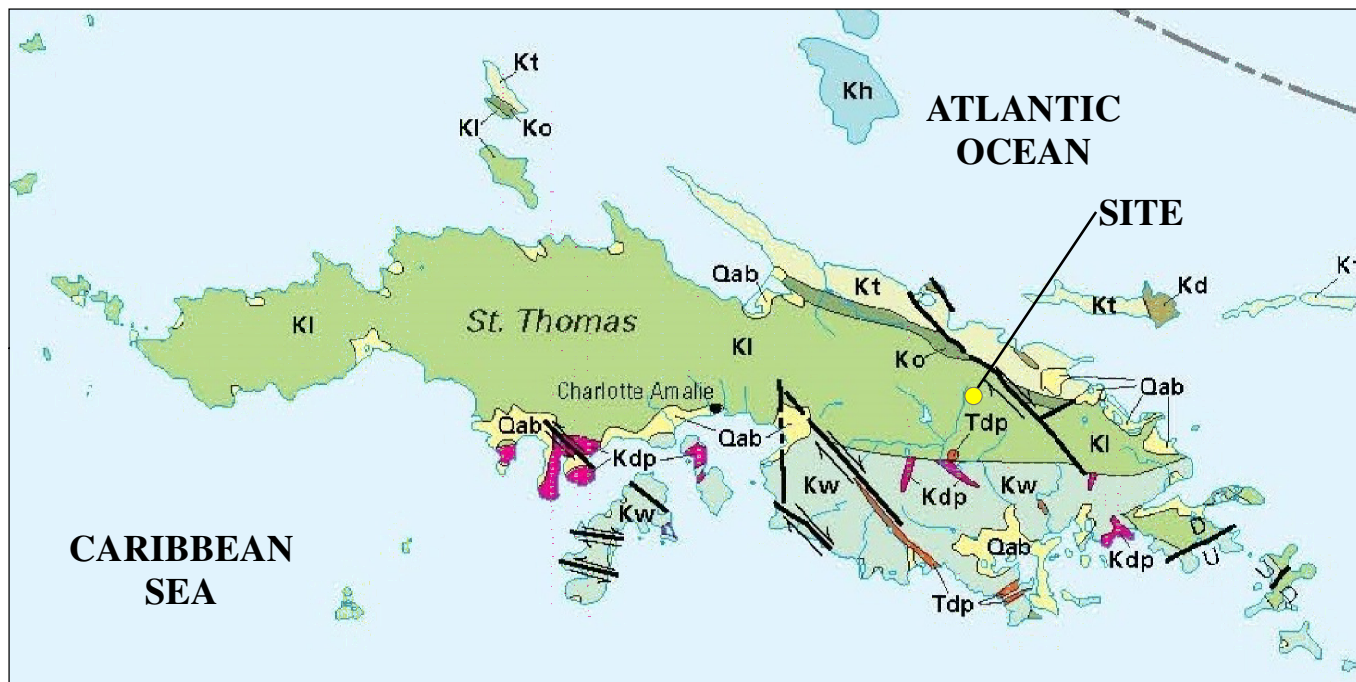


Data Source: <https://usvi.mapgeo.io>



SURFACE SOIL AND TOPOGRAPHY ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 3-3



Base Modified from U.S. Geological Survey
 Western St. Thomas, Eastern St. Thomas
 Western St. John, Eastern St. John, 1:24,000

EXPLANATION

Quaternary deposits		Kt	Tutu Formation
Qab	Alluvium, minor beach deposits	Ko	Outer Brass Limestone
Early Tertiary to Cretaceous rocks		Kl	Lousenhoj Formation
Tdp	Dikes and plugs	Kdp	Dikes and plugs
Cretaceous rocks		Kw	Water Island Formation
Kd	Dioritic rocks		
Kh	Hans Lollik Formation		



REGIONAL GEOLOGY ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 3-4

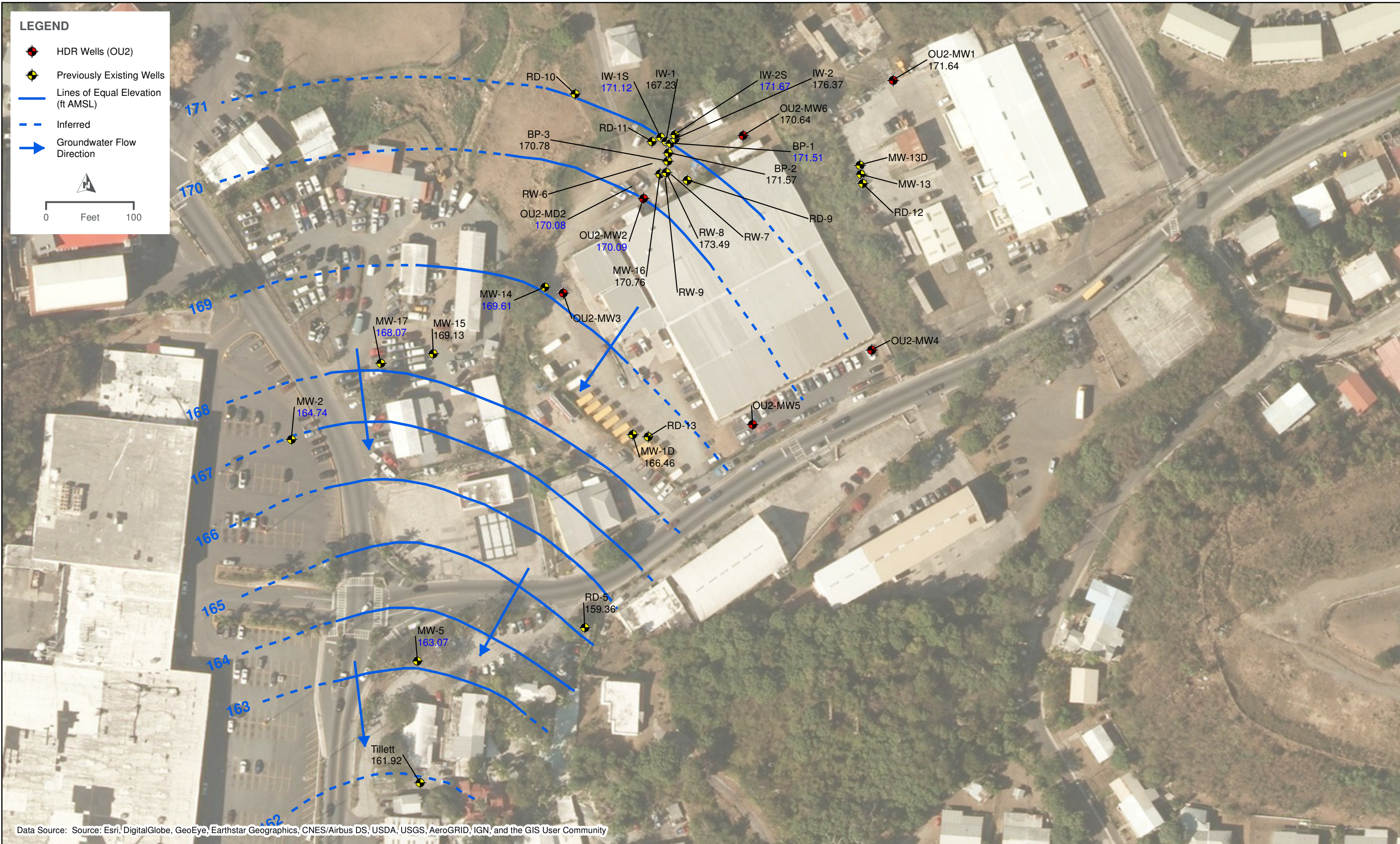


Data Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



OU2 SITE GEOLOGY
ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 3-5



Data Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

SHALLOW GROUNDWATER ELEVATION MAP - FEBRUARY 2017

ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 3-6





Data Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

SHALLOW GROUNDWATER ELEVATION MAP - JUNE 2017

ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 3-8





Data Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



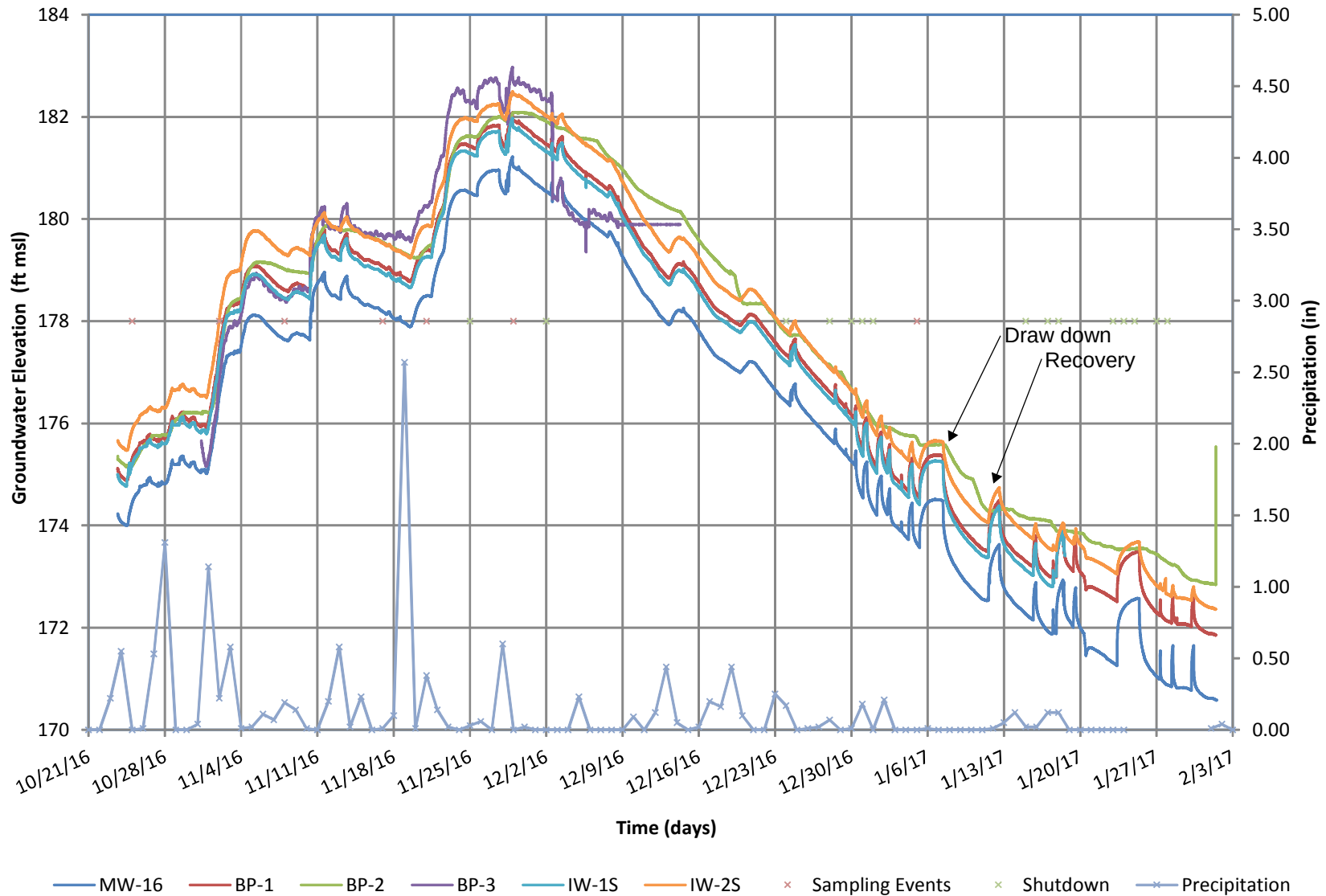
DEEP GROUNDWATER ELEVATION MAP - JUNE 2017

ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 3-9

Long-term Water Level Monitoring Study

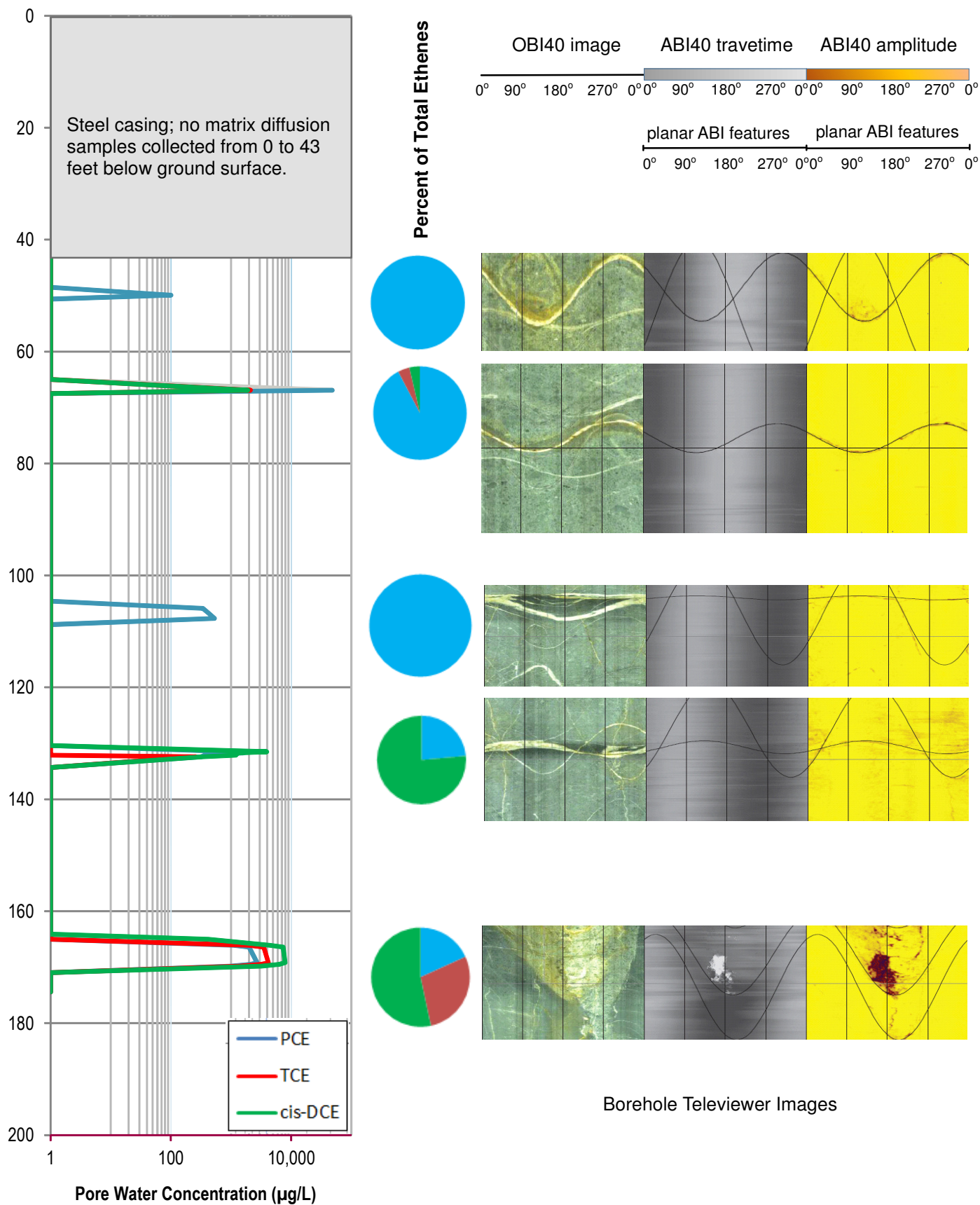
Hydrograph of Shallow Zone Wells North of the Treatment Facility



United States
Environmental Protection
Agency

TRANSDUCER STUDY HYDROGRAPHS
ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 3-10



OU2-MD2 ROCK MATRIX DIFFUSION PORE WATER RESULTS
ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 5-1

LEGEND

- HDR Wells (OU2)
- Other Wells

0 Feet 40

Analyte	PCS
1,1-DCE	7
cis-1,2-DCE	70
PCE	5
trans-1,2-DCE	100
TCE	5
VC	2

NOTES:

- Samples were collected in February/March 2017.
- Data are reported in ug/L.
- PCS = Potential Cleanup Standards
- Analytical results shown are exceedances of PCS
- PCE = Tetrachloroethylene
- TCE = Trichloroethene
- cis-1,2-DCE = cis-1,2-Dichloroethene
- trans-1,2-DCE = trans-1,2-Dichloroethene
- 1,1-DCE = 1,1-Dichloroethene
- VC = Vinyl Chloride
- K = reported value may be biased high.

Data Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Location Data:

Location ID	RD10-90
PCE	110
TCE	10

Location ID	BP3-50
PCE	16
TCE	6
VC	4.7

Location ID	RD11-97.5
VC	7.8

Location ID	RD13-112.5
cis-1,2-DCE	140
PCE	15
trans-1,2-DCE	240
TCE	50
VC	74

Location ID	MW1D-80
PCE	84
TCE	11
VC	8.4

Location ID	RD9-97.5
1,1-DCE	400
cis-1,2-DCE	160,000
PCE	92,000
trans-1,2-DCE	2,300
TCE	29,000
VC	38,000

Location ID	RW7-75
PCE	56

Location ID	RW8-80
cis-1,2-DCE	870
PCE	2,100
trans-1,2-DCE	1,500
TCE	27
VC	2,600

Location ID	RW9-55
PCE	110
TCE	10

Location ID	MW16-34.6
PCE	7.9

Location ID	OU2-MW2-49
cis-1,2-DCE	410
PCE	1,100
TCE	270
VC	180

Location ID	MW14-35.2
COCs	< PCS

Location ID	MW15-26
PCE	33

Location ID	MW17-11
COCs	< PCS

Location ID	OU2-MW3-90	OU2-MW3-140
cis-1,2-DCE	380	1,700
PCE	2,100	3,500
TCE	200	50
VC	9.2	6.2

Location ID	RD10-90
PCE	110
TCE	10

Location ID	BP3-50
PCE	16
TCE	6
VC	4.7

Location ID	RD11-97.5
VC	7.8

Location ID	RD13-112.5
cis-1,2-DCE	140
PCE	15
trans-1,2-DCE	240
TCE	50
VC	74

Location ID	MW1D-80
PCE	84
TCE	11
VC	8.4

Location ID	RW7-75
PCE	56

Location ID	RW8-80
cis-1,2-DCE	870
PCE	2,100
trans-1,2-DCE	1,500
TCE	27
VC	2,600

Location ID	RW9-55
PCE	110
TCE	10

Location ID	MW16-34.6
PCE	7.9

Location ID	OU2-MW2-49
cis-1,2-DCE	410
PCE	1,100
TCE	270
VC	180

Location ID	MW14-35.2
COCs	< PCS

Location ID	MW15-26
PCE	33

Location ID	MW17-11
COCs	< PCS

Location ID	OU2-MW3-90	OU2-MW3-140
cis-1,2-DCE	380	1,700
PCE	2,100	3,500
TCE	200	50
VC	9.2	6.2

Location ID	RD10-90
PCE	110
TCE	10

Location ID	BP3-50
PCE	

LEGEND

- HDR Wells (OU2)
- Other Wells

0 Feet 40

Analyte	PCS
1,1-DCE	7
cis-1,2-DCE	70
PCE	5
trans-1,2-DCE	100
TCE	5
VC	2

NOTES:

1. Samples were collected in February/March 2017.
2. Data are reported in ug/L.
3. PCS = Potential Cleanup Standards
4. Analytical results shown are exceedances of PCS
5. PCE = Tetrachloroethylene
6. TCE = Trichloroethene
7. cis-1,2-DCE = cis-1,2-Dichloroethene
8. trans-1,2-DCE = trans-1,2-Dichloroethene
9. 1,1-DCE = 1,1-Dichloroethene
10. VC = Vinyl Chloride
11. K = reported value may be biased high.

Data Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Location Data:

Location ID	RD10-90
PCE	110
TCE	10

Location ID	BP3-50
PCE	16
TCE	6
VC	4.7

Location ID	RD11-97.5
VC	7.8

Location ID	RD9-97.5
1,1-DCE	400
cis-1,2-DCE	160,000
PCE	92,000
trans-1,2-DCE	2,300
TCE	29,000
VC	38,000

Location ID	BP2-50
cis-1,2-DCE	760
PCE	340
TCE	310
VC	79

Location ID	BP1-49.5	BP1-49.5 Dup
PCE	13 L	13
VC	15 L	15

Location ID	OU2-MW6-120
cis-1,2-DCE	150
PCE	19,000
TCE	140
VC	2.6

Location ID	OU2-MW1-75
COCs	< PCS

Location ID	MW13D-110
PCE	5.4

Location ID	MW13-70.5
COCs	< PCS

Location ID	RD12-142.5
VC	4.3

Location ID	RD13-112.5
cis-1,2-DCE	140
PCE	15
trans-1,2-DCE	240
TCE	50
VC	74

Location ID	MW1D-80
PCE	84
TCE	11
VC	8.4

Location ID	OU2-MW5-135
PCE	86
TCE	9.3

Location ID	OU2-MW4-95
cis-1,2-DCE	140 K
PCE	2,500
TCE	130
VC	2.2

Location ID	OU2-MW3-90	OU2-MW3-140
cis-1,2-DCE	380	1,700
PCE	2,100	3,500
TCE	200	50
VC	9.2	6.2

Location ID	MW14-35.2
COCs	< PCS

Location ID	MW16-34.6
PCE	7.9

Location ID	RW8-80
cis-1,2-DCE	870
PCE	2,100
trans-1,2-DCE	1,500
TCE	27
VC	2,600

Location ID	RW9-55
PCE	110
TCE	10

Location ID	OU2-MW2-49
cis-1,2-DCE	410
PCE	1,100
TCE	270
VC	180

Location ID	RW7-75
PCE	56

Location ID	RW6-125	RW6-125 DUP
1,1-DCE	41	37
cis-1,2-DCE	7,100	4,400
PCE	6,800	12,000
trans-1,2-DCE	190	< PCS
TCE	6,600	5,700
VC	3,500	180

Location ID	IW1S-48.5
cis-1,2-DCE	190
PCE	290
TCE	14

Location ID	IW1-85
1,1-DCE	170
cis-1,2-DCE	33,000
PCE	4,100
trans-1,2-DCE	1,400
TCE	5,800
VC	12,000

Location ID	IW2S-50.3
cis-1,2-DCE	94
PCE	16
TCE	5
VC	4.6

Location ID	IW2-82.9
1,1-DCE	98
cis-1,2-DCE	28,000</

LEGEND

- HDR Wells (OU2)
- Other Wells

0 Feet 40

Analyte	PCS
1,1-DCE	7
cis-1,2-DCE	70
PCE	5
trans-1,2-DCE	100
TCE	5
VC	2

NOTES:

- Samples were collected in February/March 2017.
- Data are reported in ug/L.
- PCS = Potential Cleanup Standards
- Analytical results shown are exceedances of PCS
- PCE = Tetrachloroethylene
- TCE = Trichloroethene
- cis-1,2-DCE = cis-1,2-Dichloroethene
- trans-1,2-DCE = trans-1,2-Dichloroethene
- 1,1-DCE = 1,1-Dichloroethene
- VC = Vinyl Chloride
- K = reported value may be biased high.

Data Source: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Location Data:

Location ID	RD10-90
PCE	110
TCE	10

Location ID	BP3-50
PCE	16
TCE	6
VC	4.7

Location ID	RD11-97.5
VC	7.8

Location ID	RD13-112.5
cis-1,2-DCE	140
PCE	15
trans-1,2-DCE	240
TCE	50
VC	74

Location ID	MW1D-80
PCE	84
TCE	11
VC	8.4

Location ID	RD9-97.5
1,1-DCE	400
cis-1,2-DCE	160,000
PCE	92,000
trans-1,2-DCE	2,300
TCE	29,000
VC	38,000

Location ID	RW7-75
PCE	56

Location ID	RW8-80
cis-1,2-DCE	870
PCE	2,100
trans-1,2-DCE	1,500
TCE	27
VC	2,600

Location ID	RW9-55
PCE	110
TCE	10

Location ID	MW16-34.6
PCE	7.9

Location ID	OU2-MW2-49
cis-1,2-DCE	410
PCE	1,100
TCE	270
VC	180

Location ID	MW14-35.2
COCs	< PCS

Location ID	MW15-26
PCE	33

Location ID	MW17-11
COCs	< PCS

Location ID	OU2-MW3-90	OU2-MW3-140
cis-1,2-DCE	380	1,700
PCE	2,100	3,500
TCE	200	50
VC	9.2	6.2

Location ID	RD10-90
PCE	110
TCE	10

Location ID	BP3-50
PCE	16
TCE	6
VC	4.7

Location ID	RD11-97.5
VC	7.8

Location ID	RD13-112.5
cis-1,2-DCE	140
PCE	15
trans-1,2-DCE	240
TCE	50
VC	74

Location ID	MW1D-80
PCE	84
TCE	11
VC	8.4

Location ID	RW7-75
PCE	56

Location ID	RW8-80
cis-1,2-DCE	870
PCE	2,100
trans-1,2-DCE	1,500
TCE	27
VC	2,600

Location ID	RW9-55
PCE	110
TCE	10

Location ID	MW16-34.6
PCE	7.9

Location ID	OU2-MW2-49
cis-1,2-DCE	410
PCE	1,100
TCE	270
VC	180

Location ID	MW14-35.2
COCs	< PCS

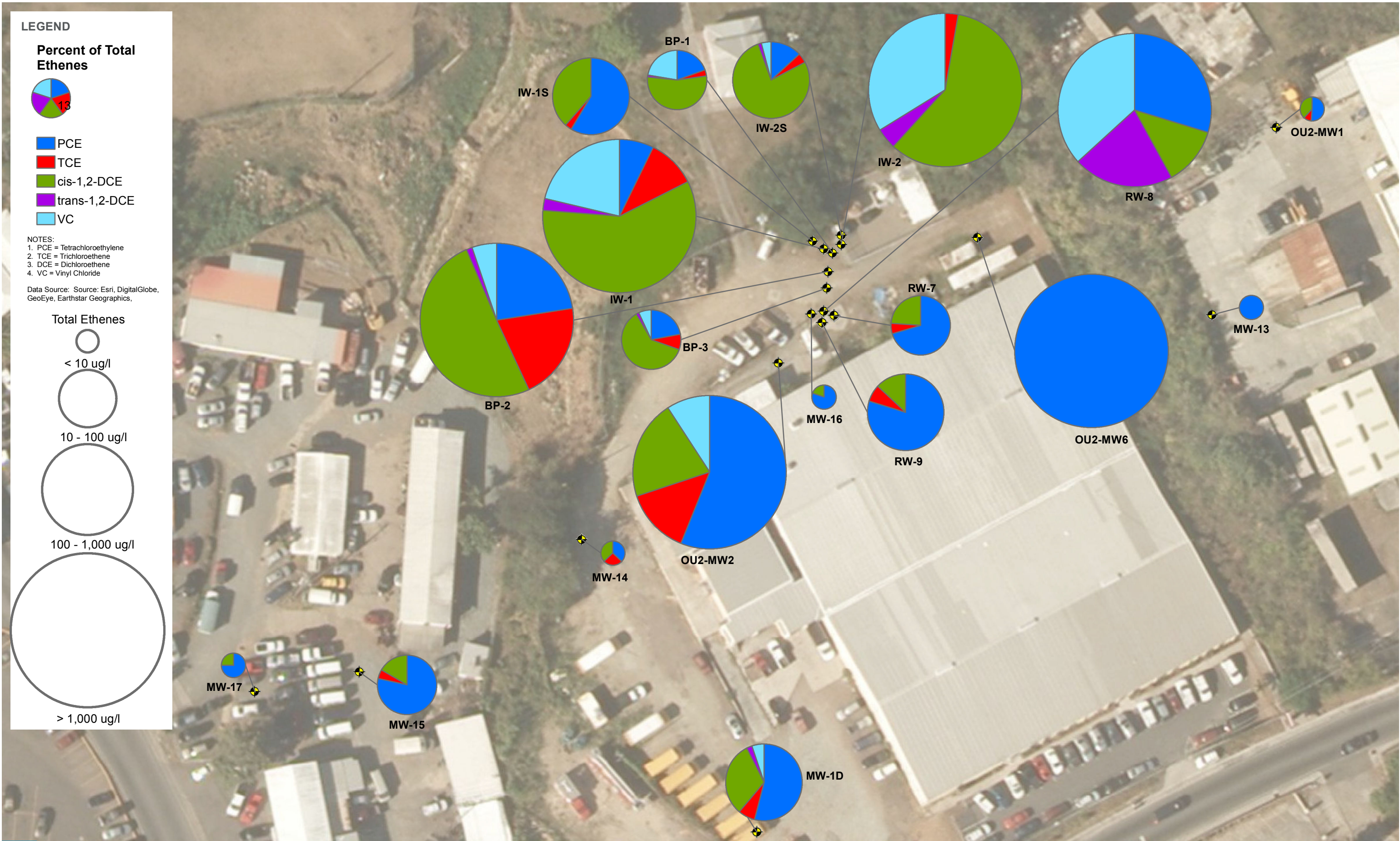
Location ID	MW15-26
PCE	33

Location ID	MW17-11
COCs	< PCS

Location ID	OU2-MW3-90	OU2-MW3-140
cis-1,2-DCE	380	1,700
PCE	2,100	3,500
TCE	200	50
VC	9.2	6.2

Location ID	RD10-90
PCE	110
TCE	10

Location ID	BP3-50
PCE	



SHALLOW GROUNDWATER, DISTRIBUTION OF TOTAL ETHENES
ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 5-3

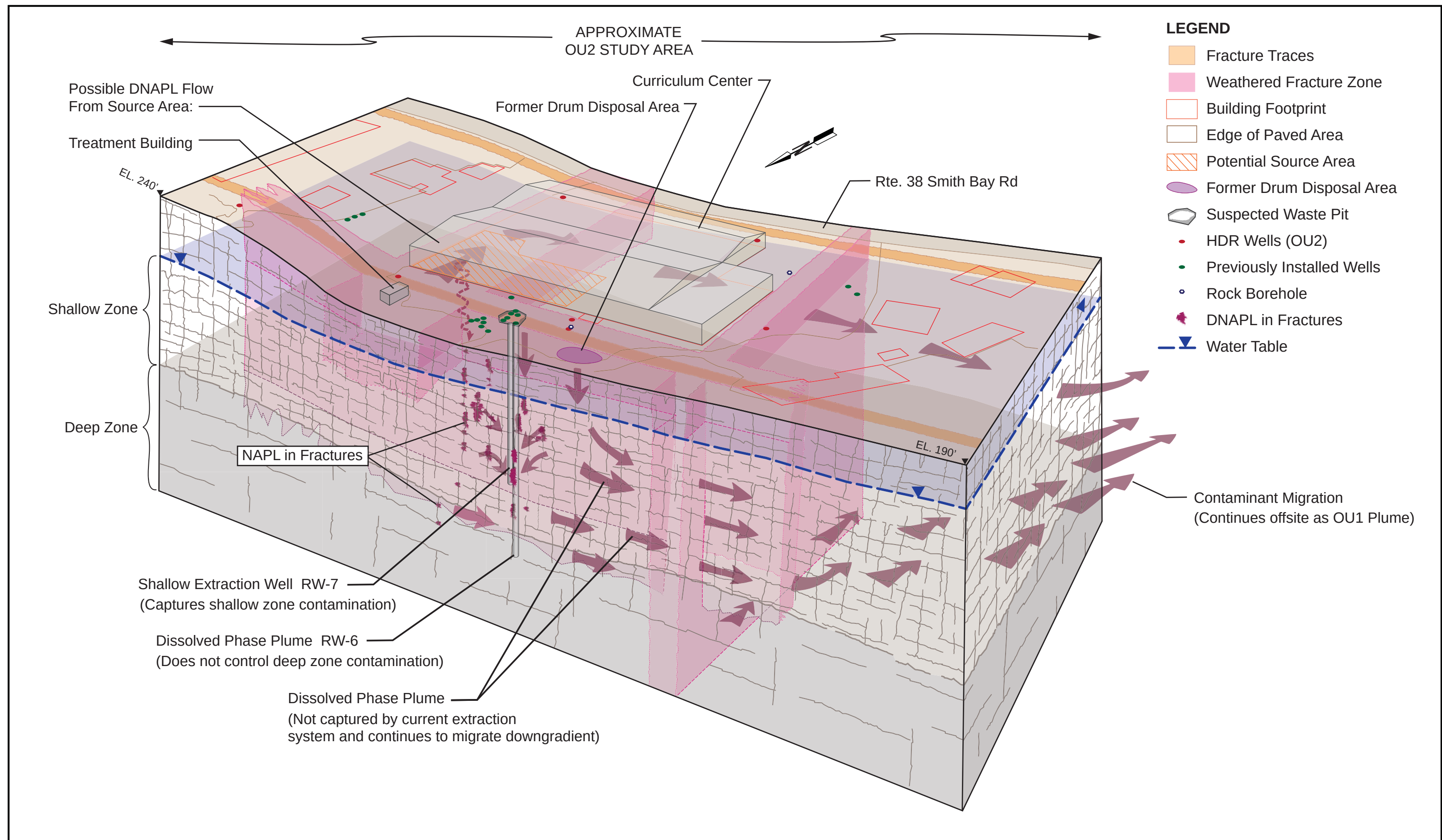




DEEP GROUNDWATER, DISTRIBUTION OF TOTAL ETHENES
ST. THOMAS, U.S. VIRGIN ISLANDS

FIGURE 5-4





1 International Blvd.
10th Floor
Mahwah, NJ 07495

Tutu Wells Superfund Site Operable Unit 2
St. Thomas, USVI

Project No.

10043126

Date

01/23/18

Conceptual Site Model

Figure No.

7-1