FINAL REMEDIAL INVESTIGATION REPORT
Jones Road Groundwater Plume
Federal Superfund Site (SUP075)
Harris County, Texas

Shaw Project No. 134515

Prepared for:

Texas Commission on
Environmental Quality
State Lead Section
Remediation Division
12100 Park 35 Circle
Austin, Texas  78753

Prepared by:

Shaw Environmental, Inc.
3010 Briarpark Dr., Suite 400
Houston, Texas  77042

April 15, 2009
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Glossary

°C    degrees Celsius
°F    degrees Fahrenheit
µg/m³  micrograms per cubic meter
A&B  A&B Laboratories
AEC  Associated Environmental Consultants, Inc.
AST  above ground storage tank
Bell Facility  Bell Dry Cleaners facility
bgs  below ground surface
BLRA  Baseline Risk Assessment
BOD  biochemical oxygen demand
BEG  Bureau of Economic Geology
Cal-EPA  California Environmental Protection Agency
CERCLA  Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS  Comprehensive Environmental Response, Compensation, and Liability Information System
CLP  Contract Laboratory Program
COCs  constituents of concern
COD  chemical oxygen demand
COPCs  chemicals of potential concern
CPT  Cone penetrometer technology
CRQL  contract required quantitation limit
CSM  Conceptual Site Model
CTE  central tendency exposure
DCE  1,2-dichloroethylene
DNAPL  dense non-aqueous phase liquid
DPT  direct-push technology
ERNS  Emergency Response Notification System
ESA  ESA Data, Inc.
ESAT  Environmental Services Assistance Team
ESN  ESN mobile laboratory
Finch’s  Finch’s Gymnastics USA and Childcare Facility
FM  Farm to Market road
FORMS  Field Operations Records Management System
FSP  field sampling plan
ft/ft  feet per foot
GAC  granular activated carbon
Geosource  Geosource Incorporated
Geo-Tech  Geo-Tech Environmental, Inc.
GP  Geoprobe
gpm  gallons per minute
GW²  groundwater ingestion PCL
HCFCD  Harris County Flood Control District
HI  hazard index
HRS  Hazard Ranking System
HSA  hollow stem auger
IARC  International Agency for Research on Cancer
LPST  Leaking Petroleum Storage Tank
LRST  Leaking Registered Storage Tanks
LSA  Limited Site Assessment
Martin  Martin Survey Associates, Inc.
MCL  maximum contaminant level
MDL  method detection limit
mg/kg  milligrams per kilogram
mg/L  milligrams per liter
MSSLS  Medium-Specific Screening Levels
MUD  Municipal Utility District
MW  monitor well
NCEA  National Center for Environmental Assessment
NOR  Notice of Registration
NOV  Notice of Violation
NPL  National Priorities List
NTP  National Toxicity Program
ORP  oxidation/reduction potential
OSSF  on-site sewage facility
OSWER  Office of Solid Waste and Emergency Response
PCE  perchloroethylene also known as tetrachloroethylene
PCL  protective concentration level
POTW  publicly-owned treatment works
PQL  practical quantitation limit
PST  Petroleum Storage Tank
PWS  public water supply
QAPP  Quality Assurance Project Plan
RBEL  risk-based exposure level
RCRIS  Resource Conservation and Recovery Information System
RfDo  reference dose
RI  Remedial Investigation
RME  reasonable maximum exposure
ROW  right-of-way
RST  Registered Storage Tanks
SCS  Superfund Cleanup Section
SF  slope factor
SFi  cancer slope factor for inhalation
SLS  State Lead Section
SOP  standard operating procedure
SOW  statement of work
TAC  Texas Administrative Code
TCE  trichloroethylene
TCEQ  Texas Commission on Environmental Quality
TDS  total dissolved solids
The study area  Jones Road Groundwater Plume Federal Superfund Site
TDSHS  Texas Department of State Health Services
TMW  temporary monitor well
TNRCC  Texas Natural Resource Conservation Commission
TNRIS  Texas Natural Resources Information System
TOC  total organic carbon
TRI  Toxic Release Inventory
TRRP  Texas Risk Reduction Program
TSD  Treatment Storage and Disposal
TWC  Texas Water Commission
ug/L  micrograms per liter
USDA  United States Department of Agriculture
USEPA  United States Environmental Protection Agency
VC  vinyl chloride
VCP  Voluntary Cleanup Program
VOCs  volatile organic compounds
WBU  water bearing unit
1.0 Introduction

The Texas Commission on Environmental Quality (TCEQ), State Lead Section (formerly Superfund Cleanup Section (SCS)), through a Cooperative Agreement with the United States Environmental Protection Agency (EPA), has conducted a Remedial Investigation (RI) at the former Bell Dry Cleaners facility (Bell facility) located within the Cypress Shopping Center at 11600 Jones Road, Houston, Texas. The RI has also focused on a plume of contaminated groundwater that originated from the Bell facility and migrated to drinking water aquifers below adjacent residential and commercial areas. Collectively, the investigation is known as the Jones Road Groundwater Plume Federal Superfund Site, herein referenced as “the site”. The contaminated groundwater plume contains perchloroethylene (PCE; also known as tetrachloroethylene). PCE is a manufactured chemical that is widely used for dry cleaning of fabrics. Major degradation products of PCE, including trichloroethylene (TCE), cis-1, 2-dichloroethylene (DCE), and vinyl chloride (VC) have also been detected in soil samples taken from the former Bell facility, and groundwater samples taken from plume. Figure 1 presents the major degradation products of PCE.

1.1 Purpose of Report

The purpose of this RI report was to define the nature and extent of contamination in soil and groundwater at the site, such that future remediation of the contaminants may proceed in a manner that is protective of human health and the environment. The RI report compiles all historical and current site data from investigations performed at the site since 2001, when impact to groundwater was initially discovered at Finch’s Gymnastics USA and Childcare Facility (Finch’s) located at 10903 Tower Oaks Blvd, and later around the Bell facility, which was determined to be the source of PCE contamination to groundwater.

1.2 Site Background

1.2.1 Site Description

The site lies in the northwest portion of Harris County, Texas, as illustrated on the Vicinity Map (Figure 2). The former Bell facility is located within the Cypress Shopping Center at 11600 Jones Road, approximately one-half mile north of the intersection of Jones Road and FM 1960, outside the city limits of northwest Houston, in Harris County, Texas, as shown on the Site Location Map (Figure 3). The location of the former Bell facility, Finch’s, and surrounding residential areas is illustrated on the Site Detail Map (Figure 4).

Locally, the area is characterized by residential, commercial, and light industrial development. Residential development has been active since the 1960s effectively eliminating wildlife habitat from the area. Jones Road is the principal north-south corridor through the area, and FM 1960 (approximately one-half mile to the south) provides a southwest-northeast corridor. Commercial development is dominant along Jones Road with residential and limited commercial development along the side streets. Cypress Creek is located approximately one mile to the northwest of the subject area, and White Oak Bayou is located approximately 3,500 feet to the south.
Most homes at the site have private water supply wells, and some homes share a single well with others. Septic systems are used in the absence of a publicly-owned treatment works (POTW) infrastructure.

The former Bell facility was located on property consisting of a rectangular parcel of land of approximately 2.1 acres in size improved with a one-story building (Cypress Shopping Center), which is about 30,870 square feet in size and contains approximately 10 tenant spaces. The building is of steel-frame construction with metal exterior walls and a flat roof. The former Bell facility was located on the western side of the building adjacent to Jones Road. In addition to the former Bell facility, other tenants of Cypress Shopping Center have included several restaurants, executive suites, a used book store, and an automotive service shop which conducts engine overhaul, brake repair, transmission repair and general automotive maintenance activities.

1.2.2 Site History

The Cypress Shopping Center was constructed in 1984, and it is believed that the Bell facility began dry cleaning operations sometime in 1988 (date that the Texas Water Commission (TWC) issued a Notice of Registration for Solid Waste Management to the Bell facility) and continued through May 2002 before the dry cleaning operations were shut down. The Bell facility was reported to utilize at least one dry cleaning machine along with conventional laundry equipment. As part of the recovery process, water and other contaminants were removed by a water separator and drained out of the machine on a continuous basis into a 5-gallon plastic bucket. The drained liquid was then discharged into a steam-heated ceramic pot to evaporate the liquid. The pot was vented through the rear wall of the facility directly to the atmosphere. However, a conflicting disposal practice was indicated by Mr. Jimmy Kim (operator of the facility and son of owner/father Dae Kim), who believed that the waste stream had been formerly disposed to the facility’s septic system or to the storm sewer located immediately behind the shopping center.

1.2.3 Previous Investigations

The Jones Road Groundwater Plume Federal Superfund Site has undergone numerous investigations from November 4, 1994 to the current date by private environmental consulting companies and regulatory agencies and their subcontractors. A chronology of previous site investigations and significant events is summarized in Table 1, and additional detail is summarized on the TCEQ web page, “Continuation of Jones Road History of Actions” located at: http://www.tceq.state.tx.us/remediation/superfund/jonesroad/fullhistory.html

1.3 Report Organization

This report was prepared using the suggested remedial investigation format from Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA (October 1988; EPA/540/G-89/004). Section 2, Study Area Investigation, provides a brief summary of previous investigations and important findings. Section 4, Nature and Extent of Contamination, references studies described in Section 2 as they pertain to the nature and extent of contamination in the source area and groundwater plume.
2.0 Study Area Investigation

2.1 Site Characterization

2.1.1 Surface Features

Ground surface elevations at the site are approximately 125 feet above mean sea level and the terrain is typically flat with a slight slope to the south/southeast. The Jones Road area is highly developed with mixed commercial/industrial and residential land use. Jones Road is the principal north-south corridor through the area, and FM 1960 (approximately one-half mile to the south) provides a southwest-northeast corridor. Commercial development is dominant along Jones Road with residential and limited commercial development along the side streets. Cypress Creek is located approximately one mile to the northwest of the subject area, and White Oak Bayou is located approximately 3,500 feet to the south. Surface water drainage is managed primarily through open road-side bar ditches, and waste water is managed through individual on-site sewage facilities (OSSFs) or septic systems. Private water wells have historically provided water to occupants of residential housing and commercial/industrial businesses in the area. However, at the time of this writing, a new municipal water main is in process of installation, and is eventually intended to replace the water wells.

2.1.1.1 Water Well Search/Surveys

In May 2004, Shaw and the TCEQ performed a walking water well inventory survey in the neighborhoods surrounding the former Bell facility in an attempt to document information about active or past drinking water sources (active water wells, inactive water wells, municipal utility districts, or other sources). Interview forms were completed for each property after interviewing property owners or other persons with knowledge about water supplies, and for instances where persons could not be located, forms were left for individuals to complete and return to the TCEQ. A total of 47 addresses were surveyed, and 14 wells were identified. Data obtained from the inventory survey was used to prepare an initial map showing the well locations. Field information, along with publicly available information was used to compile an initial database of the well ownership, address, total depth, screened interval, well diameter, use, status, etc. Refer to Remedial Investigation – Water Well Inventory Survey (Shaw, May 17, 2004) in Appendix A.

TCEQ staff conducted in-house file searches and collected available State of Texas Well Reports (water well driller’s logs) in the project area (Appendix B). Well construction information was determined to be available for approximately 30 to 40% of the wells in the area. An initial records search of public water supply (PWS) files was performed by the TCEQ, and four geophysical logs were located with a 2- to 3-mile radius of the Bell facility (Appendix C). Shaw conducted a detailed file review and collected additional lithologic logs and hydrologic testing information associated with PWS wells located within a 3-mile radius of the Bell facility. The records search indicated that there were a total of ten public supply wells located within a mile or less of the site. Five of these wells were located less than ¼ mile away; two were located within a ½ mile, and the remaining three within a mile of the site. The closest well to the source area is located on site and provides water to the Cypress Shopping Center. This well is located...
approximately 225 feet southeast of the source area and has been impacted by the PCE groundwater plume. The next closest PWS well to the site (and down gradient) is the one at Finch’s Gymnastics located on Tower Oaks Blvd. This well has also been impacted by the PCE plume. Another well, down gradient and within ¼ mile of the site is located at 11035 Jones Road (Schlotzsky’s Deli). This well has been included as part of the quarterly sampling program and has not shown any detectable concentrations of the COCs. According to the well reports for each of these wells, Finch’s well was drilled to a total depth of 238 feet and the Schlotzsky well was drilled to a depth of 375 feet. There is another PWS well southwest of the site, located at 11338 Tower Oaks Blvd. This PWS well services a children’s day care, and it has had intermittent impact from the PCE plume. A record search for PWS wells within a two mile radius resulted in 14 wells and a three mile radius showed 28 additional wells. The majority of these wells outside of the one mile radius are Municipal Utility District (MUD) wells. Information about these and additional wells is presented in Table 2.

2.1.1.2 RECRIS/CERCLIS/Other Database Information

A database search was performed within a 0.5-mile radius of the Bell facility by Geosource Incorporated (Geosource), as subcontractor for Associated Environmental Consultants, Inc. (AEC) and as reported in the Phase I Environmental Site Assessment (AEC, November 1994) (Appendix A). Geosource reviewed records of Registered Storage Tanks (RST) of the TNRCC; Leaking Registered Storage Tanks (LRST); EPA Resource Conservation and Recovery Information System (RCRIS); RCRIS Treatment Storage and Disposal (TSD) facilities; Comprehensive Environmental Response, Compensation, and Liabilities Information System (CERCLIS); National Priority List (NPL); Superfund; Emergency Response Notification System (ERNS); Spills; and Landfills. The records review revealed eight RST sites, one LRST site, and four RCRIS sites. The LRST site was listed as “final concurrence issued – case closed”. The four RCRIS sites included the Bell facility; Minit-Lube #1175 at 11813 Jones Road; PI Components Corporation at 10825 Barely Lane; and Atlas Transmission at 11642 Jones Road.

A second database search was performed within a 0.5-mile radius of the Bell facility by ESA Data, Inc. (ESA), as subcontractor for Geo-Tech Environmental, Inc. (Geo-Tech) and as reported in the Phase I Environmental Site Assessment (Geo-Tech, June 5, 2001) (Appendix A). ESA reviewed records of CERCLIS; RCRIS; TNRCC Listed Spill Sites; TNRCC State Superfund sites; TNRCC Municipal Solid Waste Sites; TNRCC Leaking Petroleum Storage Tank (LPST) sites; TNRCC Petroleum Storage Tank (PST) sites, and TNRCC Voluntary Cleanup Program (VCP) sites. Geo-Tech also performed records review of Toxic Release Inventory (TRI) sites; Texas Natural Resources Information System (TNRIS); City of Houston Fire Department; City Health Department; local power utility company records; and the City of Houston Building Department. The report did not indicate review of Harris County records. Five PST sites were identified within a 0.25-mile radius of the site. Three LPST sites were identified, with two of the LPST sites approved for closure, and the third reported to have impacted groundwater. Four RCRIS sites were identified, including Maaco Auto Painting at 10635 Tower Oaks Boulevard; the Bell facility; PI Components; and Atlas Transmission.
2.1.1.3 Elevation and Position Surveys

A topographic survey was performed by Global Surveyors, Houston, Texas on July 16 through 21, 2003 to identify and evaluate the usefulness of existing benchmarks, and to survey the intersections of Jones Road, Woodedge Drive, Tower Oaks Boulevard, and Timber Hollow Drive to provide accurate map references for map preparation. The survey was used to prepare a base map showing lot sizes and addresses, street names, benchmark locations, utilities, and water well locations. Appendix A presents the Submittal of Survey (Shaw, August 13, 2003).

On January 20, 2005, Martin Survey Associates, Inc. (Martin), Houston, Texas, performed a survey of position and top-of-casing elevations of nine private wells and monitor wells MW-6 through MW-9. Martin also performed a survey of CPT-40 through CPT-49 locations. On February 9, 2005, Martin updated the survey maps/data by adding the locations and top of casing elevations of deep monitor wells MW-10 through MW-19 (Appendix A).

2.1.2 Contamination Source Investigations (Bell Facility)

The reports and technical memoranda described in the following section are included in Appendix A, and locations of intrusive sample points (soil borings, monitor wells, etc.) are illustrated on Figure 5.

2.1.2.1 AEC Environmental Site Assessment – October 1994

In October 1994, a Phase I Environmental Site Assessment was performed at the Cypress Shopping Center housing the Bell facility by Associated Environmental Consultants, Inc. (AEC) for Metro Bank as part of a property transaction. The result of this assessment identified two 30-gallon drums of PCE and one above ground storage tank (AST) of PCE located outside near the back door of the Bell facility. The report indicated that there was no visual observation of leakage and the chemical appeared well contained. According to the report “the liquid waste generated from the Bell Cleaner Laundry operation is recycled or disposed by Safety Kleen of Houston, Texas.” In addition, drums of waste oil, motor oil, anti-freeze, solvents for part washing, batteries, and used oil filters were observed behind the Advanced Auto Repair facility, also located within the strip shopping center. These wastes were documented in the Phase I report to be recycled or disposed by States Environmental Oil Services, Inc. AEC recommended that the tenants, Bell Dry Cleaners and Advanced Auto Repair, should be continually monitored to ensure that their operations were in compliance with all applicable regulations. Reference Phase I Environmental Site Assessment (AEC, November 1994).

2.1.2.2 Geo-Tech Phase I Environmental Site Assessment - June 2001

In June 2001, another Phase I Environmental Site Assessment (ESA) was performed at the Cypress Shopping Center by Geo-Tech Environmental, Inc. (Geo-Tech) for Sterling Bank “to assist in the underwriting of a proposed mortgage loan of the property” (Geo-Tech, June 5, 2001). The Phase I ESA identified leakage from a dry cleaning machine that was draining into the storm drains behind the Bell facility. The Phase I ESA recommended sampling around the
Bell facility to determine if the Bell facility operations impacted subsurface soil and groundwater.

2.1.2.3 Geo-Tech Limited Site Assessment – June 2001

On June 25, 2001, Geo-Tech performed a Limited Site Assessment (LSA) (Geo-Tech, July 9, 2001). The LSA included the installation of three soil borings to 25 feet (B1, B2, and B3) and subsequently converting the soil borings to temporary monitor wells (TMW1, TMW2, and TMW3). Soil boring B1 was installed south of the front door of the dry cleaners, B2 was installed along the west side of the building and B3 was installed to the north of the building outside the dry cleaners back door near the storm drain. One composite soil sample from a depth of one to twenty-five feet below ground surface (bgs) was collected from each boring. The borings were subsequently converted to temporary monitor wells and water samples were collected. Soil and water samples were submitted to A&B Laboratories (A&B) in Houston, Texas for analyses of volatile organic compounds (VOCs) using EPA Method 8260B. Soil samples collected from soil boring B3 had PCE and DCE concentrations above the laboratory practical quantitation limit (PQL), and groundwater samples collected from all three temporary monitor wells had PCE, TCE, and DCE concentrations above the laboratory PQL. The highest PCE concentration in soil was 0.767 milligrams per kilogram (mg/kg), within the soil sample collected from soil boring B3. The highest PCE concentration in groundwater was 0.833 milligrams per liter (mg/L), within the groundwater sample collected from temporary monitor well TMW1.

2.1.2.4 Geo-Tech Voluntary Cleanup Program Site Investigation Report – August 2001

In August 2001, Geo-Tech submitted a Voluntary Cleanup Program Site Investigation Report to the TNRCC documenting previous work completed at the Bell facility during the Phase 1 Environmental Site Assessment (Geo-Tech, June 5, 2001) and the Limited Site Assessment (Geo-Tech, July 9, 2001).

2.1.2.5 Geo-Tech Limited Site Assessment (VCP) – November 2001

In November 2001, Geo-Tech performed a Limited Site Assessment (associated with the VCP) at the Bell facility (Geo-Tech, December 12, 2001). Three permanent monitor wells (MW1, MW2, and MW3) and two soil borings (B1 and B2) were installed. The locations of the monitor wells were close to the temporary wells installed in June and were installed to a depth of approximately 35 feet bgs. Three soil samples were collected from monitor well MW1 and four soil samples were collected from both monitor wells MW2 and MW3. The two soil borings were installed to a depth of 15 feet bgs behind the dry cleaner, running parallel to the storm sewer line. Two soil samples were collected from each of the two soil borings. Groundwater samples were collected from each of the three monitor wells following their installation.

All soil and groundwater samples were submitted to A&B Laboratories for analyses of VOCs using EPA Method 8260B. For soil samples collected from the monitor wells, PCE was the only VOC detected at concentrations above the PQL in monitor wells MW1 and MW2 within the sample intervals at approximately 22 to 25 feet bgs. No VOCs were detected in soil samples
collected from monitor well MW3. For soil samples collected from soil borings B1 and B2, PCE was detected at sample intervals of 5 and 15 feet bgs in both borings, and TCE was detected in the soil sample collected from the 15 foot depth interval of soil boring B1. Analysis of the groundwater samples revealed concentrations of PCE above the PQL in groundwater samples collected from all three monitor wells. In addition, TCE was detected in groundwater samples collected from monitor wells MW1 and MW2, and DCE and VC were detected in groundwater samples collected from monitor wells MW1 and MW3. The highest PCE concentration in soil was 0.359 mg/kg, within the 15-foot depth sample collected from soil boring B2. The highest PCE concentration in groundwater was 13.466 mg/L, within the groundwater sample collected from monitor well MW1.

2.1.2.6 Geo-Tech Limited Site Assessment – Additional Investigation (VCP) – January 2002

On January 4, 2002, three additional monitor wells (MW4, MW5, and MW6) and one additional soil boring (IB1) were installed as documented in letter report to the VCP (Geo-Tech, February 7, 2002). Monitor well MW4 was installed north of monitor well MW3, monitor well MW5 was installed east of monitor well MW3, monitor well MW6 was installed south and west of monitor well MW1, and soil boring IB1 was installed inside the dry cleaning facility. The three monitor wells were installed to a depth of approximately 35 feet bgs and soil boring IB1 was installed to a depth of approximately 2 feet below the facility concrete floor into the underlying soils. Three soil samples were collected from each monitor well and one soil sample was collected from the soil boring. On January 10, 2002, groundwater samples were collected from all of the monitor wells, including those installed on November 2, 2001, during the previous investigation.

All soil and groundwater samples were submitted to A&B Laboratories for analyses of VOCs using EPA Method 8260B. Results of the analysis revealed PCE concentrations above the PQL in soil samples collected from the 25-foot and 35-foot depth intervals of MW6 and the 2-foot depth interval of soil boring IB1. No VOCs were detected at concentrations above the PQL in soil samples collected from monitor wells MW4 or MW5.

Analysis of groundwater samples revealed concentrations of PCE, TCE, DCE, and VC above the PQL in groundwater samples taken from monitor wells MW1, MW2, MW3, and MW6. PCE and VC were detected at concentrations above the PQL in groundwater samples collected from monitor well MW4, and no VOCs were detected at concentrations above the PQL in groundwater samples collected from monitor well MW5. The highest PCE concentration in soil was 0.088 mg/kg, within the 25-foot depth sample collected from monitor well MW6. The highest PCE concentration in groundwater was 10.469 mg/L, within the groundwater sample collected from monitor well MW1.

2.1.2.7 Shaw Remedial Investigation – Cone Penetration Technology – August/September 2003

During the period from August 25 through September 8, 2003, Shaw performed a Remedial Investigation – Cone Penetration Technology (CPT) investigation (Shaw, April 29, 2004) radiating outward from the Bell facility. Thirty-six CPT borings (CPT-1 through CPT-7 and CPT-10 through CPT-38) were installed using CPT drilling methods, and three permanent monitor wells (MW-7, MW-8, and MW-9) were installed using hollow stem auger (HSA)
drilling methods. CPT borings were installed to obtain electronic soil boring logs of the underlying geologic strata, collect select groundwater samples, and determine locations for installation of the monitor wells. The CPT borings were installed to an approximate depth of 60 feet bgs. No soil samples were collected during the CPT investigation, but three soil samples were collected from each monitor well boring during their installation. Monitor well MW-7 was installed at CPT location CPT-32; monitor well MW-8 was installed at CPT location CPT-12; and monitor well MW-9 was installed at CPT location CPT-20. Each monitor well was drilled to a total depth of approximately 35 feet bgs.

Soil and groundwater samples were submitted to Severn Trent Laboratories in Houston, Texas for analysis of VOCs using EPA Method 8260B. The groundwater samples were also tested using the Color Tec field screening method to determine the accuracy of the Color Tec method to fixed laboratory analysis, and the correlation was determined to be excellent. For groundwater, analytical results revealed detectable PCE, TCE, DCE, and VC concentrations within water samples collected approximately 30 feet bgs in the interbedded zone near the Bell facility, and the lateral extent of impact was within an approximate 300-foot radius of the facility. Only CPT-32 showed detectable concentrations of PCE and TCE in water samples collected from a sand unit encountered at 51 feet bgs, which may have been an indication of shallow groundwater flow (and plume migration) to the south. At CPT-36, concentrations of DCE were detected in groundwater samples taken from sand units encountered at 46 feet and 57 feet bgs. The highest PCE concentration in groundwater was 3.810 mg/L, within the groundwater sample collected from CPT-3. Contaminant mass in the groundwater matrix was primarily PCE. However, the presence of degradation daughter products (TCE, DCE, and VC) was observed. The presence of only daughter products at locations south of the septic leach field suggested a possible secondary discharge route of PCE with possible favorable degradation conditions in the area (chemical reducing environment created by the septic system).

In all the soil samples associated with installation of the three monitor wells, the concentrations of VOCs were below the laboratory Method Detection Limit (MDL), although the maximum soil sample depth was 36.5 feet bgs, and two borings, MW-8 and MW-9, were purposely installed in CPT locations where no VOCs were detected.

The CPT investigation indicated that subsurface soils in and around the former Bell Dry Cleaner are predominately clays and silty clays to a depth of approximately 25 feet bgs, underlain by potential water-bearing sands approximately 30 feet bgs (but some of these sands did not yield water during the CPT investigation). However, the sands may not have yielded substantial groundwater because during the investigation (August 2003), drought conditions existed in the Houston area, and water levels may have been abnormally low in the soils, as were recorded in the nearby existing monitor wells as indicated in a personal communication with Marilyn Long with the TCEQ (TCEQ, June 18, 2008).

2.1.2.8 Shaw Remedial Investigation – Geoprobe – October 2003

During the period from October 22 through 29, 2003, Shaw performed a Remedial Investigation – Geoprobe investigation (Shaw, April 28, 2004). Twenty-one soil borings (GP-1 through GP-21) were installed to a maximum depth of thirty-five feet bgs using direct-push technology (DPT) drilling methods. The purpose of the investigation was to identify potential PCE
discharge points to the shallow soil, including storm water drainage areas, areas associated with the septic system (field and tank), and the foundation of the building.

All soil samples were analyzed by an off-site fixed-based laboratory performing under the Contract Laboratory Program (CLP) of the EPA for VOCs using Method OLCO4.2, and select groundwater samples were analyzed by ESN mobile laboratory (ESN) for VOCs by EPA Method 8260B. The CLP and ESN analytical results for soil and groundwater were compared to soil and groundwater results obtained from Color Tec field screening results. The Color Tec method was determined to have poor comparison to laboratory methods for soils, but better comparison to laboratory methods for groundwater.

Results of soil laboratory analysis indicated PCE, TCE, DCE, and VC impact to soil in nine of 21 DPT borings (GP-3, GP-4, GP-5, GP-6, GP-7, GP-8, GP-13, GP-16, and GP-20) with samples collected from four different sample zones (1 to 2 feet bgs; 16 to 19 feet bgs; 19 to 30 feet bgs; and 30 to 35 feet bgs). Review of the sample results concluded that PCE is the most prevalent contaminant within the upper 35 feet of site soils, with highest concentrations detected in soil borings GP-3 and GP-4 (located behind the Bell facility and representing the suspected primary discharge area). The highest PCE concentration in soil was 260 mg/kg, within the 16 to 17-foot depth sample collected from soil boring GP-4.

Results of groundwater laboratory analysis indicated PCE, TCE, and VC impact to groundwater in 17 of 20 groundwater sample locations using a combination of mobile laboratory and Color Tec screening methods. The highest PCE concentration in groundwater was 7.860 mg/L, within the groundwater sample collected from soil boring GP-3. Review of sample results concluded that PCE is the most prevalent contaminant, but degradation products of TCE, DCE, and VC is more evident in groundwater than soil, and the presence of VC (associated with relative low concentrations of PCE) in some samples collected away from the suspected primary discharge area may be an indication of southwesterly groundwater flow direction (assuming down-gradient degradation).

2.1.2.9 TCEQ Jones Road Revised Conceptual Site Model – June 2005

In June 2005, the TCEQ prepared a Revised Conceptual Site Model (CSM) for the site, with sections of the CSM focused on the Bell facility (TCEQ, June 28, 2005). The CSM provided a conceptual characterization of the site including potential sources, migration pathways, and potential receptors, which was updated from the original CSM included in the Data Quality Objectives Memorandum (TCEQ, October 17, 2003). The CSM provided a site description, data acquisition up to June 2005, regional geology/hydrology, initial CSM scenarios, description of exposure pathways and routes, data gaps, fate and transport characteristics, and observations supporting the revised CSM. Several model scenarios were considered, but the most likely scenario was determined to be vertical migration of PCE as dense non-aqueous phase liquid (DNAPL) to deeper aquifers, and lateral migration of dissolved phase PCE to shallow and deep aquifers.
2.1.2.10 Shaw Geoprobe Investigation – July 2006

During the week of July 17, 2006, Shaw performed a second Geoprobe Investigation at the Bell facility to gather recent soil and groundwater samples from the site and to collect geochemical and geotechnical samples to support a proposed bench-scale treatment study. The report, *July 2006 Geoprobe Investigation* (Shaw, January 24, 2007) documented the installation of nine DPT borings (GP-1A through GP-9A) to depths of approximately 50 feet bgs.

Soil and groundwater samples were submitted to Mitkem Corporation performing under the EPA CLP for analysis of VOCs using statement of work (SOW) VOA SOM01.1. The soil samples were also screened using the Color Tec method. Results of the Color Tec comparison to laboratory results were inconclusive, with very little apparent correlation. Select soil samples were also collected from soil boring GP-9A and submitted to Accutest Laboratories in Houston, Texas for analysis of geochemical and geotechnical parameters including fraction organic carbon, moisture content, volumetric water content, dry bulk density, total porosity, effective porosity, effective permeability, and vertical hydraulic conductivity. Results of the geotechnical testing indicated that the most prolific (having the highest porosity and permeability) water bearing zones are located approximately 22 to 23 and 30 to 32 feet bgs. Some of the geochemical parameters were to be used to evaluate compatibility of site soils with potential chemical oxidation and bioremediation remedies.

The highest PCE concentrations were detected in soil in borings GP-2A (7.8 mg/kg) and GP-3A (260 mg/kg), both within the 20 to 21-foot bgs sample interval, and both behind the Bell facility (near the back door on either side of the septic system line). The highest PCE concentration in groundwater was 190 mg/L, within the groundwater sample collected from soil boring GP-3A.

Review of the sample results concluded that contaminants in the upper 35 feet of soils above the soil/water interface are primarily impacted with PCE, and no dense non-aqueous phase liquid (DNAPL) was observed during the investigation. Contaminants in groundwater were primarily PCE, but degradation products of TCE, DCE, and VC were also present, although more evident in groundwater than soil. The lateral extent of contaminants in groundwater is greater than the lateral extent of contaminants in soil.

2.1.2.11 Shaw Attempted Deep Source Area Well Installation – July 2006

During the week of July 24, 2006, Shaw attempted to install one deep monitor well in the suspected contamination source area behind the Bell facility. The report, *Attempted Well Installation* (Shaw, May 2, 2007) documented the attempted installation of RS-1 (first attempt), and RS-2 (second attempt) using Rotosonic drilling technology. The target depth of the deep monitor well was intended to be 320 feet bgs. However, the maximum depth of investigation was 107 feet bgs, due to failure of the drilling technology (drill pipe failure). The purpose of the well was to determine the vertical distribution of contaminants below the source area, and to provide a multi-function well for potential future groundwater monitoring, remediation through injection of chemical oxidizers or biostimulants, or recovery of contaminants through groundwater pumping.
Continuous soil cores were collected during the drilling process, and each core was described, photographed, and screened using the Color Tec method. Soil samples were collected from each sample core (variable between 5 and 10 foot sample intervals) to the total depth drilled, and the samples were submitted to the EPA CLP laboratory (Mitkem Corporation) for analysis of VOCs using SOW VOC SOM01.1. No water samples were collected due to water sample collection equipment failures.

Review of the analytical data revealed PCE concentrations in all of the soil samples collected to a depth of 82 feet bgs, excluding the 36 to 37 foot sample interval. The maximum PCE concentration was 6.4 mg/kg within the 44 to 45 foot sample interval. No PCE was detected between the 82 and 107 foot sample interval, but high heat drilling conditions may have volatilized the core samples, and liberated VOCs at deeper depths. Minor concentrations of TCE and DCE were detected in the 20 to 21 foot sample interval, and no VC was detected in any samples collected to the total depth of investigation. Color Tec comparison to laboratory results (49 to 107 foot sample intervals) were poor, with no apparent comparison.

2.1.2.12 Shaw Bench Scale Treatment Study – August 2006

Shaw performed a bench scale treatment study for treatment of soils at the Bell facility during the summer of 2006. Results of the study were documented in the Final Treatability Study Report (Shaw, October 16, 2007) for the application of in-situ chemical oxidation and bioremediation treatment technologies. Treatment technologies of permanganate oxidation, bio-augmentation, bio-stimulation, and abiotic treatment (using zero valent iron) were determined to be effective during the study. Permanganate oxidation was recommended as the best potential technology for shallow source area soils, and bioremediation was recommended for deeper extended plume areas. The study also recommended preparation of an updated source area conceptual site model and pilot test work plan before implementing the technologies.

2.1.2.13 Shaw Vapor Intrusion Study – February 2008

Shaw performed a vapor intrusion study at the Bell facility from February 25 through 27, 2008. Results of the study were documented in the Vapor Intrusion Study (Shaw, May 6, 2008). The purpose of the study was to determine if completed pathway(s) exist for intrusion of vapors to workers in the Cypress Shopping Center (from the Bell facility), and if indoor vapors could pose an unacceptable risk of chronic health effects due to long-term exposure.

Two indoor ambient air samples (Center Room – Ambient and West Sump – Ambient) and two sub-slab air samples (West Sump – Subsurface and Center Room – Subsurface) were collected inside the Bell facility, and were submitted to Accutest Laboratories in Houston, Texas for analysis of VOCs using EPA Method TO-15. Results of laboratory analysis were compared to the Tier II Table from the Office of Solid Waste and Emergency Response (OSWER) Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils. PCE and TCE exhibited higher concentrations than the OSWER Tier II target concentrations for the two ambient air samples. For the Center Room - Ambient air sample, the PCE and TCE concentrations were 14 micrograms per cubic meter (µg/m³) and 1.8 (µg/m³), respectively. For the West Sump - Ambient air sample, the PCE and TCE concentrations were
9.5 (µg/m³) and 1.7 (µg/m³), respectively. The OSWER Tier II target concentrations for PCE and TCE are 8.1 (µg/m³) and 0.22 (µg/m³), respectively. Fourteen other chemicals were detected but did not exceed the OSWER Tier II target concentrations, and were suspected to be related to household (and other chemicals stored on-site) compounds that would be expected to be found at low concentrations in ambient indoor air.

Eight chemicals were detected in the sub-slab samples. PCE and TCE concentrations were 47,300 (µg/m³) and 9,080 (µg/m³) in sub-slab samples West Sump – Subsurface; and 59,700 (µg/m³) and 1,930 (µg/m³) in sub-slab samples Center Room – Subsurface, respectively. The sub-slab samples are not directly comparable to the OSWER Tier II target concentrations, and must be evaluated by estimating attenuation factors relative to soil or groundwater concentrations to indoor air concentrations. Attenuation factors for PCE and TCE for the West Sump – Subsurface were 0.003 and 0.002; and the attenuation factors for the Center Room – Subsurface samples were 0.002 and 0.009, respectively. From this data, the report concluded that a complete pathway for vapor intrusion exists, but very little vapor is migrating from the sub-slab soil into indoor air (the slab is an effective barrier to limit vapor intrusion). The report also concluded that VOCs measured in indoor air did not pose an unacceptable health risk to workers.

2.1.2.14 Shaw Source Area Conceptual Site Model – May 2008

Shaw prepared a Final Source Area Conceptual Site Model (CSM) (Shaw, May 29, 2008), to understand the contamination source area geology using new recent investigation data, and to aid in preparation of a pilot scale treatment study work plan. The Source Area CSM included cross sections and a fence diagram in the Cypress Shopping Center area, showing the local geology and distribution of PCE in soil and groundwater. The report noted primary downward migration of PCE immediately near the Bell facility and horizontal movement of PCE in groundwater-bearing units below the facility.

2.1.3 Contaminant Source Investigation (Other Suspected Areas)

A photograph taken at 10825 Barely Lane (Photo 2, Roll 2) taken on March 19, 2002 and included in the document Hazard Ranking System Documentation Record – Jones Road Groundwater Plume (TCEQ, April 2003), prompted the investigation discussed in Section 2.1.3.1. The photograph documented a 55-gallon drum containing what was identified as dry cleaning solvent elevated on a drum cradle and sitting on its side so that the solvent could be dispensed as needed. Below the drum there was a plastic secondary containment basin to collect any spillage.

2.1.3.1 Shaw Remedial Investigation – Cone Penetration Technology – August 2004

An additional source area investigation, Remedial Investigation – CPT (Shaw, November 10, 2004) (Appendix A), was performed in an area approximately 750 feet southeast of the Cypress Shopping Center (11600 Jones Road; location of the Bell facility), near the southeast corner of the property located at 10819 Barely Lane and the northern portion of the property located at 10902 Tower Oaks Boulevard (Figure 5). The investigation was intended to determine whether
or not a drum containing PCE located near the southeast corner of 10825 Barely Lane contributed to the PCE groundwater plume in the Jones Road area.

Ten CPT borings (CPT-40 through CPT-49) were installed to a depth of approximately 70 feet bgs during the period from August 25 through 27, 2004. The soil borings were installed to obtain electronic boring logs showing the subsurface lithology and also to obtain groundwater samples from the water bearing zones. Soil samples were not collected during the investigation. Two sand units were identified, including one at approximately 28 to 30 feet bgs and a second at approximately 60 to 70 feet bgs. The shallow sand unit was the target for the majority of groundwater pushes.

Groundwater samples were submitted to the EPA CLP laboratory, Liberty Analytical in Cary, North Carolina for analysis of VOCs using Method OLCO3.2. The groundwater samples were also screened in the field using Color-Tec methods. The laboratory results indicated that CPT locations CPT-41, CPT-42, and CPT-47 had concentrations for PCE that were present but estimated to be below the contract required quantitation limit (CRQL) of 0.002 mg/L. All remaining CPT locations were below the laboratory detection limit for PCE. In addition, TCE, DCE, and VC were below the laboratory detection limit for all groundwater samples submitted.

Based upon findings from this CPT investigation, the low concentrations of PCE detected suggest a small (minor) source of contaminants in the vicinity of property boundary between 10825 Barely Lane and 10902 Tower Oaks.

2.1.4 Meteorological Investigations

The only specific meteorological investigation recorded has been the Deep Monitor Well Groundwater Gauging and Rainfall Data (Shaw, November 2007) report (Appendix A), which documented rainfall data from rain gauges in the Jones Road area from a period of January 2006 through August 2007 to compare rainfall to groundwater elevations measured in deep monitor wells. The report identified Harris County Flood Control District (HCFCD) Gauge 555 as the nearest point with rainfall data. A streamflow gauge is also present at the location (White Oak Bayou at Jones Road). More general information about area meteorology has been collected from general sources such as the national weather service and websites that collect and present weather and climate information. A more general discussion of meteorological aspects of the site is presented in Section 3.1.2.

2.1.5 Surface – Water and Sediment Investigations

Because there is no surface water located within the vicinity of the site, this potential receptor does not exist. The nearest surface water is White Oak Bayou (approximately 3500 feet to the south) and also Cypress Creek (approximately 1 mile to the northwest of the site). No surface water or sediment investigations were performed at the site.
2.1.6 Geological Investigations

The reports and technical memoranda described in the following section are included in Appendix A, and locations of intrusive sample points (soil borings, monitor wells, etc.) installed near the Bell facility are illustrated on Figure 5 (Source Area Investigation Map). Locations of deep monitor wells are illustrated on Figure 6 (Deep Monitor Well Location Map).

2.1.6.1 Geo-Tech Limited Site Assessment – June 2001

The June 2001 LSA performed by Geo-Tech is described in Section 2.1.2.3. In the Bell facility area, the maximum depth of investigation was 25 feet. The text described the soils encountered from top to bottom as: concrete, grass, and overburden to 2-inches bgs; light gray plastic clay with minor silt components from 2 inches to 5 feet bgs; light gray to green silty clay with reddish brown streaks from 5 feet to 10 feet bgs; reddish brown plastic silty clay from 10 feet to 20 feet bgs; and reddish-brown moist silt with white calcareous concretions at the bottom from 20 feet to 25 feet bgs. Groundwater was encountered at 20 feet bgs.

2.1.6.2 Shaw Remedial Investigation – Cone Penetration Technology – August/September 2003

The August/September 2003 CPT investigation performed by Shaw is described in Section 2.1.2.7. In the Bell facility area, boring logs from the CPT investigation and subsequent monitor well installations indicated that the subsurface geology was determined to similar to the geology described in the Geo-Tech LSA report (described in Section 2.1.6.1). However, the geology below 20 feet was described as being comprised of interbedded layers of clay, silt, and sand with (calcareous) nodules. Groundwater bearing units (silts and sands) were not typically encountered until approximately 28 feet bgs and deeper. The CPT logs indicated that the interbedded zone was underlain by clay with minor discontinuous sand/silt intervals less than 3-feet thick. The clay unit underlying the interbedded layer extends from a depth of approximately 37 feet to the maximum depth of investigation, approximately 60 feet bgs.

2.1.6.3 Shaw Remedial Investigation – Geoprobe – October 2003

The October 2003 Geoprobe investigation performed by Shaw is described in Section 2.1.2.8. In the Bell facility area, the geologic description of the shallow soils was refined, indicating that the interbedded layer included calcareous nodules and some iron nodules encountered between 20 to 25 feet bgs, and sand and silty sand comprised the first water bearing unit at approximately 28 feet bgs.

2.1.6.4 TCEQ File Review – Date Unknown

TCEQ staff conducted file searches and collected available water driller’s logs in the project area. Well construction information was determined to be available for only 30% to 40% of the wells in the area. Initial records search of public water supply (PWS) files were performed, and four geophysical logs were located within a 2- to 3-mile radius of the Bell facility (Appendix C).
Shaw conducted a detailed file review and collected additional geophysical logs and hydrologic testing information associated with PWS wells located within a 3-mile radius of the Bell facility.

**2.1.6.5 Shaw Remedial Investigation – Cone Penetration Technology – August 2004**

The August 2004 CPT investigation performed by Shaw is described in Section 2.1.3.1. The report describes an investigation performed in another suspected source area approximately 750 feet southeast of the Bell facility, south and east of the 10825 Barely Lane property. The CPT investigation identified a sand unit approximately 28 to 32 feet bgs (similar to the lithology at the Bell facility), and a sand unit from approximately 60 to 70 feet bgs (70 feet was the maximum depth of investigation).

**2.1.6.6 Shaw Deep Monitor Well Installations – July through November 2005**

Shaw installed ten deep monitor wells during the months of July, August, and November 2005, as documented in the *Chicot Monitor Well Installation Report* (Shaw, March 23, 2006). Nine of the wells (MW-10, MW-11, MW-11R (replacement well), MW-12 through MW-16 and MW-18 and MW-19) were installed in the Chicot Aquifer. One monitor well (MW-17) was installed into the upper portion of the Evangeline Aquifer. The locations where the deep monitor wells were installed are presented on Figure 6. A summary of the well locations and construction details is presented in Table 3.

The deep monitor wells were installed to provide monitoring points around the perimeter of the study area (excluding monitor well MW-13, which was installed near the study area) where groundwater elevation data and samples could be collected. The deep monitor wells were installed (screened) below zones where private water wells were known to be producing. Geophysical logging was performed in each monitor well borehole to identify different lithological zones to help understand potential contamination migration pathways, and to aid selection of intervals for installation of the well screens during well construction activities.

The subsurface geology generally consists of silts and clays within the upper 60 feet of soils, with some thin sand lenses approximately 20 to 30 feet bgs. A well developed sand zone occurred from approximately 60 to 110 feet bgs and was dominant across the site, but thinning to the north in monitor wells MW-15 and MW-16). Clay with minor sand lenses were encountered from approximately 110 feet bgs to 150 feet bgs. A sand unit underlies the clay, and extends from approximately 150 feet to 190 feet bgs. Below the sand lies another clay unit from approximately 190 feet to 205 feet bgs, which is underlain by another sand unit from 205 feet to 230 feet bgs. The next clay unit extends from approximately 230 feet bgs to 260 feet bgs, and the clay is underlain by sand from approximately 260 to 295 feet bgs where the Chicot Aquifer screen intervals occur. A clay unit below the Chicot Aquifer extends from approximately 295 feet bgs to approximately 410 feet bgs, where the suspected top of the Evangeline Aquifer exists.

**2.1.6.7 Shaw Regional Conceptual Site Model – June 2008**

A *Regional CSM* was prepared in early July 2008. Two cross sections were prepared using geophysical well logs obtained during installation of the deep monitor wells at the site (deepest
well drilled approximately 430 feet bgs), and from deep municipal water wells drilled into the Evangeline Aquifer (deepest well drilled approximately 1845 feet bgs). The Regional CSM is discussed in more detail in Section 5.6.2.

2.1.7 Soil and Vadose Zone Investigations

A detailed soil and vadose zone investigation was not conducted at the site. However, other studies were performed that included collection of soil samples above the apparent shallow groundwater interface (approximately 20 to 22 feet bgs) in and around the source area (Bell facility).

Section 4.1.1.5.1 describes several limited soil investigations that were performed around the source area. A Remedial Investigation – Geoprobe (Shaw, April 28, 2004) was performed, with the highest PCE concentrations detected in soil borings GP-3 and GP-4 (located behind the Bell facility and representing the suspected primary discharge area). The highest PCE concentration in soil was 260 mg/kg, within the 16 to 17-foot depth sample collected from soil boring GP-4. The concentration of PCE in the 18 to 19-foot depth sample of GP-3 was 4.6 mg/kg.

Another soil investigation was performed in July 2006, titled July 2006 Geoprobe Investigation (Shaw, January 24, 2007). PCE was detected in soil in boring GP-3A within the 20 to 21-foot bgs interval (620 mg/kg) and in soil boring GP-2A within the 20 to 21-foot bgs interval (7.8 mg/kg). The sample locations for GP-3A and GP-2A were both behind the Bell facility (near the storm drain grate that drains (sub-grade) westward towards the open ditch along Jones Road). Geotechnical parameters of soils in the source area were determined through analysis of soil samples taken from soil boring GP-9A, including fraction organic carbon, moisture content, volumetric water content, dry bulk density, total porosity, effective porosity, effective permeability, and vertical hydraulic conductivity. Appendix A includes the reports referenced above, and Table 4 of the July 2006 Geoprobe Investigation (Shaw, January 24, 2007) includes a summary of the geotechnical laboratory data. Table 4 (of this report) presents a cumulative summary of analytical results for the sampling events, and Table 7 provides a summary of soil sample information collected during the soil sampling investigations.

2.1.8 Groundwater Investigations

The reports and technical memoranda described in the following section are included in Appendix A.

2.1.8.1 TCEQ Hazard Ranking System Documentation Record – January 2003

The TCEQ prepared the Hazard Ranking System Documentation Record (TCEQ, April 2003) for the Jones Road Ground Water Plume site in cooperation with EPA Region VI. The report was prepared as part of the response to the Emergency Order Docket No. 2002-0584-IHWE that referred the site to the Superfund program. The documentation record notes that in December 2000, PCE, DCE, and chloromethane were detected in the well serving Finch’s Gymnastics USA and Childcare. Subsequent sampling of the well in January and May 2001 confirmed the presence of the chemicals at concentrations exceeding the MCLs. TCEQ sampled 220 wells in
the area, and based on samples collected from March to December 2002, the approximate boundaries of the groundwater plume were determined to be:

- Northern boundary – southern end of Echo Spring
- Southern boundary – Tower Oaks
- Eastern boundary – Jones Road
- Western boundary – Timber Hollow

The boundaries of the plume were later expanded as the size of the plume became better known. The Hazard Ranking System (HRS) score was determined to be 46.5, and the CERCLIS Site ID Number was established (TXN 000 605 460).

2.1.8.2 Shaw/TCEQ Routine Quarterly Groundwater Sampling – August 2003 to May 2008

Routine quarterly sampling at the site began in August 2003 and has continued for nearly five years (latest May 2008). Two earlier rounds of groundwater sampling, in February and May of 2003, sampled similar wells in the area during the same approximate quarterly sampling intervals. The number of addresses with wells sampled during individual quarterly sampling events has ranged from 90 to 201, and currently about 180 properties have wells sampled. Cumulative analytical results for the quarterly sampling events are presented in Table 4.

Private water supply wells are currently sampled every three months (quarterly) by the TCEQ to monitor any plume migration and concentration of PCE in the wells. The sampling area is larger than the known contamination plume, and includes wells with state-supplied GAC filtration systems that have confirmed concentrations of PCE above the MCL (5 µg/L). At the beginning of the quarterly sampling activities in August 2003, GAC systems were installed on 24 wells. By 2008 there were 35 wells fitted with GAC filtration systems. Under current sampling guidance, all water supply wells at the site with measurable concentrations of PCE, as well as wells located in areas threatened by the migration of contaminants, are included in the quarterly sampling regime. Based upon data collected to date, the study area has expanded to the west to include Oak Valley Drive, Woodedge Drive and the end of Timber Hollow Drive to the north, the eastern end of Barely Lane and Tower Oaks Boulevard, and to the south by the Center Point Energy right-of-way (ROW) south of Mulligan’s Golf Course (east side of Jones Road) and Tower Oaks Blvd. on the west side of Jones Road.

2.1.8.3 Shaw Water Well Inventory Survey – May 2004

In May 2004, Shaw and the TCEQ performed a walking water well inventory survey in the neighborhoods surrounding the Bell facility in an attempt to document information about active or past drinking water sources. A total of 47 addresses were surveyed, and 14 wells were identified, 13 active wells and 1 inactive well. Data obtained from the inventory survey was used to prepare an initial map showing the well locations. Field information, along with publicly available information was used to compile an initial database of the well ownership, address, total depth, screened interval, well diameter, use, status, etc. Information about these and other wells is collected in Table 2.
2.1.8.4 Shaw General Groundwater (Inorganic) Quality Characterization and Comparison – March 2004

Shaw prepared Remedial Investigation – General Groundwater (Inorganic) Quality Characterization and Comparison, March 2004 (Shaw, May 27, 2004) to characterize general inorganic groundwater quality parameters from select monitor wells and private water wells, and also to compare water quality between wells to assess whether the groundwater from different wells represented the same, similar, or different water bearing units to help assess the nature and extent of contaminant migration. Groundwater samples were collected from three monitor wells and 15 private wells. The groundwater samples analyzed for common earth metals, boron, chloride, alkalinity, nitrate, sulfate, TDS, TOC, phosphate, fluoride, BOD, and COD. Box and whisker plot diagrams were prepared to compare groundwater quality from the various wells. Groundwater quality in the water-bearing units (WBUs) represented by the samples was generally similar. This similarity suggested that vertical mixing of groundwater occurs between the WBUs, and aquifer connection.

2.1.8.5 Shaw Groundwater Elevation Data Investigation – October 2004 through August 2005

This investigation collected water level elevation data using electronic pressure transducers in five water wells. This was a continuation of the investigation reported in First Three-Month Water Level Measuring Event Report (Shaw, February 2005), with the extended investigation period October 2004 through August 2005. Slight water level elevation changes throughout the year were suspected to be related to pumping demand upon the aquifer during peak use seasons (summer) and less use seasons (winter). Groundwater flow direction remained unchanged to the south, with an average groundwater gradient of 0.011032 ft/ft. The details of this investigation can be found in the Final Groundwater Elevation Data Report (Shaw, October 2005).

2.1.8.6 Shaw Deep Monitor Well Gauging and Rainfall Data Investigation – March to August 2007

This investigation recorded alternate-week groundwater gauging of ten deep monitor wells in the Jones Road area during the months of March through August 2007. Also recorded was rainfall data from local rainfall data collection stations during the months of January 2006 through August 2007. The Chicot Aquifer groundwater flow direction was determined to be to the southeast with a gradient ranging from 0.00248 to 0.00267 ft/ft. The information collected was intended to support an accurate groundwater model of the site under current water use conditions (pumping from area water wells). The details of this investigation can be found in the Deep Monitor Well Groundwater Gauging and Rainfall Data, (Shaw, November 12, 2007).

2.1.8.7 Shaw Groundwater Model Identification Report – June 2008

Shaw prepared a Groundwater Model Identification Report (Shaw, June 2008) for the study area. The purpose of the report was to document an approach for development of a site-specific groundwater model. The report indicated that a series of numerical groundwater flow simulations would be conducted in order to characterize the PCE groundwater plume dynamics over time and to evaluate potential groundwater remediation and/or treatment options. The report also indicated that calibration of the model would be conducted using trial and error
methods and/or automatic calibration methods available in the most recent version of MODFLOW (McDonald and Harbaugh, 1988). Section 5.3.2 presents more detail on groundwater model development.

2.1.9 Human Population Surveys

The study area is located in northwest of Houston in Harris County, Texas. The census bureau tracked the area primarily under census tract 5524 and to a lesser extent 5525 in the 2000 census. Tract 5524 is the area west of Jones Road, north of FM 1960, east of Eldridge Drive, and south of Cypress North Houston Road. Tract 5525 is the tract immediately east of Jones Road across from tract 5524. The census bureau information for Harris County and these census tracts provided most of the demographic information for human population at the site. Section 3.1.7.1 describes details about the demographics.

No direct surveys of the human population were made as part of previous site investigations. However, some information has been gathered incidentally as part of work investigating other aspects of the site. The June 2002 sampling of all wells within one half mile of the site generated a list of 216 names, addresses, and phone numbers for properties where groundwater wells were present. No population or demographic information was collected with the list.

Finch’s Gymnastics and Childcare represents a potential sensitive receptor population for groundwater exposure. The early TNRCC investigations focused on the groundwater well at that business. A preschool location, likely to have young students, was also identified in the area.

2.1.10 Ecological Investigations

Residential development has been active since the 1960s effectively eliminating natural wildlife habitat from the area. See Appendix D for the completed TCEQ Tier I (Ecological) Exclusion Criteria Checklist prepared for the Jones Road Groundwater Plume site.

2.1.11 Data Management (Electronic Database)

Electronic data for the Jones Road project were compiled from a number of sources in order to build a cumulative database of analytical data (Table 4), which is organized into two subcategories including soil analytical data and groundwater analytical data. Groundwater analytical data are further categorized into samples collected from (1) monitor wells, (2) water wells, and (3) DPT, CPT, and other sample collection methods. Since the majority of groundwater samples were collected from water wells, so further categorization of water well samples was performed based on the street name adjacent to the water wells from which samples were collected.

Sources of this data include quarterly groundwater data gathered from EPA and CLP laboratories and compiled in the TCEQ database, and soil and groundwater reports from Shaw’s electronic files. The quarterly groundwater data has been saved in the database from May 2003 to the current date. Groundwater and soil data from source area investigations around the Bell facility have been saved in the database since February 2002 and September 2003, respectively. The
data were a combination of excel files and lab data files that were converted into text files and imported into the project ShawView data base. The ShawView data base is an Oracle-based system developed in-house for managing environmental data.

At the time of this writing, there were approximately 6,600 groundwater samples and 90 soil samples registered in the data base. The samples have approximately 408,000 corresponding analytical records for groundwater and 5,200 analytical records for soil. One analytical record is defined as one analytical result from one sample point from one sampling event.

Quality control data were included in the database, such as trip blanks, field blanks, duplicates, and equipment rinse blanks. The quality control data are typically not used for trend analysis or indication of contamination impact at individual sample locations, so quality control data has been flagged with a code USE=N in the data base so that it can be filtered from database sorting routines. Due to the variety of sources and inconsistency between sources, not all data base fields were able to be populated with information. Missing dates have been set to 01-JAN-1950. Missing numbers have been set to -99. Data in fields such as dilution factor, detection limit, and method detection limit were only updated if the data existed in the source file. Lab qualifier and validation qualifier fields were set according to the field names in the source file. When only one qualifier field was included, the qualifiers went into the lab qualifier field.

ShawView provides several options and formats for generating output documents. These range from Microsoft Excel™ files to Oracle™ exports to Adobe™ files depending on specific reporting requirements. Many output formats can be modified to meet specific project needs.

### 2.1.11.1 Sample Nomenclature for Quarterly Water Sampling Events

Routine quarterly water samples were collected at individual residences and businesses at the site. Some of the locations have two GAC filtration vessels installed in series to remove (filter) PCE and daughter products from the water supply. For locations without GAC filtration systems, one sample was collected as near as possible to the well head for chemical analysis. For locations with GAC filtration systems, three samples were collected from the sample ports, including one sample before the first GAC unit, one sample between the two GAC units, and one sample after the second GAC unit.

The samples were pre-assigned specific sample numbers by the EPA CLP administrator prior to sampling activities. In addition, the samples were identified and labeled according to the location (street address) where the samples were collected and the date of collection using year and month format (YYMM). For example, TH11635 (0405) is a sample collected from 11635 Timber Hollow Lane in May 2004. Duplicate samples were identified with an A at the end of the location, for example, a duplicate sample collected concurrent with the environmental sample described above would be TH11635A (0405). A summary of street name codes for sample nomenclature is presented in Table 5.

Samples with multiple sample points at the same location were identified with a code number. For example, FV11610-3 (0305) represents a sample collected from 11610 Forest Valley Drive in May 2003 from Sample Point Code 3. A summary of sample point codes and descriptions for sample nomenclature is presented in Table 6.
2.1.11.2 Sample Nomenclature for Source Area Sampling (non CLP samples)

A simpler, more conventional (non CLP) sampling nomenclature was used to identify samples collected primarily associated with investigations around the Bell facility. Investigations conducted around the Bell facility were performed in stages by several different environmental consulting companies, since July 2001. Generally, soil borings were designated with prefix letters such as B (soil boring), CPT (cone penetration technology), and GP (Geoprobe; direct-push technology), followed by a sequential numbering system indicating the sample name, such as 1, 2, 3, etc. For example, the fifth soil boring installed during the October 2003 Geoprobe investigation was named GP-5. The sample depths associated with the soil borings were generally identified as numbers between parentheses. For example, a soil sample collected from soil boring GP-5 from a depth of 20 to 21 feet below ground surface would be identified as GP-5 (20-21).

A similar sample nomenclature was used to identify groundwater samples collected from monitor wells (MW) and temporary monitor wells (TMW), but since groundwater samples typically do not have depth intervals associated with the sample nomenclature, samples were simply identified by the monitor well name, such as TMW3. Samples were distinguished by including the sample date in the record (on the chain-of-custody form, lab reports, and tables). For soil and groundwater sample nomenclatures, a hyphen between the prefix and sample point number was not used in some early investigations performed by Geo-Tech (for instance, temporary monitor well MW3). In later investigations performed by others, a hyphen was used (for instance, monitor well MW-6).

2.1.12 Sample Collection Methods

Environmental samples were collected in multiple media (groundwater, soil, and indoor air) for evaluation of chemical impact of PCE and daughter products. The majority of groundwater and soil samples were collected using CLP protocol. However, some investigations used standard TCEQ protocol for sample collection and subsequent local fixed-laboratory (non-CLP) analysis. Sample collection protocol pertaining to each of the various previous investigations is discussed in the individual reports. Generally, sample collection methods followed protocol described in the Field Sampling Plan (Shaw, August 30, 2003), Amendments to the Field Sampling Plan (Shaw, October 17, 2003), Addendum to the Field Sampling Plan (Shaw, July 28, 2005), Addendum to the Field Sampling Plan (Shaw, August 24, 2006), TCEQ Remediation Division Quality Assurance Project Plan (QAPP) for the Superfund Program (Revision 4) (TCEQ, March 25, 2004), TCEQ Superfund Program Standard Operating Procedures (TCEQ, January 2001), and EPA’s Contract Laboratory Program Guidance for Field Samplers (August 2004) included in Attachment 4 of the QAPP.

2.1.12.1 CLP Sample Protocol

Routine quarterly water sampling at the site, and in some soil and groundwater investigations around the Bell facility have been performed through the EPA Superfund Contract Laboratory Program. The Contract Laboratory Program Guidance for Field Samplers (OSWER 9240.0-35; EPA540-R-00-003) is presented as Attachment 4 of the TCEQ QAPP. The CLP has established
strict quality control procedures and detailed documentation requirements, and requires samplers to use the functionality provided by the Field Operations Records Management System (FORMS) II Lite™ software.

Generally, during the quarterly water sampling activities, a select set of samples were submitted to the CLP laboratories for analysis, and the remaining samples were sent to the EPA Region 6 Laboratory for analysis. Water samples collected from the domestic and public water wells, along with samples collected from the second sample port (Sample Point Code 2; between the GAC vessels) and the third sample port (Sample Point Code 3; after the second GAC vessel) of GAC filtration units were submitted for analysis by the CLP laboratories. Water samples collected from the monitor wells and the first sample port (Sample Point Code 1; before the GAC vessels) of GAC filtration units were submitted to the EPA Region 6 Laboratory for analysis. The same sample collection and labeling protocol is used for submittal of samples to the EPA laboratory, as was used for submittal of samples to the CLP laboratories, using CLP sampling protocol.

### 2.1.12.2 Color-Tec Screening

Soil and groundwater samples have been screened during various investigations at the site using the Color-Tec method. The Color-Tec screening method was usually performed immediately upon collection of environmental samples; for groundwater, samples were screened using the Color-Tec method immediately after purging the wells. For soil sampling, Color-Tec screening was performed immediately after extracting the soil sample from the soil sampling device.

The Color-Tec screening method employs a colorimetric gas detector tube designed to estimate levels of contaminants in ambient air. The method concentrates purged volatile organic chemicals from the sample through the colorimetric tube, which reacts to any chlorinated ethenes present. The process for Color-Tec screening is included in Section 5 and Appendix E of the FSP (Shaw, August 30, 2003).

### 2.1.12.3 Groundwater Sample Collection Methods

#### 2.1.12.3.1 Water Level Measurement

Water levels are measured in all monitor wells and open water wells prior to collecting groundwater samples. Water levels are not measured in water wells that are obstructed or fitted with down-hole pumps and conductor piping/wiring prior to sampling. TCEQ standard operating procedure (SOP) 7.1 Water Level/Sediment Measurement was used for obtaining all water level measurements. The water level measurements were obtained to the nearest 0.01-foot interval (measured from the north side of the top-of-casing lip), and were recorded on field forms during each gauging event.

#### 2.1.12.3.2 Low-Flow Well Purging

All groundwater samples collected since May 2003 have utilized low-flow purging methods. The deep monitor wells and open water wells were purged with a stainless bladder pump with dedicated tubing, whereas the shallow monitor wells associated with the Bell facility were purged using a peristaltic pump with dedicated tubing. The pump intake or tubing intake was set
at the mid-point of the well screen. During the groundwater purging process and subsequent sampling, the groundwater flow rate was maintained at a constant rate (<0.5 liters/min) using a flow control device. All purged water was pumped through a calibrated flow-through cell so that water quality parameters (temperature, conductivity, pH, dissolved oxygen, and ORP) could be measured and recorded. The wells were purged a minimum of 15 minutes until consecutive readings for pH (+/- 0.5 pH), temperature (+/- 1°C), and conductivity (+/- 10%) were achieved. The water quality parameters and flow rates were recorded on Groundwater Sampling Purge Sheet forms in two- to five-minute intervals during the purging process.

For locations with operating water wells, pumps were not needed to extract samples from the wells, and water was tested by simply flowing water from the garden spigot or inside kitchen sink (through a garden hose) to purge the water while collecting water quality parameters as discussed above. The following TCEQ SOPs were followed during the purging process:

- SOP 7.4 Micro Purging a Monitor Well
- SOP 7.5 Measurement of Field Parameters

### 2.1.12.3.3 Groundwater Sampling

After groundwater levels were measured, and groundwater was purged using low-flow protocol, groundwater samples were collected. Groundwater sampling was performed immediately after collecting water quality parameters by disconnecting (or diverting the flow) from the calibrated flow-through cell to clean, laboratory provided sample bottles. Groundwater sampling using low-flow techniques were used for all groundwater collection activities since May 2003. Sampling performed by others before May 2003 was not described in historical documents. The following TCEQ SOPs were followed during the groundwater sampling process:

- SOP 6.3 Collection of VOC Samples
- SOP 7.8 Groundwater Sampling Using Low-Flow Techniques

### 2.1.12.4 Soil Sample Collection Methods

Various drilling methods were utilized to collect subsurface soil samples, primarily in the area near and around the Bell facility as described in Section 2.1.2, but also in areas around the perimeter of the groundwater plume at the site where deep monitor wells were installed. The drilling methods included HSA, CPT, DPT, sonic, and mud rotary. Soil sampling tools associated with the drilling methods included split barrel samplers, core barrels, and Shelby tubes. After the soil cores were extracted from the sampling tools, individual soil samples were collected using closed-system field collection techniques per Method SW846-5035. The following TCEQ SOPs were followed during the soil sampling process:

- SOP 6.3 Collection of VOC Samples
- SOP 6.4 Sample Handling and Control
- SOP 6.5 Collection of QA/QC Samples
- SOP 10.2 Soil Sampling Using a Split Barrel Sampler
- SOP 10.4 Soil Sampling Using Direct Push
- SOP 10.5 Soil Sampling Using Shelby Tube Sampler
2.1.12.5 Vapor Sample Collection Methods

A single vapor intrusion study was performed within the Bell facility as discussed in Section 2.1.2.13. The vapor sample collection methods included the use of summa canisters for ambient air and sub-slab vapor collection, following EPA Method TO-15 and TCEQ SOP 14.5 Air Sampling Using a Summa Canister.

2.1.13 Analytical Methods

Analytical methods following Test Methods for Evaluating Solid Waste, Physical/Chemical Methods (U.S. EPA SW-846, most recent update) is described in the TCEQ Remediation Division Quality Assurance Project Plan (QAPP) for the Superfund Program (Revision 4) (TCEQ, March 25, 2004).

2.1.13.1 VOC Method SW8260B for Soils and Groundwater

Soil and groundwater samples were analyzed for VOCs using Method SW8260B, which uses a capillary column gas chromatograph/mass spectrometry (GC/MS) technique. Preparation involves the use of a purge and trap technique using Method 5030B for water and Method 5035 for soil. A complete description of the SW8260B Method is described in the TCEQ QAPP, Section B.5.1.9.

2.1.13.2 VOC CLP Method SOM01.1 for Soils and Groundwater

VOC analysis was performed under the EPA CLP, using Analytical Services/Method SOM01.1, recently updated by SOM01.2 in June 2007. Two VOC analytical methods were performed under Analytical Services SOM01.1, including Analysis of Low/Medium Concentrations of VOCs, and Analysis of Trace Concentrations of VOCs. Refer to the Superfund Analytical Services/Contract Laboratory Program web page for more information – http://www.epa.gov/superfund/programs/clp/som1.htm.

2.1.13.2.1 Analysis of Low/Medium Concentrations of VOCs

Low/medium concentrations of VOCs were analyzed by the CLP based on EPA SW-846 Method 624, which is a purge-and-trap GC/MS technique for aqueous and medium-level (concentration) soil samples and closed-system purge-and-trap for low-level (concentration) soil samples.

2.1.13.2.2 Analysis of Trace Concentrations of VOCs

Trace concentrations of VOCs were analyzed by the CLP based on EPA Method 524.2, which is a purge-and-trap GC/MS technique, and may include Selected Ion Monitoring (SIM analysis) if requested. Trace VOC analysis typically includes samples collected from drinking water wells and monitor wells requiring trace VOC analysis.
2.1.13.3 Inorganic Methods for Groundwater

An investigation of inorganic groundwater characterization and comparison was performed at the site as described in Section 2.1.8.4. Calcium, barium, boron, iron (+3), magnesium, manganese, potassium, sodium, and zinc were analyzed using Method SW6010B, which utilizes Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES). The metals were prepared using Method 3010. A complete description of the SW6010B Method is described in the TCEQ QAPP, Section B.5.1.15.

2.1.13.4 VOC Method TO-15 for Air

A Vapor Intrusion Study was performed within the Bell facility as discussed in Section 2.1.2.13. VOCs in ambient air and sub-slab vapors were analyzed using EPA Compendium Method TO-15. Method TO-15 uses a high resolution gas chromatograph coupled to one or more mass spectrometers. A complete description of the TO-15 Method is described in the TCEQ QAPP, Section B.5.1.22.

2.1.14 Monitor Well Borehole Advancement and Well Construction

2.1.14.1 Monitor Well Borehole Advancement

Temporary and permanent monitor wells were installed at the site to monitor groundwater conditions in shallow and deep groundwater-bearing units. Temporary monitor wells were installed around the Bell Facility during the initial intrusive investigation (Section 2.1.2.3), and permanent monitor wells were installed into the shallow groundwater-bearing units (less than 40 feet bgs) using HSA drilling methods during and after the VCP investigations (Sections 2.1.2.5 through 2.1.2.7), and monitor wells installed at depths greater than 280 feet bgs were installed using mud rotary drilling methods (Section 2.1.6.6). An attempt to install a deep monitor well in the source area was performed using sonic drilling methods, but the attempt failed to reach the target depth of 320 feet bgs as discussed in Section 2.1.2.11.

Hollow stem auger drilling methods utilize hollow augers that are rotated and advanced into the ground in a cork-screw fashion. The HSA drilling method pushes soil up and out of the borehole along the outside of the auger as the auger is advanced. The HSA drilling method does not require the use of drilling fluids, and allows for collection of discrete soil samples during drilling (which helps identify lithologic changes), and it allows for installation of monitor well materials prior to removing the augers from the borehole (ensuring a proper screen placement and filter pack installation). Hollow stem auger drilling methods are limited to drill depths of approximately 75 to 80 feet bgs in the Houston area.

Mud rotary drilling methods utilize a drill bit suspended on smaller diameter drill pipe that is rotated and advanced while drilling fluid (mud) is circulated through the drill bit and back up the borehole. Drilled cuttings are suspended in the mud and transported to the ground surface where they are removed from the mud through gravity settling. The barren mud is then re-circulated in a continuous manner through the drill pipe. Collection of soil samples is possible, but the quality of the samples is questionable due to invasion of the sample pore spaces with drilling mud.
Identification of lithologic changes is possible by examining drill cuttings at the surface, but the process is not always precise, and identification of fine sand units may be unnoticed since the cutting separation process favors larger cuttings like gravel and clay cuttings. During well material installation process, drilling mud must be displaced with grout, and installation of filter media around the screen is not possible (using well construction methods employed for this project). Mud rotary drilling is a more rapid method of borehole advancement than HSA, and drilling depths are almost unlimited for typical environmental investigations. The following TCEQ SOPs were followed during monitor well drilling (advancement):

- SOP 5.2 Hollow Stem Borehole Advancement
- SOP 5.3 Mud Rotary Borehole Advancement

### 2.1.14.2 Monitor Well Construction

Monitor wells near the Bell facility were installed using HSA drilling methods. The monitor wells were installed to a maximum depth of 35 feet bgs. Upon completion of drilling activities, a 15-foot long, two-inch diameter polyvinylchloride (PVC), Schedule 40 well screen with 0.01-inch slots was connected to a 20-foot long, two-inch diameter PVC, Schedule 40 blank pipe (riser). The well screen was fitted with a bottom cap and the entire well assembly was installed into the borehole with the HSA augers in place. Clean filter pack (20/40 silica sand) was placed between the well assembly and augers as the augers were slowly removed and until the filter pack was positioned approximately two feet above the top-of-screen elevation. Bentonite pellets were placed on top of the filter pack as the augers continued to be removed, and the bentonite pellets were subsequently hydrated with clean water. Grout slurry comprised of Portland cement and bentonite gel was prepared in a mixing vessel and then pumped into the remaining annular space between the well assembly and the borehole as the remaining augers were removed. The grout was installed to a depth near the ground surface. A flush-mount traffic vault was installed at the ground surface and a locking cap was installed on the PVC riser opening to limit access to the well and prevent objects or contaminants from entering the well. The traffic vault was secured in place by installing a 3-foot square concrete pad flush with the existing parking lot or grassy areas.

Deep monitor wells surrounding the study area plume were installed using mud rotary drilling methods. Nine monitor wells were installed to depths ranging from 284 feet to 357 feet bgs in the Chicot Aquifer, and one monitor well was installed to a depth of 430 feet bgs in the Evangeline Aquifer. Upon completion of drilling activities, each borehole was logged using geophysical methods to determine the sand intervals to be screened. The borehole geophysical logging tools/methods included natural gamma, 16-inch short normal resistivity, 64-inch long normal resistivity, and single point resistivity. Copies of the geophysical logs (printed output) are included in the Chicot Monitor Well Installation Report (Shaw, March 23, 2006) included in Appendix A. Following logging, the borehole was enlarged and reamed out while circulating drilling mud to condition and stabilize the borehole walls. The drill pipe was subsequently removed, and 20-foot lengths of four-inch diameter PVC casing was connected together (threaded couplings) and installed open-ended (without a screen) into the borehole to a depth immediately above the sand unit to be screened. Grout slurry comprised of Portland cement was prepared in a mixing vessel and then pumped through the PVC casing and up the borehole
annular space to the ground surface until all of the drilling mud was displaced by the grout. A wiper plug was then installed inside the PVC casing, and was pushed to the bottom to displace the remaining grout from the casing. The grout was allowed to set overnight, and the next day the wiper plug was drilled out and the borehole was advanced into the sand unit to the desired screen depth. The drill pipe was removed from the well, and a two-inch diameter, Schedule 40 PVC liner fitted with a K-packer on one end and a 20-foot long stainless steel, wire-wrapped screen with 0.01-inch slots and end plug was installed on the other end. The liner and screen assembly was installed into the well such that the top of the screen was positioned near the bottom of the 4-inch PVC casing and top of the desired sand interval. A flush-mount traffic vault was installed at the ground surface and a locking cap was installed on the PVC riser opening. A 3-foot square concrete pad was installed around the traffic vault. The wells were constructed per TCEQ SOP 5.5 Monitoring Well Installation and Completion.

2.1.14.3 Monitor Well Development

The shallow monitor wells installed near the Bell facility were developed using a bailer or a small submersible pump to remove fine sediments from the filter pack and formation surrounding the well screen. The deep monitor wells were developed by pumping compressed air to the bottom of the well to lift mud and silt laden formation water to the ground surface. Each of these development methods were performed until the formation water removed from the well was clear and water quality parameters had stabilized. Monitor well development was performed in accordance with TCEQ SOP 5.6 Monitoring Well Development/Abandonment.

2.1.15 Data Quality Evaluation

This section presents the Data Quality Evaluation (DQE) completed for the laboratory analyses of environmental samples collected as part of the RI process. The analytical results discussed in this evaluation are derived from the analyses performed by selected laboratories on groundwater and soil samples collected between March 2003 and May 2008. The analytical data generated for this project were obtained from 11 different laboratories and included the following types of data:

- Groundwater data from laboratories
- Soil data from laboratories
- Vapor data from laboratories
- Field screening tests on Soil and Groundwater

Data from the field screening tests were not validated, but were compared with lab results from samples sent to the laboratory. Data from CLP laboratories were validated by the laboratories performing the analysis and EPA conducted a final review of the validated data prior to the data release. Data from non-CLP laboratories were reviewed to assess usability for site evaluation and risk assessment. The items reviewed included holding time compliance, surrogate recoveries, matrix spiked sample results, method blank results, laboratory control samples, and field sample duplicate results as noted and discussed in the following sections.
2.1.15.1 Data Quality Evaluation Process

The purpose of the DQE process is to assess the effectiveness of the overall analytical process on the usability of the data. The two major categories of data evaluation are laboratory performance and matrix interferences. Evaluation of laboratory performance is a check for compliance with the method requirements; either the laboratory analyzed the samples within the limits of the analytical method, or they did not. Evaluation of matrix interferences is more subtle and involves the analysis of several areas of results, including surrogate spike recoveries, matrix spike recoveries, and duplicate sample results.

Before the analytical results were released by the laboratory, both the sample and QC data were carefully reviewed to verify sample identity, instrument calibration, detection limits, dilution factors, numerical computations, accuracy of transcriptions, and chemical interpretations. Additionally, the QC data were reduced and the resulting data were reviewed to ascertain whether they were within the laboratory-defined limits for accuracy and precision. Any non-conforming data were discussed in the data package cover letter and case narrative.

Sample results that were not within the acceptance limits were appended with a qualifying flag, which consists of a single or double-letter abbreviation that indicates a potential problem with the data. Although the qualifying flags originate during the data review and validation processes, they are included in the data summary table deliverables so that the data will not be used indiscriminately. The following flags were used singularly and in combination:

- **U** – undetected. Samples were analyzed for this analyte, but it was not detected above the method detection limit (MDL) or instrument detection limit (IDL).
- **J** – estimated. The analyte was present, but the reported value may not be accurate or precise. Coupled with “U”, indicates the detection limit may not be accurate or precise.
- **R** – rejected. The data are unusable. Results should not be used for any purpose.
- **L** – low biased. Actual concentration may be higher than the concentration reported.
- **M** – Reported concentration should be used as a raised quantitation limit because of interferences and/or laboratory contamination.

These flags are applied to data in the compiled electronic database, and are presented with the numeric results in tables and figures when necessary.

2.1.15.2 Analysis Summary

The eight laboratories involved in the analysis of samples for the Jones Road Groundwater Plume Superfund Site tested site samples using the analytical methods listed below.
A4 Scientific (A4)
EPA CLP, SOW VOC SOM01.1 – VOCs in Groundwater

A&B Laboratories
EPA Method 8260B – VOCs in Soil and Groundwater

Accutest Laboratories, Inc.
EPA Method TO-15 - VOCs in Air
EPA Method 624 – VOCs in water
EPA Method 625 – SVOCs in water
EPA Method 405.1 – BOD in water
EPA Method 150.1 – pH in water
EPA Method 415.1 – TOC in water
EPA Method 351.2 – total kjeldahl nitrogen (TKN) in water
EPA Method 350.1 – ammonia nitrogen (AMN) in water
EPA Method 353.2 – nitrate in water
EPA Method 365.2 – total phosphorus in water
EPA Method 353.2 – nitrite in water
EPA Method 160.2 – total suspended solids in water
EPA Method 1664 – Oil and Grease in water
EPA Method 410.4 – COD in water
EPA Method 8260 – VOCs in soil
Reactivity, Corrosivity, and Ignitability (RCI) – in soil.

DATAC
EPA CLP, SOW VOC SOM01.1 – VOCs in Groundwater

EPA Region 6 Laboratory
EPA Method 524.2 – VOCs in Groundwater

ESN Mobile Laboratory
EPA Method 8260B – VOCs in Groundwater

Liberty Analytical
Method OLCO3.2 – VOCs in Groundwater

LCRA Laboratory
EPA Method 524.2 – VOCs in Groundwater

Mitkem Corporation
EPA CLP, SOW VOC SOM01.1 – VOCs in Soil and Groundwater

Severn Trent Laboratories
EPA Method 8260B – VOCs in Soil and Groundwater
EPA Method 524.2 – VOCs in Groundwater
Shealy
EPA CLP, SOW VOC SOM01.1 – VOCs in Groundwater

Shaw Environmental provided independent data review for the March 2003, and August 2003 Groundwater sampling at the Jones Road Groundwater Plume Superfund Site. The reviews are documented in a summary letter dated July 23, 2003, for the March 2003 data, and a data usability summary report dated October 2003 for the August 2003 data from LCRA. Environmental Services Assistance Team (ESAT) in Houston, Texas provided data review for the November 2003 quarterly groundwater sample results produced by A4.

ESAT provided independent data review for the February 2004 quarterly groundwater sample results produced by A4 and Shealy. ESAT provided data review for the May 2004 quarterly groundwater sample results produced by A4. ESAT provided data review for the August 2004 quarterly groundwater sample results produced by Shealy and Liberty. ESAT provided data review for the November 2004 quarterly groundwater sample results produced by DATAC.


ESAT provided data review for the February 2006 quarterly groundwater sample results produced by A4 and Liberty. ESAT provided data review for the May 2006 quarterly groundwater sample results produced by A4, DATAC, and Shealy. ESAT provided data review for the July 2006 quarterly groundwater sample results produced by Mitkem. ESAT provided data review for the August 2006 quarterly groundwater sample results produced by KAP and Mitkem. ESAT provided data review for the November 2006 quarterly groundwater sample results produced by DATAC and Mitkem.


ESAT provided data review for the February 2008 quarterly groundwater sample results produced by KAP. ESAT provided data review for the May 2008 quarterly groundwater sample results produced by Mitkem.

These data reviews are provided in Appendix E.
2.1.15.3 Holding Times

The holding times for each parameter were evaluated according to SW-846 methodology. All samples were originally analyzed within holding times, except the May 2006 quarterly groundwater samples, which were analyzed days beyond the allowable holding times, so were flagged as “R” unusable. Samples out of holding time during the May 2006 quarterly sampling event were re-sampled and re-submitted for analysis.

2.1.15.4 Potential Field Sampling and Laboratory Contamination

Four types of blank samples were used to monitor potential contamination introduced during field sampling, sample handling, shipping activities, and sample preparation and analysis at the laboratory.

Trip Blanks

A trip blank sample is a sample used to check for VOC cross-contamination during sample handling and shipment from the field to the laboratory. Trip blank samples were collected at a frequency of one trip blank for each day of VOC sampling. If more than one cooler of VOC samples was shipped on the same day, then a trip blank was shipped with each cooler. Trip blank samples were assigned a separate sample number and were submitted blind to the laboratory. Trip blanks were prepared at a location outside the known contamination area using water demonstrated to be free of the contaminants of concern and placed in the cooler used to ship the VOC samples. A few trip blanks in the May 2007 quarterly groundwater sampling contained excessive chloromethane contamination.

Equipment Blanks

Equipment blanks are intended to detect any COC contamination to the samples caused by contaminated sampling equipment. Equipment blanks were collected at a frequency of one blank per day. The equipment blank samples were assigned a separate sample number and were submitted blind to the laboratory.

Field Blanks

A field blank sample is a sample collected to check for cross-contamination from the sample containers, from sample collection, from sample shipment, and in the laboratory. Field blank samples were collected at a frequency of one field blank for each group of samples of similar matrix per each day of sampling. Field blank samples were assigned a separate sample number and were submitted blind to the laboratory. A few field blanks in the August 2007 quarterly groundwater sampling contained excessive chloromethane contamination.
Method Blanks

Method blanks are used to monitor laboratory performance and contamination introduced during the analytical procedure. A laboratory method blank is prepared at the laboratory using ASTM Type II water that is treated as a sample in that it undergoes the same analytical process as the corresponding field samples. One method blank was prepared and analyzed for every twenty samples or per analytical batch, whichever was more frequent. Method blanks from the February 2006 groundwater sampling event contained excessive chloromethane contamination.

Concentrations of common organic contaminants detected in samples at less than 10 times the concentration of the associated blanks can be attributed to field sampling and laboratory contamination rather than environmental site conditions. Common organic contaminants include acetone, methylene chloride, 2-butanone, and the phthalate compounds. For inorganic and non-common organic contaminants, five times the concentration detected in the associated blank samples is used to qualify results as potential field and/or laboratory contamination rather than environmental contamination.

When evaluating any significant amount of data such as this, there may be instances in which common laboratory contaminants are reported at low levels in samples, but are not detected in any associated blank samples. Therefore, they cannot be qualified as “U” (undetected), based upon blank evaluation. However, the reported levels of these compounds must be evaluated carefully to determine if they are truly indicative of environmental conditions, or of low level contamination from the field or laboratory. Also, care must be taken in those instances where common laboratory contaminants are reported in samples that have been diluted for analysis. Acetone and methylene chloride are used as extraction solvents by the laboratory and are, therefore, very common laboratory contaminants. Acetone, 2-butanone, 2-hexanone, and 4-methyl-2-pentanone are often associated with equipment rinsate samples, because solvents such as isopropanol are often used in the decontamination process. Incomplete drying of the rinsate solvent during decontamination can cause carryover of these contaminants. Phthalates are used as plasticizers, the most common of which is bis(2-ethylhexyl)phthalate, and may be introduced into samples during handling. Some August 2003 groundwater sample results for acetone were qualified as undetectable due to the presence of acetone in the equipment and field blanks.

2.1.15.5 Matrix Effects

This section describes the matrix effects demonstrated in the analyses, as evaluated using surrogate spike, matrix spike, and internal standard performance criteria.

Surrogate Spike Recovery

Surrogate spike recoveries (SSRs) were used to monitor both laboratory performance and matrix interferences. SSRs from field and laboratory blanks were used to evaluate laboratory performance because the blanks should represent an “ideal” sample matrix. SSRs for field samples were used to evaluate the potential for matrix interferences. According to EPA National Functional Guidelines, data are not qualified with respect to surrogate recoveries (SRs) unless one or more volatile surrogates are out of specifications.
Some March 2003 groundwater sample results were qualified as estimated with a low bias because of surrogate recovery below the acceptable range. Some 2005, 2006, 2007, and 2008 groundwater sample results were qualified as estimated or unusable due to zero or low recovery of some surrogates.

**Matrix Spike/Matrix Spike Duplicates**

A matrix spike (MS) is an aliquot of sample spiked with a known concentration of target analyte(s). The sample is spiked with the solution containing target compounds before sample preparation and analysis. A matrix spike is used to document the bias of a method in a given sample matrix. The matrix spike duplicate (MSD) is an intra-laboratory-split sample spiked with identical concentrations of target analyte(s), and treated just as the matrix spike sample. Accuracy is evaluated from the spike recoveries, while precision is evaluated from comparison of the percent recoveries of the MS and MSD.

Samples for MS/MSD analyses were collected at a frequency of one for every twenty samples in accordance with TCEQ SOP 6.5 (Collection of QA/QC Samples). The MS/MSD sample was identified as such on the chain of custody. For each MS/MSD water analyses, the sampler collected three volumes of the sample in three separate sample containers. All MS/MSD samples and the original sample were designated as one single sample. Problems with MS/MSD performance are not sufficient cause to qualify data results, so no data was qualified based on MS/MSD performance.

**Internal Standard Performance**

Internal standard calibration involves comparing instrument responses from the target compounds in the sample to the responses of specific standards added to the sample or sample extract before injection. Internal Standards (IS) performance criteria ensure that gas chromatograph/mass spectrometer (GC/MS) sensitivity and response are stable during every analytical run. The use of internal standards is required for GC/MS analysis.

Some August 2003 groundwater results were qualified “J” and “UJ” because of poor recovery for methyl acetate in the laboratory control sample. Some May 2006 and August 2006 groundwater results were qualified as unusable “R” because of poor internal standard response. Some May 2006, July 2006, and February 2007 groundwater results were qualified as unusable “R” because of poor or no calibration of the instrument for certain chemicals.

**2.1.15.6 Field Duplicate Sample Results**

A field duplicate sample is a second sample collected at the same location as the original sample. Duplicate sample results are used to assess total precision, which includes variability associated with both the sample collection process and with laboratory analysis. Duplicate samples were collected simultaneously or in immediate succession, using identical recovery techniques, and treated in an identical manner during storage, transportation, and analysis.
Duplicate samples were collected at a frequency of one for every ten samples and in accordance with TCEQ SOP6.5 (Collection of QA/QC Samples). The QA Officer was responsible for ensuring that the frequency requirements for field duplicate samples were met.

According to the EPA National Functional Guidelines, there are no qualification criteria for field duplicate precision, expressed as Relative Percent Difference (RPD). The RPD results for soil sample field duplicate pairs (3% to 46% in 2006) typically showed greater variability than the RPD results for groundwater sample field duplicate pairs (0% to 17% in 2006). No data were qualified as a result of the RPD results for Field Duplicates.

2.1.15.7 PARCCs

PARCCs refer to Precision, Accuracy, Representativeness, Completeness, and Comparability, all factors used to evaluate the quality of the analyses.

Precision is defined as the agreement between duplicate results, and was estimated by comparing duplicate matrix spike recoveries, native duplicates, and field duplicate sample results. Precision was within the standard limits for groundwater samples. Precision was usually within the standard limits for soil samples, which are naturally more variable than water samples. No data was qualified as a result of concerns about precision.

Accuracy is a measure of the agreement between an experimental determination and the true value of the parameter being measured. For the organic analyses, each of the samples was spiked with a surrogate compound, and for organic and inorganic analyses, an MS and Laboratory Control Sample (LCS) were spiked with a known reference material before preparation. Each of these approaches provides a measure of the matrix effects on the analytical accuracy. The LCS results demonstrate the accuracy of the method and the laboratory’s ability to meet the method criteria. MS/MSD and native duplicate results establish precision and accuracy of the matrix. Accuracy can be estimated from the analytical data and was not measured directly. No data was qualified as a result of accuracy concerns.

Representativeness is a qualitative measure of the degree to which sample data accurately and precisely represents a characteristic environmental condition. Representativeness is a subjective parameter and is used to evaluate the efficacy of the sampling plan design. Representativeness was demonstrated by providing full descriptions in the project scoping documents of the sampling techniques and the rationale used for selecting sampling locations. The groundwater sample data are representative of the groundwater at the site. The soil sample data are representative of soil in the parts of the study area that were sampled.

Completeness is defined as the percentage of measurements that are judged to be valid compared to the total number of measurements made. Valid data consists of all the data that have not been rejected (flagged with an R). Less than one percent of the data was rejected. Therefore, the completeness goal of 90 percent valid data has been met.

Comparability is another qualitative measure designed to express the confidence with which one data set may be compared to another. Factors that affect comparability are sample collection and
handling techniques, sample matrix type, and analytical methods. Comparability is limited by the other PARCC parameters because data sets can be compared with confidence only when precision and accuracy are known. Results from laboratory testing are considered to be comparable to results from other laboratories. Due to the nature of field screening tests, and the sometimes divergent results when compared to laboratory results on split samples, the field screening test results cannot be considered comparable to the laboratory results.

2.1.15.8 Summary and Conclusions

Conclusions of the data validation process are as follows:

The laboratories analyzed the samples according to the EPA methods stated in the work plan as demonstrated by the results of the evaluation of data package QC summaries and the analytical run sequences. Samples collected for QA/QC purposes represent more than 15% of the total samples collected.

Groundwater results were most often rejected for reasons of poor surrogate recovery, although poor spike recovery and exceeding holding times also caused some results to be rejected as unusable “R”. The number of rejected results was 3,275 out of 424,008, for a completeness percentage of more than 99% for the groundwater results.

Detected results and detection limits were qualified as estimated or biased due to the presence of headspace in sample jars, problems with dilution, surrogate recoveries, instrument calibration, and spike recoveries.

Some detected results were reclassified as not detected due to presence of the chemical in associated blanks.

The project objectives, or PARCCs, were met, and the validated data can be used in the project decision making process as qualified by the DQE process.

2.1.16 Investigation-Derived Waste

Investigation-derived waste for the study area was managed in accordance with TCEQ SOP 1.4 Management of Investigative Derived Waste.

2.1.16.1 Waste Soil Characterization and Disposal

During site assessment activities associated with the Bell facility, drill cuttings were generated and stored in sealed and properly labeled 55-gallon drums until the waste could be characterized for disposal. A total of 11 drums of soil cuttings were generated and disposed at EPA approved facilities. Nine drums of soil were disposed at the Atascocita Road Disposal Facility (ARDF) in Humble, Texas on October 28, 2003, and the other two drums of soil were disposed on August 30, 2004, at the BFI McCarty Road Landfill in Houston, Texas.
Drill cuttings were also generated during the installation of the ten deep monitor wells in July
and November of 2005. These cuttings were staged in sludge boxes until waste characterization
was complete. On July 6, 2005, one representative soil sample was collected from the sludge
boxes staged at Barely Lane, and the sample was submitted to Accutest Laboratories in Houston,
Texas, for analysis of VOCs using EPA Method 8260, and reactivity, corrosivity, and ignitability
(RCI). The analytical results indicated that all VOC constituents were below the laboratory
detection limits. The RCI results indicated that the samples were not reactive, the corrosivity
(pH) was 8.7 and the ignitability (flashpoint) was greater 210 degrees Fahrenheit. Therefore this
waste classified for disposed as a Class II non-hazardous waste. On August 5, 2005, 30 yards of
soil was disposed at the Waste Management Coastal Plains facility in Alvin, Texas, and on
August 26, 2005, another 60 yards of soil cuttings were disposed at the Waste Management
facility in Alvin, Texas.

In October/November of 2005, Chicot monitor wells MW-11R and MW-19 were installed. Drill
cuttings were generated during this activity and were stored in sludge boxes until all liquids had
been decanted to a holding tank. On November 7, 2005, five yards of soil was disposed at the
Waste Management Coastal Plains facility. Two days later, on November 9, 2005, an additional
30 yards of soil was disposed at the same facility. In total 125 cubic yards of soil was generated
and disposed as a result of the deep monitor well installations. Waste disposal manifests for soils
are presented in Appendix F.

2.1.6.2 Waste Water Characterization and Disposal

Purge water was generated from the nine shallow monitor wells near the Bell facility during their
installation and during to each quarterly sampling event. The purge water was staged behind the
Bell facility in sealed and labeled 55-gallon drums. Some of the drums contained relatively high
concentrations of PCE and TCE and required disposal as hazardous waste. One drum of purge
water was disposed at Philip Services in Houston, Texas on October 28, 2003. A second drum of
purge water was disposed at the ENSCO facility located in El Dorado, Arkansas on August 30,
2004. An additional 15 drums of decontamination water were generated during the CPT site
investigation performed in August and September 2003. These drums were disposed at the BFI
Facility located on McCarty Road in Houston, Texas on August 30, 2004.

A large volume of water was generated during installation of the ten deep monitor wells. The
drilling water was collected at each well site by a vacuum truck and then transferred to the
sludge boxes and 5,000-gallon poly tanks staged at a central location in the neighborhood. As
the solids settled and dropped out in the sludge boxes, the liquids were decanted off the top and
transferred into the poly tanks. Initially the plan was to discharge the liquids into the HCFCD
drainage ditch, which required wastewater discharge classification. Therefore, waste water
sample DF1 was collected on July 7, 2005, and was submitted to Accutest Laboratories for
analysis of VOCs by EPA Method 624; Semivolatile Organics by EPA Method 625; biochemical
oxygen demand (BOD) by EPA Method 405.1; pH by EPA Method 150.1; total organic carbon
(TOC) by EPA Method 415.1; total kjeldahl nitrogen (TKN) by EPA Method 351.2; ammonia
nitrogen (AMN) by EPA Method 350.1; nitrate by EPA Method 353.2; total phosphorus by EPA
Method 365.2; nitrite by EPA Method 353.2; total suspended solids (TSS) by EPA Method
160.2; oil and grease by EPA Method 1664; and chemical oxygen demand (COD) by EPA
Method 410.4. The analytical results from this water sample indicated elevated levels of pH and TSS, so permission to discharge to the HCFCD drainage ditch was denied. Therefore, all generated water was transported and disposed at the Intergulf Corporation recycling facility located at 10020 Bayport Boulevard in Bayport, Texas. A total of 28,000 gallons of Class I water was generated during this drilling program. Waste disposal manifests for the waste water is presented in Appendix F.

2.2 Informal Memorandums (Not Used)
3.0 Site Features

3.1 Physical Site Characterization

The Jones Road Groundwater Plume Superfund Site is located in northwest Harris County, on the Gulf Coast Plain. This physiographic province is characterized by nearly flat topography. The coastal plain is gently inclined toward the Gulf of Mexico at about 5 feet per mile or less. Most of the coastal area is low-lying and drained by meandering bayous and sloughs. Greens Bayou is located east of the site, and trends in a general easterly direction. White Oak Bayou is located south of the site and trends in a more southeasterly direction. Cypress Creek is located northwest of the site, and trends in a general northeasterly direction north of Houston, and then trends in a general southeasterly direction (Figure 3).

3.1.1 Surface Features

Locally, the area is characterized by residential, commercial, and light industrial development on mostly flat terrain with ditches and depressions present only as created by landscaping and drainage projects. Jones Road is the principal north-south corridor through the area and is an undivided multilane road that is signal-controlled at major intersections at Woodedge, Tower Oaks, and FM 1960. FM 1960 (approximately one-half mile to the south) provides a major southwest to northeast travel corridor and is a larger undivided multilane road providing peripheral access around the northwest edge of Houston. Commercial development is dominant along FM 1960 and Jones Road with residential and limited commercial development along the side streets.

3.1.2 Meteorology

Houston has a humid subtropical climate, with southerly prevailing winds that bring heat from the deserts of Mexico and moisture from the Gulf of Mexico during most of the year. Summers are hot and humid and are often characterized by afternoon rain storms. Winters are cool and temperate, with rare occurrences of snow and some rain. The coolest month is January and the hottest month is August. Spring and early summer are usually the wettest times of the year where monthly rainfall averages over 4 inches per month. The average yearly rainfall is about 50 inches. The average low temperature in Houston is 72°F (22°C) in the summer and 42°F (6°C) in the winter. The average high temperature is 93°F (34°C) in the summer and 66°F (19°C) in the winter. Humidity during the summer can reach 90% or higher. Temperature and rainfall statistics were obtained from the website www.weatherbase.com for Houston, Texas based on a 27 year record.

The report, Deep Monitor Well Groundwater Gauging and Rainfall Data, (Shaw, November 12, 2007) collected local rainfall information from weather stations near the site, with Gauge 555 located at the intersection of White Oak Bayou and Jones Road, south of the site. For the year 2007, Gauge 555 recorded approximately 55 inches of rainfall. Historically, work at the site required planning to account for potential weather delays from rain, and potential weather hazards of thunderstorms, tropical storms, and hurricanes.
3.1.3 Surface Water Hydrology

Surface water drainage is managed primarily through open roadside bar ditches. Drainage at the site generally flows into the ditches, then to drainageways that flow south to White Oak Bayou. White Oak Bayou flows southeast into downtown Houston where it enters Buffalo Bayou. Buffalo Bayou flows through the Houston Ship Channel towards Galveston Bay and thence to the Gulf of Mexico.

3.1.4 Geology

3.1.4.1 Regional Geology (Gulf Coast Aquifer)

Definition of individual geologic units that comprise the geology of the Texas Gulf Coast is complex and controversial despite abundant studies, with more than seven proposed classification systems for naming the individual geologic units and definition of their boundaries. Classification of the individual geologic units has been difficult due to considerable heterogeneity of sediments, discontinuity of the beds, general absence of index fossils, and lack of diagnostic electric (geophysical) log signatures (markers) (TWDB Report 365, February 2006).

The Gulf of Mexico Basin was formed by down-faulting and down-warping of the Paleozoic basement rocks during the breakup of the Paleozoic mega-continent Pangaea and opening of the North Atlantic Ocean in the Late Triassic, approximately 200 million years ago. Sediments of the Gulf Coast Aquifer in Texas were deposited in the coastal plain of the Gulf of Mexico Basin through repeated sea-level changes and natural basin subsidence during the Tertiary and Quaternary periods, less than seven million years ago (TWDB Report 365, February 2006).

The Gulf Coast Aquifer is comprised (from deepest to shallowest) of the Frio Formation, Anahuac Formation, Catahoula Tuff or Sandstone (collectively known as the Catahoula Confining System); Oakville Sandstone and Lower Fleming Formation (Jasper Aquifer); Upper Fleming Formation (Burkeville Confining System); Goliad Sand (Evangeline Aquifer); Willis Sand; Lissie Formation, Beaumont Clay, and alluvium (Chicot Aquifer). Figure 7 presents a stratigraphic and hydrogeologic column of the aquifers and formations that comprise them as presented in TDWR Report 236 (Baker, 1979). For purposes of discussion relative to the study area, only sediments that comprise the upper portion of Gulf Coast Aquifer (above the Burkeville Confining System) will be discussed herein. Formations that outcrop in the Houston area are presented on Figure 8, taken from the Geologic Atlas of Texas – Houston Sheet (Bureau of Economic Geology, 1982).

Goliad Sand

The Goliad Sand (Pliocene age) overlies the Fleming Formation (Miocene age) and consists of course-grained sediments, including sand, gravel, cobbles, clay balls, and wood fragments at the base of the formation. The upper part of the Goliad consists of finer-grained sands that are cemented with calcium carbonate. The Goliad includes irregular bedding, and presence of gravel suggests deposition in a high-energy riverine depositional environment (Hosman, 1996). The
sands of the Goliad are typically whitish gray or pinkish gray, but in areas of increased amounts of chert, sands may have a salt-and-pepper appearance (Sellards and others, 1932). The Goliad is entirely within the Evangeline Aquifer, and the upper boundary of the Evangeline Aquifer probably follows closely with the top of the Goliad (Baker, 1979). The Goliad only occurs in the subsurface (does not outcrop) in the Houston area, and has a maximum thickness of approximately 250 feet.

**Willis Sand**

The Willis Sand (Pleistocene age) overlies the Goliad Formation. The Willis has a maximum thickness of 75 feet in the Houston area, and is comprised of clay, silt, sand, and minor siliceous gravel (granule to pebble size including some petrified wood). Sands of the Willis are coarser than those in the Lissie Formation, and are often identified by coarsening-upward sequences indicative of delta-front facies (Kreitler and others, 1977). Deposits are deeply weathered and lateritic; indurated by clay and cemented by iron oxide. Concretions of iron oxide are numerous, and deposits are non-calcareous. The Willis was deposited in a fluvial depositional environment (Bureau of Economic Geology (BEG) Geologic Atlas of Texas, Houston Sheet, Revised 1982).

**Lissie Formation**

The Lissie Formation (Pleistocene age) has a maximum thickness of 200 feet in the Houston area, and is divided into the Upper Lissie Formation and the Lower Lissie Formation. The Upper Lissie Formation consists of clay, silt, sand, and very minor siliceous gravel (granule and small pebble size), which is more abundant in the northwestern areas of Houston (at the site). The Upper Lissie Formation also contains calcium carbonate concretions, iron oxide, and iron-manganese oxides common in the zone of weathering. The Upper Lissie Formation was deposited in a fluvial depositional environment, and surface features are fairly flat and featureless except for numerous rounded shallow depressions and pimple mounds. The Lower Lissie Formation consists of clay, silt, sand, and minor gravel. Gravels are slightly coarser than in the Upper Lissie Formation. The Lower Lissie Formation is non-calcareous, but iron concretions are more abundant than in the Upper Lissie Formation. The Lower Lissie Formation was also deposited in a fluvial depositional environment, and is gently rolling (BEG Geologic Atlas of Texas, Houston Sheet, Revised 1982). The study area is situated on the Lissie outcrop.

**Beaumont Clay and Alluvium**

The Beaumont Clay (Pleistocene age) and alluvium (Quaternary age) is not present at the site, as the Beaumont Formation outcrop is located several miles southwest of the site (Figure 8). Major alluvium deposits are associated with large river systems like the Brazos River and the San Jacinto River, which are not local to the study area.

### 3.1.4.1.1 Geological Setting

The site is located within the West Gulf Coast Plain, which is part of the Coastal Plain physiographic province. The province consists of marine and fluvial sedimentary rocks that tilt gently seaward towards the Atlantic Ocean and the Gulf of Mexico (Fenneman, 1938).
maximum elevation of the Coastal Plain ranges from sea level at the coast to over 800 feet above sea level in the southwestern region of the Coastal Plain physiographic province (BEG, 1992).

3.1.4.1.2 Depositional Environment

Sediments of the Gulf Coast Aquifer were deposited under fluvial-deltaic to shallow-marine environments. Repeated sea-level changes and natural basin subsidence produced discontinuous beds of sand, silt, clay, and gravel (Kasmarek and Robinson, 2004). These sediments were deposited in formations dipping toward the Gulf of Mexico forming sedimentary wedges that decline and thicken toward the coast. Growth faulting generally parallel to the coastline is common in the sedimentary sequence as a result of differential settling of the sediments.

3.1.4.1.3 Regional Cross Sections

A dip-oriented regional cross section was prepared (Baker, 1979; Kasmarek, unpublished data) as modified and reported in Figure 2-14 of Texas Water Development Board Report 365 (TWDB, February 2006). The regional cross section provides a profile of underlying geologic units in the vicinity of the study area (Figure 9).

3.1.4.1.4 Type Section

A type section was not prepared for the site, since the sand units at the site are highly variable in vertical position and thickness (channel sand systems created in fluvial depositional environments). However, Section 5.6.2 describes the Regional Conceptual Site Model for which two stratigraphic cross sections were prepared using geophysical well logs obtained during installation of the deep monitor wells at the site (deepest well drilled approximately 430 feet bgs), and from deep municipal water wells drilled into the Evangeline Aquifer (deepest well drilled approximately 1845 feet bgs). The cross sections provide an illustration of the local area subsurface geology. Figures 10 and 11 present Stratigraphic Cross Sections A-A’ and B-B’, respectively.

3.1.4.2 Local Geology

Subsurface geology as identified from State of Texas Well Reports and geophysical logs available for domestic wells and monitor wells MW-10 through MW-19, along with review of lithologic logs prepared during the drilling of the monitor wells indicates that the local geology above approximately 400 feet bgs consists of clay, sand, and silt deposited in fluvial depositional environments. At least six major water bearing units were identified from approximately 60 feet below ground surface to 430 feet bgs. Sand units tend to be discontinuous laterally and major channels have developed as indicated by downward scouring into underlying clay units. In some cases scouring has occurred completely through the underlying clays into the next sand unit or sand units below the clays, thus creating hydraulic communication between sand units.

Review of geophysical logs in and around the general study area was performed to better understand the deep local geology. A municipal well log for Harris County Municipal Utility District No. 130 (State Well No. 65-04-7; TNRCC Code G1012097A), located approximately 3
miles southwest of the Bell Facility, was drilled to a total depth of 1,845 feet bgs, and multiple well screens were installed from a depth of 592 feet to 959 feet bgs. This well represents the deepest known water well drilled near the site. The quality of the geophysical logging was poor, and identification of the sand and clay units was not readily apparent. Another municipal water well (G1010016A) was drilled to a total depth of 1,455 feet bgs, and at least 12 major water bearing units were identified that could have potential for municipal use.

### 3.1.4.3 Shallow Source Area Geology

The *Source Area CSM* (Shaw, May 29, 2008) indicates that the subsurface geology was deposited in a fluvial depositional environment, as shown by discontinuous silt and sand units deposited under high to medium energy flow regimes, and thick clay units deposited under low energy flow regimes. The site is generally underlain by high plasticity clay (CH) from the ground surface to a depth of approximately 20 feet bgs. An interbedded zone consisting of sand (SP), silt (ML), and silty clay (CL) underlies the high plasticity clay, and extends from a depth of approximately 20 feet to 35 feet bgs. The interbedded zone appears to be laterally continuous at the site. High plasticity clay underlies the interbedded zone, and extends from a depth of approximately 35 feet to 60 feet bgs. The high plasticity clay includes randomly distributed discontinuous sand lenses comprising less than ten percent of the high plasticity clay zone. A thick, major sand (SP) unit was encountered while installing soil boring RS-1, which extended from a depth of approximately 60 feet to 107 feet bgs (107 feet is the total depth of RS-1). Figure 12 presents a cross section prepared in the source area showing the subsurface geology to a maximum depth of 107 bgs. For RS-1, some compression of soils during the sampling process (using sonic drilling methods) is suspected, since the lithologic profile of soil boring RS-1 appears deeper than the soil profile data obtained during installation of the CPT soil borings. Therefore, the lithologic profile of soil boring RS-1 was disregarded for correlation purposes during construction of Figure 12.

### 3.1.5 Soils

#### 3.1.5.1 Shallow Surface Soils

Those areas not covered by paved surface to a depth of six to eight inches below ground surface are designated as topsoil. In general, the topsoil at the site is rich in organic material and is derived from underlying soil horizons. Soil descriptions described below were obtained from the U.S. Department of Agriculture (Soil Survey of Harris County, Texas, USDA). A map showing the distribution of various soil types at the site is presented on Figure 13.

**Aris-Gessner Group**

The underlying soil group at the site along Tower Oaks Blvd. and south to FM 1960 is the Aris-Gessner Complex. The complex consists of 30 to 50 percent Aris soil (fine sandy loam to clayey loam), 20 to 30 percent Gessner soil (loam with more sand), and 20 to 30 percent other soils. The soils in this complex are intricately mixed and inseparable at the depth of the site.

The Aris soil has a surface layer of friable, neutral pH, dark grayish brown sandy loam about seven inches thick. The layer below is friable, slightly acid, grayish brown fine sandy loam that extends to a depth of 21 inches. The next layer extends to a depth of 28 inches and is a firm,
medium acid, gray sandy clay loam. The layer below that extends to a depth of 46 inches and is very firm, strongly acid, dark gray clay mottled with red and strong brown. The next layer is very firm, medium acid, gray clay that extends to a depth of 60 inches where it grades to a very firm, slightly acid, light gray clay loam.

The Gessner soil has a surface layer of friable, slightly acid, dark grayish brown loam about seven inches thick. The layer below that is about 9 inches thick and is friable, slightly acid, grayish brown loam. It tongues into a friable, neutral, dark gray loam that is slightly more clayey. That layer extends to a depth of 34 inches. The underlying layer is friable, moderately alkaline, light brownish gray loam about 19 inches thick. Below that, extending to a depth of 84 inches is a layer of firm, moderately alkaline, light gray sandy clay loam that has distinct mottles of yellowish brown and brownish yellow. These soils are poorly drained and saturated with water during wet seasons of the year. Excess water ponds on the Gessner soil for long periods. Permeability is moderate to very slow, with a medium available water capacity.

The area of land north of Tower Oaks Boulevard consists of the Gessner-Urban land complex. Gessner soils make up 20 to 80 percent of this unit, urban land 10 to 75 percent, and other soils 10 to 20 percent. The soils in this complex are intricately mixed and inseparable at the site level. Urban land consists of soils that have been altered or are covered by buildings or other urban structures and of other disturbed areas. Besides the urban structures, cutting, filling or grading, has disturbed other areas. In some areas six to 24 inches of fill material covers the entire soil profile. Gessner soils have severe limitations for streets, low cost roads, septic fields and urban development due to poor drainage. Standing water remains after rains and the soil remains wet long after surface water has evaporated, and can become muddy and boggy.

Addicks Loam Soil Group

The residential area soil of the land on Forest Valley Drive and Jones Road south of Woodedge consist of the Addicks Loam soil group. The surface layer is friable, neutral pH, black loam about 11 inches thick. The layer below that is friable, neutral dark gray loam about 12 inches thick. The next layer is about 26 inches thick and consists of friable, moderately alkaline, light gray loam that is about 20 percent by volume visible calcium carbonate. It is underlain by a layer of firm, moderately alkaline, light gray loam that has distinct yellow and yellowish brown mottles and is about five percent visible calcium carbonate. This soil is poorly drained and remains saturated with water for short periods of the year. Surface runoff is slow, internal drainage is slow and permeability is moderate. The available water capacity is high.

Gessner Loam Soil Group

East of Jones Road, the Gessner-Urban soil complex consists of the Gessner loam soil group. This soil is poorly drained and is generally saturated in wet periods. Surface runoff and internal drainage is very slow. Permeability is moderate and the available water capacity is high.
3.1.6 Hydrogeology

3.1.6.1 Regional Hydrogeology (Gulf Coast Aquifer)

Section 3.1.4.1 describes the relationship between geologic formations and aquifer systems. For purposes of this investigation, the Upper Gulf Coast Aquifer (portion of the aquifer above the Burkeville Confining Unit) will be discussed herein. The two major aquifers that comprise the Upper Gulf Coast Aquifer are the Evangeline Aquifer and the Chicot Aquifer. The Chicot Aquifer is the youngest hydrostratigraphic unit, and it outcrops at the site. The Evangeline Aquifer underlies the Chicot Aquifer. The Chicot Aquifer provides good to superior quality water for local residential and agricultural use, whereas the Evangeline Aquifer provides primarily superior quality water to local municipal water works.

The primary source of recharge into the Chicot Aquifer is infiltration of precipitation into the outcrop area of the aquifer. The recharge predominantly occurs in the northern, up-dip sections of the Chicot Aquifer (within the Lissie Formation). In down-dip areas towards the Gulf away from the outcrop area, the Chicot Aquifer acts as a confined system, with exchange to and from the shallow sediments impeded by the interbedded sand and clay layers. At the site, it is believed that the Chicot Aquifer is unconfined and therefore the overlying shallow sediments most likely are a source of recharge for the aquifer. Recharge to the Evangeline Aquifer is also primarily from infiltration of precipitation into the outcrop area of the aquifer. In down-dip areas towards the Gulf away from the outcrop area (such as the site), the aquifer acts as a confined system (Kasmarek and Strom, 2002). The site is approximately 25 miles south of the Evangeline (Goliad Formation) outcrop area (Figure 8). Monitor wells MW-17 and MW-18 were installed adjacent to one another with screen intervals of 410 to 430 feet bgs (Evangeline Aquifer) and 284 to 297 feet bgs (Chicot Aquifer) as described in the Chicot Monitor Well Installation Report (Shaw, March 23, 2006). Groundwater levels as reported in the Deep Monitor Well Groundwater Gauging and Rainfall Data, (Shaw, November 12, 2007) revealed a hydraulic head difference of approximately 80 feet between the two wells, suggesting that the Evangeline Aquifer is under a confined or semi-confined hydraulic condition.

The Chicot and Evangeline Aquifers discharge into streams and rivers from naturally occurring seeps and springs in areas of low topographic relief. Additional discharge occurs as evapotranspiration from the groundwater flow systems. Groundwater discharge at the site is primarily affected by water withdrawal from the aquifers due to groundwater development (commercial, residential, and municipal water wells). Harris County is one of the principal areas of groundwater withdrawal, along with Fort Bend County and Galveston County. The highest total groundwater withdrawal for the two counties occurred in 1990, with 493 million gallons being extracted per day from wells developed in both the Chicot and Evangeline Aquifers (Kasmarek and Strom, 2002). The magnitude of groundwater withdrawal has since declined with the addition of the Lake Livingston surface water source for water supply and the formation of the Harris-Galveston Subsidence Districts.

Hydraulic conductivity values for the Chicot Aquifer in Harris County range from 14 to 35 feet per day (ft/d) (Young et al., 2006), and 20 to 100 ft/d in the Evangeline Aquifer (LDEQ, 2003).
Groundwater in these aquifers generally flows from the northwest to the southeast perpendicular to the Gulf of Mexico coastline, but is locally influenced by large municipal water well pumping (Kasmarek and Strom, 2002); Figure 14. Recent groundwater elevation data obtained from gauging of the deep (Chicot Aquifer) monitor wells indicates that the flow is consistent to the southeast; Deep Monitor Well Groundwater Gauging and Rainfall Data, (Shaw, November 12, 2007).

Numerous large regional groundwater models have been prepared for the Gulf Coast Aquifer since 1965 (Wood and Gabrysch, 1965) such that local conservation districts (such as the study area’s Harris-Galveston Subsidence District) would have tools for managing groundwater resources. The most recent computer program model, Groundwater Availability Model (GAM), was prepared by the U. S. Geological Survey in cooperation with the Texas Water Development Board (TWDB) and the Harris-Galveston Subsidence District, and includes a specific model of the northern portion of the Gulf Coast Aquifer (Kasmarek and Robinson, 2004). The GAM simulations generally supported measured water levels in the region, with continued groundwater level declines and subsidence associated with greater groundwater withdrawals exceeding recharge. Recently, groundwater recharge has increased due to the increased use of surface water from Lake Livingston.

3.1.6.2 Local Hydrogeology

For purposes of this investigation, the top of the Chicot Aquifer is at ground surface (Lissie Formation outcrop). The depth to the bottom of the Chicot Aquifer/top of the Evangeline Aquifer has been estimated to be approximately 400 feet bgs, which is based upon Well Number 6 in the cross section presented on Figure 9, modified from TDWR Report 236 (Baker, 1979). TCEQ State Lead Section (formerly the Superfund Cleanup Section) discussions with the TCEQ Surface Casing and the Texas Department of Licensing and Registration (TDLR) confirmed the approximate aquifer interface depth of approximately 400 feet bgs (TDLR, January 24, 2003). At the site, five major WBUs have been identified within the Chicot Aquifer, based on cross section A-A’ (Figure 10) and cross section B-B’ (Figure 11). At least seven major WBUs have been identified within the Evangeline Aquifer, based on a geophysical log obtained for water well G1010016A, which was the deepest well in the area with a geophysical log having high enough quality for evaluation of WBUs within the Evangeline Aquifer (Figure 14A). Water well G1010016A is located approximately 2.75 miles south of the Bell Facility.

The local hydrogeology is characterized by the interconnection of sand units by downward erosion of channels (cutting) into lower clay units. Correlation of geophysical logs indicates that some downward channeling may have connected upper sand units to lower ones, making them locally hydrologically connected. Downward channeling likely created groundwater migration between the Chicot and Evangeline Aquifers. Section 2.1.8.4 describes water quality testing of different aquifer intervals at the site; General Groundwater (Inorganic) Quality Characterization and Comparison, March 2004 (Shaw, May 27, 2004). Chemical analyses for inorganic data showed similarities between water quality samples collected from WBUs at varying depths. Similar groundwater geochemistry within the sand units may suggest possible groundwater mixing between the Chicot and Evangeline Aquifers. However, no soil geochemical data was available from individual WBUs to support the theory.
Section 2.1.8.5 describes a water level investigation conducted in four inactive private water wells and one active private water well at the site from October 2004 through August 2005; Final Groundwater Elevation Data Report (Shaw, October 2005). The report indicated slight water level elevation changes throughout the year that were suspected to be related to pumping demand upon the aquifer during peak use seasons (summer) and less use seasons (winter). The average groundwater flow direction was reported to be south, southwest, and southeast, with a gradient of 0.011032 ft/ft, for wells screened from 173 to 210 feet bgs (screen intervals were known for two of the five wells monitored). The spatial distribution of the well points was not optimum but provided preliminary groundwater flow direction information. Section 2.1.8.6 describes a water level investigation conducted in ten deep monitor wells during the months of March through August 2007; Deep Monitor Well Groundwater Gauging and Rainfall Data, (Shaw, November 12, 2007). The groundwater flow direction was determined to be to the southeast with a gradient ranging from 0.00248 to 0.00267 ft/ft for deep monitor wells screened from 294 to 357 feet bgs. Due to the number, distribution, and known screened intervals of the monitor wells, more accurate groundwater elevation and flow direction was obtained, which was very similar to the regional flow direction (Figure 14).

Pump test data from wells completed in the Chicot Aquifer WBUs were not available; testing of relatively shallow (mostly private) water wells that are not used for PWS is rare. However, reported well yield values were noted on some State of Texas Well Reports for local water wells screened within the Chicot Aquifer, which reported well yield values ranging from 6 gallons per minute (gpm) to 75 gpm.

A 36-hour pump test was performed in November 2003 for Harris County Municipal Utility District No. 130 (State Well No. 65-04-7; TNRCC Code G1012097A), with multiple well ten-inch diameter screens installed from a depth of 592 feet to 959 feet bgs (Evangeline Aquifer). The pump test resulted in 57 feet of drawdown at a constant pumping rate of 403 gpm. The test is a good example of how local wells are constructed in the Evangeline Aquifer and typical well yields that they produce.

3.1.6.3 Shallow Source Area Hydrogeology

Two shallow subsurface WBUs were identified during previous investigations, and summarized in the Source Area CSM; see Section 2.1.2.14 and Section 5.6.1, Final Source Area Conceptual Site Model (CSM) (Shaw, May 29, 2008). The first (shallow) WBU was identified from a depth of approximately 20 feet to 35 feet bgs consisting of interbedded sand, silt, and silty clay. Groundwater yield is the first WBU is poor, and would likely not be a viable groundwater resource for drinking water. Geotechnical testing of soils from the first WBU was performed to gather information for treatment technology evaluation, as discussed in Section 2.1.2.10 and reported in the July 2006 Geoprobe Investigation (Shaw, January 24, 2007). Hydraulic conductivities of soil samples collected between 22 to 32 feet bgs ranged from $2.67 \times 10^{-7}$ centimeters per second (cm/s) (or 0.0008 ft/d) to $1.48 \times 10^{-6}$ cm/s (or 0.0042 ft/d).

Historical measured groundwater elevations within monitor wells that penetrate the shallow source area WBU have been highly erratic (highly variable in elevation), as evaluated during
individual sampling events, possibly due to discontinuous fluvial water-bearing lenses within the shallow source area WBU under perched aquifer conditions. No potentiometric maps for the shallow source area WBU have been prepared to date due to the erratic groundwater elevation data.

The second WBU was identified at a depth of approximately 60 feet, and extended to the maximum depth of investigation, 107 feet bgs. The second WBU was comprised of fine sand and likely represents the first major WBU of the Chicot Aquifer. No geotechnical testing was performed on samples collected from the second WBU, nor was any hydrologic testing performed on the aquifer during the attempted well installation that penetrated the second WBU. Reference Section 2.1.2.11; Attempted Well Installation (Shaw, May 2, 2007).

3.1.7 Demography and Land Use

The site is located in northwest Harris County, Texas. The site is primarily contained in census tract 5524, with some overlap into tract 5525. The zip codes for the area are 77065 (west of Jones Road) and 77070 (east of Jones Road).

3.1.7.1 Population Density and Location

The study area is located in northwest Harris County, Texas. Based on the most current demographics (2007 census), Harris County has a population of approximately 3.94 million people and has a land area of 1,729 square miles. This equates to a population density of approximately 2,279 people per square mile. The median age is 31.2 years and the majority of the population is between 17 and under 65 years old. Harris County has experienced substantial population growth, with most of that growth due to immigrants from other states and/or other countries. The minority population is growing and is expected to continue to grow, surpassing more than half of the county population, making Harris County a “majority minority” area. The population of Harris County is projected to grow to over 6 million by the year 2040 according to census estimates.

The area around the site seems to follow these same general demographics. The 2000 population of census tract 5524 was 4,266, with a median age of 33.9 years. Tract 5524 had a slightly lower percentage of minorities and was slightly older than the whole of Harris County. Census tract 5524 is north of FM 1960 and west of Jones Road.

3.1.7.2 Potentially Sensitive Subpopulations

Potentially sensitive subpopulations in the area include children and elderly people. An internet search using Google Maps (http://maps.google.com/) for the address 11600 Jones Road turned up specific locations within and near the study area. Individual children and elderly people are also present in the area as residents, workers, or travelers.

Groups of children can be found at Finch’s Gymnastics and Childcare at 10903 Tower Oaks, and the Little School House at 11338 Tower Oaks. Both of these are inside the study area and were previously identified in the course of site investigations. The well where PCE contamination
was initially identified was at Finch’s Gymnastics, and the well continues to show PCE concentrations higher than the MCL. The Little School House has another PWS well that has been sampled multiple times, but only once showed an estimated PCE concentration of 0.25 µg/L, which is below the MCL.

There are several assisted living apartments and nursing homes south of FM 1960 that are the closest concentrations of elderly people to the site. All of these establishments are outside the limits of the study area and beyond the extent of known PCE contamination. Somerville Assisted Living is at 11500 Fallbrook Drive, Hearthstone Assisted Living is at 11246 Fallbrook Drive, Park Manor of Cy Fair is at 11001 Crescent Moon Drive, and Cypresswood Health & Rehab is at 10851 Crescent Moon Drive.

3.1.7.3 Location and Use of Surface Waters

There are no apparent surface waters on or near the site. There are ditches in the area that drain rainwater into White Oak Bayou, approximately 1.5 miles to the south.

3.1.7.4 Local Use of Groundwater as a Drinking Water Source

The site is located along the border between Harris County annexed or non annexed areas of the City of Houston with limited water and sewer infrastructure currently in place. A majority of the private homes are therefore on private well water supply and septic systems. Local area municipal utility districts and water supply districts are connecting water and sewer systems as new homes are built in the area, which is replacing the use of individual water wells and/or septic systems. A municipal water supply line is currently under construction at the site, and residences/businesses in the area are in process of being connected to the water line to replace water supplied by water wells. The water line installation is described in Section 7.2.

3.1.7.5 Human Use or Access to the Site and Adjacent Areas

Human use of the site primarily consists of using groundwater from wells drawing water from the affected groundwater zones. Access to individual wells is restricted primarily by the individual well owner. The source area was developed for commercial use and is currently being operated as Cypress Shopping Center.

3.1.7.6 Current and Expected Land Use

Due to lack of zoning, Houston and Harris County has a diverse mixture of urban commercial and residential land use. Land use near the site is a mixture of commercial and light industrial properties (generally focused along the north/south Jones Road corridor) and residential properties primarily located west of Jones Road. The immediate area around the site is transitioning from low density to higher density as the City of Houston grows larger bringing development to peripheral areas. Comparison of the 1995 Satsuma, Texas Quadrangle Map to current aerial photos available on the internet indicates that additional commercial and residential development is replacing open spaces. Locally in particular, athletic fields have been replaced by apartments, and a mobile home park is being replaced with high density individual homes.
Further densification of residential and commercial development is expected. Little or no industrial development is expected to take place, and the power line and drainage right-of-ways in the area may be expected to remain free from further surface development.

3.1.8 **Ecology (Not Used)**

Residential development has been active since the 1960s effectively eliminating natural wildlife habitat from the area. See Appendix D for the completed TCEQ Tier I (Ecological) Exclusion Criteria Checklist prepared for the Jones Road Groundwater Plume site.

3.1.8.1 **Local Flora and Fauna (Not Used)**

3.1.8.2 **Identification of Sensitive Ecological Environments (Not Used)**

3.1.8.3 **Endangered Species and Their Habitats (Not Used)**

3.1.8.4 **Species consumed by Humans or Found in the Human Food Chain (Not Used)**

3.1.8.5 **Species with Key Ecological Functions (Not Used)**
4.0 Nature and Extent of Contamination

4.1 Site Characterization Summary

4.1.1 Sources

The source of PCE (and related daughter products including, but not limited to TCE, DCE, and VC) impact to soil and groundwater at the site is the former Bell facility. Improper management of dry cleaning fluid waste (PCE) and apparent disposal of waste directly to the ground surface or septic system were presumed to have been performed by workers at the Bell facility. The Bell facility operated over a period of 14.5 years from January 1988 through June 2002.

4.1.1.1 Facility Characteristics and Process Knowledge

PCE is a chlorinated hydrocarbon (CHC) that is widely used as a cleaning solvent in the dry cleaning industry. The former Bell facility was reported to have used PCE in at least one dry cleaning machine.

Dry cleaning machines typically consist of a motor-driven washer/extractor/dryer that holds from 20 to 100 pounds of clothes or fabrics in a rotating, perforated stainless-steel basket. The basket is mounted in a housing that includes motors, pumps, filters, still, recovery coils, storage tanks, fans, and a control panel. In all modern equipment, the washer and the dryer are in the same machine. Dry cleaning machines clean in cycles. During the first cycle, clothes rotate in the perforated basket and PCE solvent is sprayed into the basket and chamber constantly, immersing the clothes while gently dropping them against baffles in the cylinder. During the first cycle, there is a constant flow of clean solvent from the pump and filter system. The dirty solvent is pumped continuously through the filter and re-circulated through the machine. A typical machine will pump PCE through the clothes at a rate of approximately 1,500 gallons per hour. The second cycle of cleaning drains and rapidly spins the clothes to expel the solvent, followed by a third drying cycle where warm air is circulated through the clothes. The remaining fumes and solvent are vaporized by warm air and then condensed over cooling coils. The distilled solvent is separated from any water (that may have remained in the clothes or system) and returned to the tank as distilled solvent. Since any moisture that may have condensed into water during the process floats on top of PCE, it can be separated and removed periodically.

4.1.1.2 Waste Management Practices and Spill/Disposal Pathways

For the former Bell facility, water and other contaminants were removed from the dry cleaning machine by a water separator and drained out of the machine on a continuous basis into a 5-gallon plastic bucket. This liquid was then discharged into a steam-heated ceramic pot to evaporate the liquid. The pot was vented through the rear wall of the facility directly to the atmosphere. However, a conflicting disposal practice was indicated by Mr. Jimmy Kim (operator of the facility and son of owner/father Dae Kim), who believed that the waste stream had been formerly disposed to the facility’s septic system or to the storm sewer located
immediately behind the shopping center. Figure 5 illustrates the layout of the storm sewer and septic system at the site.

4.1.1.3 Waste Type and Estimated Quantities of Source Materials

On September 12, 2002, the TCEQ prepared a Compliance Evaluation Investigation (CEI) report documenting several Notice of Violation (NOV) reports that had been issued to the Bell facility for mismanagement of waste manifests. The CEI report was included as Reference 21 of the Hazard Ranking System Documentation (TCEQ, April 2003; Appendix A).

The Bell facility Notice of Registration (NOR) (TXD982287302), issued on January 4, 1988, identified three hazardous waste streams, including:

- Waste Steam (WS) 0506609H (PCE sludge hazardous for D007 (chromium) and F002 (spent PCE)), which was waste generated from routine cleaning of the dry cleaning machine filters.
- WS 090631; the actual PCE filters, which is hazardous for D039 (pure PCE) and F002 (spent PCE).
- WS 991002; an older listing for WS 0506609H.

The CEI discovered a liquid waste that was generated from the dry cleaning machine water separator that was not listed on the Bell facility NOR, and which should have been listed as F002 (spent PCE). At least three gallons of liquid per day was generated from the dry cleaner liquid separator. Based on a six day work week and four weeks per month, the Bell facility should have generated approximately 579 pounds of liquid per month (6,948 pounds per year).

The CEI report also estimated that the facility generated an average of 95 pounds of PCE sludge (WS 0506609H) per month (1,140 pounds per year). However, the 1992 Annual Waste Summary (AWS) submitted by Bell indicated that 1.2 tons (2,400 pounds) of waste sludge was generated at the Bell facility.

Review of partial records provided by Bell indicated that Safety-Kleen Systems (SK) transported 5,115 pounds of waste PCE in 1999; 1,755 pounds in 2000; 1,157 pounds in 2001; and 787 pounds in 2002. Assuming that all of the sludge was disposed properly and that the liquids were not, as much as 6,948 pounds of liquid potentially could have been disposed improperly (behind the Bell facility or in the sewer or septic system).

4.1.1.4 Waste Physical and Chemical Characteristics

The primary chemical of concern at this site is PCE. PCE is a manufactured chlorinated organic compound used as a solvent by automotive repair shops, paint shops, machine shops, and dry cleaning establishments. A single molecule of PCE consists of a double carbon bond surrounded by four chlorine atoms. PCE has a high vapor pressure (18.2 mm Hg), and it can easily evaporate into air or be partitioned from liquid into the vapor phase. PCE is a colorless nonflammable liquid at room temperature and has a density of 1.62 g/cm³ compared to water which is 1.00 g/cm³ (Groundwater Chemicals Desk Reference, Montgomery and Welkom, 1989).
Liquid PCE has a limited ability to mix with or dissolve in water and has a solubility of 200 mg/L. In other words, about 1.5 fluid ounces of PCE will dissolve in 100 gallons of water. If any additional PCE were added to this solution, it would exist as a separate liquid phase. Because PCE is denser than water and has a low solubility, PCE tends to sink through water and can exist in a saturated environment as a separate dense non-aqueous phase liquid (DNAPL). Therefore, when PCE is introduced into the subsurface, it sinks to the lowest point it can attain until reaching a low permeable barrier. At this point it spreads out under the influence of gravity (it can actually oppose groundwater flow) or can sink even further fractures are present in the low permeable barrier. Unlike other hydrocarbons that are less dense than water and float near the surface of the water table, PCE can sink through water hundreds of feet, thus contaminating a much larger volume of groundwater as discussed in Dense Chlorinated Solvents (Pankow & Cherry, 1996).

**4.1.1.5 Location and Extent of Spill/Disposal Area (Bell Facility)**

Results of extensive soil and groundwater sampling around the Bell facility indicate that the suspected primary discharge area of PCE was likely located immediately behind the Bell facility and around the sub-slab floor drain. Contaminants in groundwater were primarily PCE, but degradation products of TCE, DCE, and VC are also present, although more evident in groundwater than soil. The lateral extent of contaminants in groundwater is greater than the lateral extent of contaminants in soil, indicating that the plume is primarily expanding in groundwater-bearing units in the dissolved phase.

**4.1.1.5.1 Distribution of PCE in Soils (Bell Facility)**

Several limited soil investigations were performed in the area until October 2003, when a thorough DPT investigation was conducted around the Bell facility, Remedial Investigation – Geoprobe (Shaw, April 28, 2004). Results of soil laboratory analysis indicted PCE, TCE, DCE, and VC impact to soil in nine of 21 DPT borings (GP-3, GP-4, GP-5, GP-6, GP-7, GP-8, GP-13, GP-16, and GP-20) with samples collected from four different sample zones (1 to 2 feet bgs; 16 to 19 feet bgs; 19 to 30 feet bgs; and 30 to 35 feet bgs). Review of the sample results concluded that PCE is the most prevalent contaminant within the upper 35 feet of site soils, with highest concentrations detected in soil borings GP-3 and GP-4 (located behind the Bell facility and representing the suspected primary discharge area). The highest PCE concentration in soil was 260 mg/kg, within the 16 to 17-foot depth sample collected from soil boring GP-4.

Another important soil investigation was performed in July 2006, titled July 2006 Geoprobe Investigation (Shaw, January 24, 2007). Nine DPT borings (GP-1A through GP-9A) were drilled to depths of approximately 50 feet bgs to support a bench-scale treatment study for application of in-situ chemical oxidation and bioremediation remedies.

Two of the highest PCE concentrations were detected in soil in boring GP-3A within the 20 to 21-foot bgs interval (620 mg/kg) and within the 49 to 50-foot bgs interval (85 mg/kg). The third-highest PCE concentration was detected in GP-2A within the 20 to 21-foot bgs interval (7.8 mg/kg). The sample locations for GP-3A and GP-2A were both behind the Bell facility (near the storm drain grate that drains (sub-grade) westward towards the open ditch along Jones Road).
Review of the sample results concluded that contaminants immediately behind the Bell facility are at least 50 feet bgs. No dense non-aqueous phase liquid (DNAPL) was observed during the investigation.

Soil sampling was performed south of the septic system leach field and adjacent to the septic system drainage lines during the October 2003 DPT investigation. Some minor concentrations of PCE were detected in soil samples collected near the septic system leach field in soil borings GP-1 (0.009 mg/kg; estimated), GP-2 (0.003 mg/kg; estimated), GP-16 (0.029 mg/kg), and GP-20 (0.018 mg/kg). The highest concentration was detected in GP-20, which is located adjacent to the septic leach field. Two soil borings (GP-18 and GP-19) were installed directly south of the leach field, and PCE was not detected in soil sampled taken from the borings. Results of the soil analyses indicate that the septic system may be a minor secondary source area of PCE release compared to the major source area directly behind the Bell facility. Table 4 presents a cumulative summary of analytical results for the various sampling events, and Table 7 provides a summary of soil sample information collected during the soil sampling investigations. Figure 15 presents a map showing the distribution of PCE in soils around the former Bell facility. The map was prepared by plotting the highest PCE concentration detected in each sample location, regardless of depth, to a maximum depth of investigation of 50 feet bgs.

### 4.1.1.5.2 Distribution of PCE in Groundwater (Bell Facility)

A groundwater investigation was conducted in August and September 2003, titled Remedial Investigation - CPT (Shaw, April 29, 2004). Thirty-six CPT borings (CPT-1 through CPT-7 and CPT-10 through CPT-38) were installed using CPT drilling methods, and three permanent monitor wells (MW-7, MW-8, and MW-9) were installed using hollow stem auger (HSA) drilling methods. The CPT sample points and monitor wells were installed for collection of groundwater samples; no soil samples were collected. PCE was detected in three CPT borings installed close to the Bell facility at depths approximately 30 feet bgs. PCE concentrations in CPT-3, CPT-5, and CPT-6 were 3.81 mg/L, 0.062 mg/L, and 0.238 mg/L, respectively. One groundwater sample was taken from a depth of 51 feet bgs in down-gradient soil boring (CPT-32), and PCE was detected at 2.48 mg/L. Soil boring CPT-32 was subsequently converted to monitor well MW-7, but the monitor well was screened to a depth of 35 feet to monitor the same groundwater-bearing unit as the other monitor wells in the area. The significance of the CPT investigation was that PCE had migrated from shallow source area soils to two shallow groundwater-bearing units in an apparent down-gradient direction.

February 2008 mapping of PCE in the shallow monitor wells (35 feet bgs) indicates that the PCE plume has moved farther down-gradient from the source area since it was investigated in 2003. The highest PCE concentrations are now detected in monitor well MW-6 near the southwest corner of the site. The concentration of PCE in monitor well MW-6 was 6 mg/L in August 2003, and has increased to a concentration of 167 mg/L in February 2008. A similar increase in PCE concentrations has occurred in monitor well MW-1, which was installed immediately down-gradient of the suspected source area. The concentration of PCE increased from 3.9 mg/L in August 2003 to 27.9 mg/L in February 2008. The increase in PCE in monitor well MW-1 could be an indication that PCE is still being released from soils in the suspected source area. Table 4 presents a cumulative summary of analytical results for the site. Figure 16 shows the
distribution of PCE in shallow (less than 35 feet bgs) groundwater for the February 2008 sampling event.

### 4.1.2 Soils and Vadose Zone

Shallow groundwater levels in the source area, as measured in monitor wells installed to a depth of approximately 35 feet are highly variable. For instance, the depth to water ranged from 16.25 feet (monitor well MW-8) to 31.83 feet (monitor well MW-6), with an average (mean) water depth of 22.05 feet bgs during the February 2008 gauging event. The variable groundwater depths may be related to discontinuous sand/silt lenses within the interbedded zone. The Source Area Conceptual Site Model (Shaw, May 29, 2008) indicates that the interbedded zone is positioned approximately 20 to 35 feet bgs, and is also the first groundwater-bearing unit. The vadose zone and shallow soils exist above an approximate depth of 20 feet bgs, and are primarily comprised of clay.

#### 4.1.2.1 Soil as a Potential Pathway

Soil in the source area has been determined to be a probable pathway for PCE migration to groundwater. Soil and groundwater samples, especially collected immediately behind the Bell facility, suggest that PCE has traveled through the soil and into the underlying groundwater-bearing units. Because the density of PCE is greater than that of water, it tends to move downward to the bottom of any sandy zone and pool on top of less permeable silt or clay layers. Density differences of ~1% influence fluid movement in the subsurface, and the density of PCE is 60% greater than that of water (1.6 compared to 1.0). The relatively high density of PCE means that it may penetrate the water table and flow downward, directed by paths of least capillary resistance (possibly against the direction of groundwater flow). PCE penetrates clay by moving through fractures, and where clay layers are discontinuous, PCE will simply flow over the edges of discontinuous clay lenses and continue downward through more permeable material (Environment Agency R&D Publication 133, June 2003).

#### 4.1.2.2 Nature and Extent of Soil and Vadose Zone Contamination

The Remedial Investigation – Geoprobe (Shaw, April 28, 2004) indicated the highest PCE concentrations were detected in soil samples taken from the 18 to 19 foot interval bgs in soil borings GP-3 (4.6 mg/kg) and in the 16 to 17 foot interval bgs in soil boring GP-4 (260 mg/kg), which is situated within the lower horizon of shallow soils/vadose zone and the suspected source area. A specific investigation to study soils above the water table was not performed, but extensive soil sampling was performed as described in Section 4.1.1.5.1, Distribution of PCE in Soils.

#### 4.1.2.3 Contaminated Soil Impact to Human or Environmental Receptors

The soils in the source area that are impacted with PCE near the ground surface (to a depth of approximately 20 feet bgs) are primarily covered with concrete associated with the building foundation (Cypress Shopping Center) and concrete parking lot/back alley. There is currently a low potential for human exposure to soil through dermal contact or ingestion. Exposure to
burrowing animals is also unlikely considering the highly urbanized area and unlikely ecological habitat.

4.1.3 Groundwater

4.1.3.1 Groundwater as a Potential Pathway

Groundwater is a known pathway for contaminant exposure, as PCE has been detected in shallow groundwater in and around the source area and also in numerous drinking water wells that obtain water from deeper drinking water aquifers at the site. The groundwater pathway is completed when groundwater is pumped to the surface for consumption. As an interim measure the TCEQ installed GAC filtration systems on wells where PCE concentrations were at or exceeded the MCL. The EPA and TCEQ are currently funding a project to install a waterline at the site to provide municipal water to the area, which is intended to replace individual water wells used for potable water consumption.

4.1.3.2 Nature and Extent of Groundwater Contamination

Groundwater contamination originates from soil contamination in the source area. Dissolution of PCE from free product (if any) and impacted soils has created a groundwater plume that has migrated laterally and vertically away from the source area, and in a down-gradient direction. In the shallow groundwater-bearing unit (less than 35 feet bgs) of the source area, the distribution of PCE in groundwater indicates that the groundwater flow direction is southwest. However, the Deep Monitor Well Groundwater Gauging and Rainfall Data (Shaw, November 2007) report showed the flow direction within a deep aquifer (screened within depths from approximately 233 to 296 feet bgs) to be highly consistent to the southeast, with a groundwater gradient ranging from 0.00248 to 0.00267 ft/ft.

The distribution of PCE in nearby commercial and residential water wells occurs primarily west, southwest, and southeast of the source area, but water wells located north and northwest of the source area are also impacted. Movement of the plume north and far west of the source area would not be expected under static groundwater flow conditions and in uniform/isotrophic geologic formations. However, groundwater flow conditions are likely not static; flow may be influenced by seasonal pumping of numerous private and commercial water wells surrounding the source area. Historically, increased PCE concentrations have been observed during February and May sampling events, and may be related to surface drought conditions that promote increased water demand (pumping from water wells) to irrigate lawns in the area. Also, the subsurface geology is not uniform/isotrophic; the geology is comprised of complex fluvial deposits, such as paleo river channels and over-bank deposits that may provide lateral pathways to aquifers north and northwest of the source area. Estimates of the plume size based on surface distance measurements to impacted water wells, suggests that the width is approximately 2,000 feet, the length is approximately 3,000 feet, and the depth is approximately 300 feet. The discussion below provides a detailed discussion of contaminant distribution within the underlying WBUs with reference to figures. In addition, Table 8 presents the quarterly PCE groundwater sampling results from May 2003 through February 2008.
At the site, the complex subsurface geology precludes identification of distinct and continuous WBUs within the Chicot and Evangeline aquifers. As a proxy for distinct WBUs, the wells have been divided into various categories by screened depth to allow some analysis of travel paths for PCE contamination in the groundwater. The monitor wells and water wells have been divided into five groups, less than 200 feet bgs, 200 to 230 feet bgs, 231 to 260 feet bgs, 261 to 300 feet bgs, and 301 to 540 feet bgs. There are 49 wells (23 sampled) in the less than 200 feet group, 158 wells (65 sampled) in the 200 to 230 group, 94 wells (40 sampled) in the 231 to 260 group, 60 wells (19 sample) in the 261 to 300 group, and 45 wells (8 sampled) in the 301 to 540 group. There are also 193 sampled wells for which the screened interval and total depth are unknown.

4.1.3.2.1 Wells Less Than 200 Feet BGS

For groundwater less than 200 feet bgs, the groundwater samples consist of many shallow samples at and near the Bell facility, including multiple samples from nine shallow (less than 35 feet bgs) monitor wells (MW-1 through MW-9), and multiple samples from 14 deeper water wells to the south and mostly west of the Bell facility.

In groundwater less than 200 feet bgs, PCE has been found above the MCL in wells at seven properties, FV11022, JR11600, TT11014, TT11106, TC11027, TC11107, and TC11115 (Table 8). It appears that PCE traveled vertically down and primarily southwest in the groundwater less than 200 feet bgs. The inferred groundwater flow direction is to the southwest, but that has not been firmly established. The PCE plume is bounded to the west by wells with PCE concentrations below the detection limit, but not in other directions. Figure 17 and Figure 22 show the inferred groundwater plume of PCE greater than the MCL in groundwater less than 200 feet bgs for November 2007 and November 2006 respectively.

4.1.3.2.2 Wells 200 to 230 Feet BGS

For groundwater between 200 and 230 feet bgs, the groundwater samples consist of multiple samples from 65 water wells mostly to the west of the Bell Facility, and some to the southeast. In groundwater 200 to 230 feet bgs, PCE has been found above the MCL at nine locations, FV11102, JR11427, JR11527, JR11600, TC11126, TH11723, TO10835, TT11011, and TT11107. FV11022 was only sampled once, and TH11723 only had PCE exceeding the MCL once. The others consistently had PCE concentrations exceeding the MCL (Table 8). It appears that PCE continued downward and primarily southeast in the groundwater 200 to 230 feet bgs. The inferred groundwater flow direction is to the southeast, but that has not been firmly established. The 200-230 PCE plume is bounded from south around to northwest, and on part of the east side, but not in other directions. Figure 18 and Figure 23 show the inferred groundwater plume of PCE greater than the MCL in groundwater from 200 to 230 feet bgs for November 2007 and November 2006 respectively.

4.1.3.2.3 Wells 231 to 260 Feet BGS

For groundwater between 231 and 260 feet bgs, the groundwater samples consist of multiple samples from 2 monitor wells and 38 water wells mostly to the west of the Bell Facility, and some to the southeast. In groundwater 231 to 260 feet bgs, PCE has been found above the MCL at seven locations, FV11014, FV11130, TC11019, TO10903, TO11024, TT11123 and TT11127. Sampling at TO11024 ended in May 2006. The others consistently had PCE concentrations
exceeding the MCL (Table 8). It appears that PCE continued downward and slightly northwest in the groundwater 231 to 260 feet bgs. The inferred groundwater flow direction is to the southeast, but that has not been firmly established. The 231-260 PCE plume is bounded from west around to north, and partially to the southeast, but not in other directions. Figure 19 and Figure 24 show the inferred groundwater plume of PCE greater than the MCL in groundwater from 231 to 260 feet bgs for November 2007 and November 2006 respectively.

4.1.3.2.4  Wells 261 to 300 Feet BGS

For groundwater between 261 and 300 feet bgs, the groundwater samples consist of multiple samples from seven monitor wells and 12 water wells mostly to the west of the Bell facility, and some to the southeast. In groundwater 261 to 300 feet bgs, PCE has not been found above the MCL (Table 8). There have been some scattered detections at concentrations below the MCL, but nothing consistent. It appears that PCE continues downward and slightly northwest in the groundwater 261 to 300 feet bgs, but PCE at concentrations above the MCL have not reached deeper depths. The inferred groundwater flow direction is to the southeast, and that has been well documented by groundwater elevations in the monitor wells. The seven monitor wells surround the PCE plume, and PCE has not been detected in any of the monitor wells screened to total depths between 258 and 297 feet bgs (although low VC concentrations have been detected in the monitor wells and will be discussed later). Figure 20 and Figure 25 show the results for properties with wells screened in groundwater from 261 to 300 feet bgs for November 2007 and November 2006 respectively.

4.1.3.2.5  Wells 301 to 535 Feet BGS

At the site, PCE, TCE, DCE, and VC were not detected in water samples collected from water wells drilled deeper than 300 feet bgs as summarized in Table 9.

For groundwater between 301 and 535 feet bgs, the groundwater samples consist of multiple samples from 1 monitor well and seven water wells mostly to the west of the Bell facility, and some to the southeast. In groundwater 301 to 535 feet bgs, PCE has not been detected above the MCL (Table 8). There has been only one detection of PCE (0.23 µg/L), but it was less than the MCL. It appears that PCE continues downward and slightly north in the groundwater 301 to 535 feet bgs, but detectable PCE has not reached this depth. The inferred groundwater flow direction is to the southeast, but that has not been firmly established. The water well at 11115 Tall Timbers Drive is located near the center of the dissolved-phase PCE plume within overlying sand units, and the water well at 11414 Jones Road lies under the southeast arm of the plume. The other deep wells are located beyond the known area of the plume. Figure 21 and Figure 26 show the results for properties with wells screened in groundwater from 301 to 535 feet bgs for November 2007 and November 2006 respectively.

4.1.3.2.6  Wells of Unknown Depth

In the wells of unknown depth, groundwater samples were collected from 193 water wells to the north, west, south, and east of the Bell facility. Of the 193 water wells, 162 had PCE concentrations below the detection limits, but were not used to delineate the horizontal extent of PCE at any particular depth.
4.1.3.3 **Groundwater Impact to Human or Environmental Receptors**

The groundwater exposure pathway is complete at the Jones Road Groundwater Plume Federal Superfund Site. However, installation of GAC filtration systems, along with quarterly groundwater monitoring, has been implemented as a short-term precaution to prevent exposure to humans. In addition, a government funded water line is currently under construction to provide a reliable source of safe drinking water to the community; connection to the water line will be voluntary. Groundwater is not known to impact any ecological receptors.

4.1.4 **Surface Water and Sediments**

Sediment sampling was not conducted at the site to assess potential impact of sediments by PCE. However, three soil borings were installed within the northerly trending drainage ditch between Cypress Shopping Center and Jones Road during a soil investigation in October 2003; see *Remedial Investigation – Geoprobe* investigation (Shaw, April 28, 2004), **Section 2.1.2.8 and Figure 5**. DPT soil boring GP-13 was installed at the intersection of the drainage ditch and the Bell Facility storm sewer outfall. Soil boring GP-21 was installed in the drainage ditch approximately 70 feet north of soil boring GP-13, and soil boring GP-12 was installed within the drainage ditch approximately 90 feet south of GP-13.

Estimated low concentrations of PCE (2 µg/kg) and TCE (4 µg/kg) in the near surface soil sample (1 to 2 feet bgs sample interval) of soil boring GP-13, along with no PCE or TCE concentrations above the detection limits in near surface soil samples collected from soil borings GP-12 and GP-21 may indicate that the overlying sediment in the drainage ditch likely contains only minor PCE or TCE concentrations, since the contaminants would be expected to leach downward from sediments into the shallow surface soils. Sampling from the same boreholes was performed at deeper depths, and increasing concentrations of PCE, TCE, and VC were detected in soil boring GP-13, although likely related to lateral movement of the contaminants through groundwater originating from the source area. PCE was detected (with estimated concentrations) at concentrations ranging from 37 to 39 µg/kg within two samples collected at depths of 17 and 23 feet bgs, respectively. TCE was detected in the same samples at concentrations ranging from 140 to 170 µg/kg, and VC was detected in two of the samples at concentrations of 54 µg/kg. No PCE, TCE, or VC was detected below a depth of 34 feet bgs in soil boring GP-13. Soil samples collected from soil borings GP-12 and GP-21 (four soil samples from each boring) revealed no PCE, TCE, or VC concentrations above the detection limit (10 µg/kg).

A separate soil investigation was performed on February 5, 2008 by EPA through their contractor, WL Construction. The soil investigation involved collection three soil samples (at a depth of 16 feet bgs) north and south of the Bell facility storm drain outfall, to identify potential contamination exposure to workers that might be encountered during installation of the water line. Results of the EPA investigation revealed all soil samples to have VOC concentrations below the detection limit. A formal report was not prepared for this activity; only a lab report was available for review.
It appears that a small release may have occurred along the drainage ditch, but significant accumulation of contamination is not apparent. For the same reason, transportation of contaminants in waters of the ditches was likely minimal. No known surface waters have been impacted by PCE released from the source area.

4.1.4.1 Pathway and Location(s), of Contaminant Entry to Surface Waters

No pathways of contamination entry to surface waters are known at this time.

4.1.4.2 Nature and Extent of Sediment Contamination

No sediment contamination is known at this time; only near surface soil samples were collected from the roadside ditch as explained above.

4.1.4.3 Contaminated Sediment Impact to Human or Environmental Receptors

No sediment contamination is known at this time.

4.1.5 Air

No studies have been performed to determine if (outside) air poses a threat to human health or the environment. However, Section 2.1.2.13 describes a vapor intrusion study performed at the former Bell facility, Vapor Intrusion Study (Shaw, May 6, 2008) to investigate indoor air to determine if completed pathway(s) exist for intrusion of vapors to workers in the Cypress Shopping Center (from the Bell facility), and if indoor vapors could pose an unacceptable risk of chronic health effects due to long-term exposure.

4.1.5.1 Air as a Potential Pathway

No studies have been performed to determine if (outside) air poses a threat to human health or the environment.

4.1.5.2 Nature and Extent of Indoor Air Contamination

During the Vapor Intrusion Study two indoor ambient air samples and two sub-slab air samples were collected inside the former Bell facility, for analysis of VOCs using EPA Method TO-15. Results of laboratory analysis were compared to the Tier II Table from the OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils. PCE and TCE exhibited higher concentrations than the OSWER Tier II target concentrations for the two ambient air samples. In one ambient air sample, the PCE and TCE concentrations were 14 micrograms per cubic meter (µg/m³) and 1.8 (µg/m³), respectively. For the other ambient air sample, the PCE and TCE concentrations were 9.5 (µg/m³) and 1.7 (µg/m³), respectively. Fourteen other chemicals were detected but did not exceed the OSWER Tier II target concentrations, and were suspected to be related to household compounds (and other chemicals stored on-site) that would be expected to be found at low concentrations in ambient indoor air.
Eight chemicals were detected in the sub-slab samples. PCE and TCE concentrations were 47,300 (µg/m³) and 9,080 (µg/m³) in one sub-slab sample, and 59,700 (µg/m³) and 1,930 (µg/m³) in another sub-slab sample, respectively. The sub-slab samples were evaluated by estimating attenuation factors relative to soil or groundwater concentrations to indoor air concentrations.

4.1.5.3 Contaminated Air Impact to Human or Environmental Receptors

For indoor air, the Vapor Intrusion Study concluded that a complete pathway for vapor intrusion exists, but very little vapor is migrating from the sub-slab soil into indoor air (the slab is an effective barrier to limit vapor intrusion). The report also concluded that VOCs measured in indoor air did not pose an unacceptable health risk to workers. No outdoor air investigations were performed to evaluate impact to human health or environmental receptors.

4.1.6 Exposure Pathways Defined by the Texas Commission on Environmental Quality (TCEQ) Texas Risk Reduction Program (TRRP)

The TCEQ Memo dated October 21, 2003, Determining Which Releases are Subject to TRRP describes the process for evaluating exposure pathways. Soil is evaluated separately as surface soil and subsurface soil. Surface soil is evaluated against the combined pathway protective concentration limits (PCLs) and the ingestion pathway PCLs. Subsurface soil is evaluated against the ingestion pathway PCLs and the vapor pathway PCLs. Groundwater is evaluated against the ingestion pathway PCLs and the vapor pathway PCLs.

At the Jones Road Groundwater Plume site, the soil pathways were evaluated and determined to be incomplete. The development of the land over the contaminant source area includes buildings, parking lots, and roadways, all of which combine to limit direct contact with the soil and discourage prolonged human presence in the area.

The vapor pathways were evaluated in the Vapor Intrusion Study (Shaw, May 2008). The conclusion of that study was that the presence of buildings and pavement in the source area limits exposure along the vapor pathway from either soil or groundwater.

The groundwater pathway was evaluated and found to be complete. Chemicals are present in groundwater at levels exceeding the groundwater ingestion pathway PCLs. Public and private water wells tap into that groundwater and provide it for domestic and commercial use, completing the groundwater ingestion pathway.

4.1.6.1 TRRP Groundwater Classification

Groundwater resources below a depth of approximately 60 feet are used or are potentially used for human consumption. The regulatory citation for groundwater classification is 30 Texas Administrative Code (TAC) §350.52. The TCEQ Regulatory Guidance on Groundwater Classification (RG-366/TRRP-8) (TCEQ, March 2003), outlines the process of groundwater classification.
Under the TRRP rule, groundwater is classified as Class 1, Class 2, or Class 3, with Class 1 groundwater being the most desirable and best groundwater for human consumption, and Class 3 groundwater being the least desirable and likely not useable for human consumption. The groundwater tapped by private and public water supply wells at the study area is classified as Class 1 groundwater. The criteria for a Class 1 groundwater resource are:

- Affected groundwater WBU is within 0.5 miles of a PWS well and COCs could migrate to the well production zone; or

- The affected WBU is the only reliable source of water in area, with a depth < 800 ft below grade, total dissolved solids concentration less than 1000 mg/L, and sustainable well yield greater than 5,000 gallons per day.

Because PCE is present at levels above the MCL in the PWS well at Finch’s Gymnastics at the site, the groundwater must be Class 1 groundwater according to the first criteria.

The criteria for Class 2 groundwater are:

- The WBU is a production zone for an existing water supply well (other than PWS well) within 0.5 miles which is used for human consumption, agriculture, or other purpose which could result in human or ecological exposure.

If there were no PWS wells at the site, the groundwater could be a Class 2 groundwater. Because PWS wells are present, the groundwater is Class 1.

The groundwater intercepted by the shallow monitor wells has not been tested. Therefore, the classification of groundwater has not been determined. Because the wells in the surrounding area all tap into much deeper WBUs, and one of the monitor wells (MW-6) is intermittently dry, the groundwater intercepted by the shallow monitor wells would most likely be a Class 3 groundwater resource. Based on the General Groundwater (Inorganic) Quality Characterization and Comparison report (Shaw 2004), TDS values for monitor wells MW-7, MW-8, and MW-9 ranged from 408 to 508 mg/kg, which are concentrations below the Class 3 classification criteria. Therefore, a flow rate test is needed to confirm such classification to confirm Class 2 groundwater. Slug testing of monitor wells in the source area will be performed during the feasibility study phase of work scheduled for the site.
5.0 **Contaminant Fate and Transport**

5.1 **Potential Routes of Migration and Human Exposure**

Based upon data collected to date, the *Source Area CSM* supports the primary source of discharge of PCE as being directly onto the ground surface and/or into the storm drain outside the back door of the former Bell site. Soil data collected during previous investigations show this area as having the highest concentration of COCs. A secondary discharge point was the floor drain inside the former Bell site leading to the septic system. DPT borings along this sewer line to the septic leach field indicated detections of PCE in shallow soils. Although the septic system is a secondary source of discharge, it is considered to be minimal as PCE concentrations in groundwater near the leach field of the septic system are low. The limited extent of PCE impact to soil indicates the main pathway for PCE transport was likely vertical in the form of DNAPL rather than horizontal (although DNAPL was never confirmed during sampling activities). The DNAPL migrated vertically and provided a continuous source for dissolved-phase PCE plumes. The dissolved-phase PCE plumes migrated laterally primarily in the down-gradient direction through permeable zones (sands), or through permeable zones influenced by nearby pumping from water wells. When the impacted water was pumped to the ground surface, the migration pathway was completed for human exposure.

Human exposure through soil ingestion or vapor inhalation is considered unlikely, since the source area is paved with concrete in both the parking lot and building foundation. A *Vapor Intrusion Study* was performed, and results of the study indicated that minimal vapor intrusion into the Cypress Shopping Center is likely, and indoor air samples collected indicate that the vapors do not pose an unreasonable risk to human health.

5.2 **Contaminant Persistence**

The contaminants of interest at the Jones Road Groundwater Plume site are PCE and its daughter products. The chemicals are persistent in the environment when not exposed directly to sunlight or favorable natural subsurface degradation processes. The chemicals may be diluted to undetectable levels over long periods of time by natural diffusion and dispersal, but during the process, the chemicals would continue to be present at unacceptable exposure levels. However, treatment technologies are available to dramatically increase the degradation process. Shaw performed a bench scale treatability study for the treatment of soils and groundwater at the Bell facility as discussed in Section 2.1.2.1.2. Results of the study were documented in the *Final Treatability Study Report* (Shaw, October 16, 2007) for the application of in-situ chemical oxidation and bioremediation treatment technologies. Treatment technologies of permanganate oxidation, bio-augmentation, bio-stimulation, and abiotic treatment (using zero valent iron) were determined to be effective during the study. Permanganate oxidation was recommended as the best potential technology for shallow source area soils, and bioremediation was recommended for deeper extended plume areas. The success of these treatment technologies is highly dependant upon the delivery system used to deploy the technologies to the respective impacted media.
5.2.1 Media of Interest

The media of interest at the Jones Road Groundwater Plume site are soil and groundwater. The presence of PCE and daughter products in soil has been confirmed by source area investigations. The presence of PCE and daughter products in groundwater has been confirmed by groundwater investigations and quarterly well monitoring.

5.2.2 Biostimulation, Bioaugmentation, and Abiotic Treatment Technologies

Biostimulation and bioaugmentation are in-situ remedial biotechnologies that have been shown to be effective treatments for removal of chlorinated ethenes such as PCE and daughter products. Abiotic treatment of chlorinated ethenes using zero valent iron (ZVI) is another treatment technology that has shown to be effective treating PCE and daughter products. PCE can be degraded under anaerobic conditions by specific bacteria through reductive dehalogenation, where PCE is sequentially reduced to TCE, DCE, VC, and then finally to ethylene, which is a harmless gas. In each case, the reactions are mediated by bacteria that thrive under low oxidation-reduction potential, and are driven by the presence of an electron donor (carbon source or hydrogen). In order for complete biodegradation/dechlorination of PCE to occur, specific bacteria capable of degrading chlorinated ethenes to ethane must be present or introduced to the impacted media. Biostimulation involves stimulating favorable indigenous microbial populations with electron donor (substrate) and/or nutrients into the subsurface. Bioaugmentation involves introduction of favorable microbial populations, substrate, and nutrients into the subsurface. ZVI involves introduction of iron filings into the subsurface to provide a surface for electron transfer needed for reductive dehalogenation reactions. Results of the Final Treatability Study Report (Shaw, October 16, 2007) indicated that biostimulation, bioaugmentation, and ZVI treatment technologies could effectively treat PCE and its daughter products. Biostimulation with lactate added as the substrate had the best reaction kinetics, and would likely be best deployed in the deeper (greater than 35 feet bgs) dissolved-phase groundwater plume in the source area.

5.2.3 In-Situ Chemical Oxidation Treatment Technologies

In-situ chemical oxidation (ISCO) using potassium or sodium permanganate is an effective treatment technology for the removal of chlorinated ethenes such as PCE. Permanganate reacts rapidly with nonaromatic double bonds in chlorinated ethenes, and oxidizes the chlorinated ethenes to carbon dioxide and chloride ions. Results of the Final Treatability Study Report (Shaw, October 16, 2007) indicated that potassium permanganate was the most effective ISCO treatment technology for the shallow (less than 35 feet bgs) source area soils and groundwater.

5.3 Contaminant Migration (Prediction through Modeling)

5.3.1 Factors Affecting Contaminant Migration

There are several factors affecting contaminant migration within the media of interest when developing groundwater models for specific sites. The migration of dissolved-phase contaminants can be thought of as a two-step process: 1) groundwater flow, which includes
development of a flow net of groundwater velocity vectors, and 2) hydraulically downgradient movement, adsorption, and degradation of contaminants released into that flow field.

The rate of groundwater flow is defined by Darcy’s Law and can be expressed as:

\[ V = \frac{Ki}{n} \]

where,

- \( V \) = groundwater velocity (in units of length/time \([L/T]\))
- \( K \) = hydraulic conductivity \((L/T)\)
- \( i \) = the hydraulic gradient, horizontal and vertical \((L/L)\)
- \( n \) = the effective porosity

In the field, hydraulic conductivity is measured either by a slug test or an aquifer test and gives an estimate of an aquifer’s ability to transmit water. The gradient is simply the difference in hydraulic head measured at two wells, divided by the distance between the wells. Effective porosity, if not determined by testing formation samples, is often estimated from literature values and knowledge of the local geology. An additional parameter in determining the rate and direction of groundwater flow is any factor that adds or removes water from the aquifer. For example, extraction wells can greatly affect the hydraulic gradient in an aquifer; hence the location and pumping rate of nearby wells is very important to the calculation. In areas where the aquifer is relatively shallow, surface recharge can greatly affect flow rates, as can streams or rivers that are in hydraulic communication with the aquifer.

Once the flow field is well defined, contaminants should be evaluated as being released into the aquifer, either as a single event or as a continuous source. Contaminant transport can be defined numerically as:

\[ \frac{dC}{dt} = D \left( \frac{dC}{dx} \right) \]

where,

- \( \frac{dC}{dt} \) = the change in contaminant concentration with respect to time
- \( D \) = the dispersion coefficient, a function of groundwater velocity and a mixing coefficient known as Dispersivity.
- \( \frac{dC}{dx} \) = the change in contaminant concentration with respect to space (shown here as one dimensional [in the x-direction], but in fact is three dimensional).

Dispersivity is the most uncertain of all transport parameters and is rarely known for a site. Literature values are nearly always used in calculations and this contributes to uncertainty in travel time estimates.

Two other factors affecting transport are adsorption (or retardation) and degradation. Adsorption is the process by which compounds adsorb chemically to geologic media that are higher in organic carbon, such as clays and fine-grained silts. Adsorption is probably not a significant factor in much of the predominantly sandy Chicot and Evangeline aquifers, but may be within...
the clay units separating the sand units. Degradation is a more important process to consider; as discussed below, many organic compounds degrade along a known path and at a rate that is highly dependent on site-specific chemical conditions.

*Anaerobic Degradation of PCE*

The compounds PCE, TCE, DCE, and VC are part of a degradation series. Under favorable conditions, anaerobic microbial activity will sequentially replace a chlorine atom with a hydrogen atom in each compound to yield the reductive dechlorination sequence:

\[
\text{PCE} \rightarrow \text{TCE} \rightarrow \text{cis-1,2-DCE} \rightarrow \text{VC} \rightarrow \text{Ethene}
\]

Ethene will eventually degrade to carbon dioxide and water. The compounds PCE and TCE are commonly used as commercial cleaners and solvents, but DCE and VC are mostly used in the manufacturing of plastics, and are not in common commercial use as cleaning agents. The presence of DCE and VC therefore indicates that degradation is occurring via reductive dechlorination (EPA, 1998). If conditions are favorable, all of the compounds will eventually degrade to non-detectable concentrations when these sequential reactions are completed, but temporary increases in daughter products may occur because the parent and daughter compounds degrade at different rates. In fact, temporary increases in daughter products provide evidence that microbial degradation is effectively proceeding.

Favorable conditions for complete reductive dechlorination of PCE include low redox potential, non-detectable dissolved oxygen, and high (greater than 20 mg/L) total organic carbon. It is also favorable to have nitrate concentrations below ~1 mg/L, and sulfate below ~20 mg/L because these anions buffer redox conditions at potentials that are above those required for complete degradation.

*Natural Attenuation Parameters*

Indirect evidence for natural attenuation is based on evaluation of the “natural attenuation parameters”, which change relative to background conditions in response to microbial degradation of chlorinated solvent compounds as discussed below. The nature and magnitude of these changes provide information on the attenuation processes that are occurring.

The mechanisms for microbial degradation involve aerobic respiration and the anaerobic processes of denitrification, manganese reduction, iron reduction, sulfate reduction, and methanogenesis. Degradation via aerobic respiration will preferentially occur first. During aerobic respiration, contaminants are oxidized, resulting in consumption of oxygen and generation of carbon dioxide (CO₂). After sufficient oxygen is consumed, the system will become reducing, and anaerobic microbes will sequentially utilize nitrate, manganese, iron, sulfate, and CO₂ in that order. Nitrate will be reduced to nitrogen gas or ammonia, Mn⁴⁺ and Mn³⁺ will be reduced to Mn²⁺, Fe³⁺ will be reduced to Fe²⁺, sulfate will be reduced to sulfide, and finally, CO₂ will be converted methane (CH₄).
Each of these sequential steps occurs at progressively lower oxidation/reduction potentials. Different zones of the plume may be dominated by different microbial processes, depending on the local oxidation/reduction conditions and concentrations of nutrients that are present. It is also expected that the locations of the zones will shift as conditions change over time. Establishing the occurrence of natural attenuation at the site involves monitoring changes in contaminant concentrations as well as measuring the relative changes in the concentrations of the natural attenuation parameters both inside and outside of the plume. In addition, temperature and pH need to be in a favorable range for microbial degradation to proceed at a reasonable rate.

Desorption of Chlorinated Solvents

An additional potentially important process that affects the observed concentrations of the organic contaminants in groundwater is their adsorption/desorption behavior. A contaminant such as PCE will adsorb to some extent on sediments. At equilibrium, some fraction of the PCE will be in an adsorbed state, and the remaining fraction will remain dissolved in the groundwater. The equilibrium ratio of the adsorbed mass to the dissolved mass is described by the adsorption coefficient ($K_d$), which is a function of a number of compound- and site-specific parameters.

The compounds PCE, TCE, and DCE have high organic carbon partition coefficients ($K_{oc}$) which is a measure of the tendency of the compound to adsorb on naturally occurring organic carbon along the groundwater flow path. For instance, PCE has a $K_{oc}$ of 359 mL/g at 20°C (Jeng et al., 1992), which means that in a carbon-PCE-water system at equilibrium, there will be 359 times more PCE in an adsorbed state than in a dissolved state (EPA, 1998).

Microbes will preferentially degrade the dissolved fraction. If some of the dissolved PCE is degraded to TCE, then the distribution ratio of adsorbed-to-dissolved PCE is disturbed from equilibrium. The system will respond by desorbing additional PCE from the sediments into the groundwater so that the equilibrium ratio is maintained. In such a two-phase (groundwater and sediment) system, the dissolved PCE concentration is partially replenished by desorption as degradation proceeds. This process will continue until both the adsorbed and dissolved fractions of PCE are completely degraded. This process might explain the observation of steady-state (or even increasing) concentrations in groundwater even though degradation may actively be proceeding. The chlorinated solvents (PCE and TCE) and solvent degradation products (cis-1,2-DCE and VC) are all subject to this effect to varying degrees.

### 5.3.2 Modeling Methods

A *Groundwater Model Identification Report* (Shaw, June 2008) discusses a planned approach to develop a groundwater model for the study area. The proposed groundwater model will be developed and a series of numerical groundwater flow simulations will be conducted in order to characterize the PCE groundwater plume dynamics over time and to evaluate potential groundwater remediation and/or treatment options.

Following model calibration, simulations will be based on a simplified subsurface, where there are two zones of hydraulic conductivity. The two zones of hydraulic conductivity used in the preliminary simulations will be for the Chicot and Evangeline Aquifers. The hydraulic
conductivity zone associated with the Chicot Aquifer in the simplified subsurface will be scaled using a harmonic mean of the conductivity value assigned to the interbedded sand, silt, and caliche horizons and the Chicot Aquifer materials. In addition, recharge will be averaged over the entire surface area of the model domain, which is a simple and conservative approach. The model will be calibrated as needed to simulate increased recharge that might occur along road ditches, and decreased recharge on paved surfaces and building footprints.

During the preliminary, simplified simulations it will be assumed that adsorption of PCE in the aquifer materials is negligible. A value of one (1) will be input for the retardation factor to reflect that the arrival times of PCE in wells is not affected by adsorption reactions along flowpaths.

The purpose of the preliminary, simplified simulations will be to generate a model that converges and calibrates as a platform for further, more complex simulations. Increasing levels of complexity will be added to the model domain to simulate the subsurface hydraulic relationships within the Chicot Aquifer, as well as relationships between the Chicot Aquifer and the land surface. In addition, the validity of the assumption of no PCE retardation will be determined through simulations, which is the most conservative scenario.

Simulations will include scenarios where percentages of private wells will be assigned a pumping rate of zero to evaluate what will happen to plume dynamics as private well owners transition to using city water in place of their private water supply. The scenario of no private wells pumping will also be evaluated during the course of groundwater model simulations.

The impact of a series of injection wells will also be evaluated during the groundwater model simulations. The number, placement, and rate of injection for the hypothetical injection wells (possibly installed for application of in-situ treatment technologies) will be based on model results and discussions with the TCEQ.

5.3.2.1 Proposed Models, Input Data, and Limitations

The Jones Road Groundwater Plume site groundwater flow and transport model will be constructed in the Groundwater Vistas™ Graphical User Interface. Groundwater Vistas™ fully supports the model codes MODFLOW (McDonald and Harbaugh, 1988) and MT3D (Zheng and Bennett, 1995), which will be used to design and execute the Jones Road site flow and transport model. The regional Groundwater Availability Model (GAM) for the northern part of the Gulf Coast Aquifer could be used for the study area, but has not been examined as of this date.

A recent version of MODFLOW (McDonald and Harbaugh, 1988) will be used to characterize the movement of groundwater through the system, and MT3D (Zheng and Bennett, 1995) to characterize the transport of soluble contaminants through the system. MODFLOW is a three-dimensional, finite-difference, groundwater flow model developed by the USGS. MODFLOW was selected for use in this project because the code is nonproprietary, well documented, and it has been verified for a wide range of field problems (Anderson, 1993). MT3D is a comprehensive, three-dimensional model code for solute transport, designed by Chunmiao
Zheng at the University of Alabama (Zheng and Bennett, 1995). MT3D was selected because it is a public domain code that was specifically designed for use with MODFLOW.

The model structure will include a model grid parallel to the dominant direction of groundwater flow, multiple layers (approximately 8 to 10), wells (367 identified wells), flow conditions, and boundary conditions. The grid, layer, and boundary condition definitions are somewhat arbitrary within certain limitations, and will be appropriately defined or revised as the groundwater model is developed. Some data gaps exist for well information and flow conditions that will need to be filled before the groundwater model becomes operational.

Some wells are not associated with locations on maps of the study area. To accurately model these wells, they will need to be plotted at least approximately at their surface locations. Similarly, the screened interval is unknown for many of the private wells. This information is necessary to assign the well to the appropriate layer in the model design. Individual well pumping rates would also be desirable where that information can be found.

Flow conditions depend on water level measurements and aquifer properties to determine flow directions. Water levels measured in the 19 monitor wells at the site will provide specific directional information. Physical and hydraulic characteristics of the WBUs are known from only a few measurements, and characteristics for several modeled layers may need to be tested or estimated. Slug tests conducted in wells within 1 mile of the Bell facility would be beneficial for estimating hydraulic conductivity values for the model.

Chemical properties of the contaminants will be estimated from measured site-specific values or those available in the literature. Concentrations of chemicals will be taken from the most recent available quarterly groundwater sample results. A useful check on the model will be a comparison of predicted concentrations to the results of later groundwater sampling results.

5.3.2.2 Groundwater Fate and Transport Before Water Line Installation

The groundwater model will be used to predict groundwater fate and transport prior to the water line installation. This prediction will assume initial conditions for the model equal to the concentration distribution of the existing plume, as indicated by the most recent groundwater sampling results available when modeling begins. The PCE concentrations input into the model will be correlated to the well where the sample was collected. The transport of daughter products in the model domain will also be evaluated through the use of groundwater sampling results. All of the wells in the model will be treated as constant flux boundary conditions representing a drain on the groundwater system.

5.3.2.3 Groundwater Fate and Transport After Water Line Installation

The groundwater model will be used to predict groundwater fate and transport after the water line installation. This prediction will assume the same general conditions as above, with the difference that an appropriate percentage of the wells, or particular wells, will be removed from the model to represent that the well has been plugged and abandoned, or taken out of service. It is anticipated that at least two scenarios will be examined for after the water line installation, a
50% participation rate (half the private wells closed) and a 100% participation rate (all private wells closed).

5.4 Contaminant Migration (Through Analysis of Historical Data)

Contaminant migration at the site was examined through analysis of historical groundwater data collected from 2003 through 2008. The simplest analysis of PCE concentrations in groundwater was performed by reviewing historical tabulated analytical data (Table 8). An overall evaluation (regardless of the known depths of PCE impact) was made by reviewing historical concentrations in select wells to determine general concentration trends. Also, historical PCE concentrations were evaluated based on water well screened intervals (known depths of PCE impact). Finally, historical reports were reviewed to determine the groundwater flow direction and gradient, which was determined to be to the southeast with a gradient ranging from 0.00248 to 0.00267 ft/ft for deep monitor wells screened from 294 to 357 feet bgs.

5.4.1 Review of Historical Concentration Trends

A few select water wells were examined to determine general historical PCE concentration trends. Wells that were sampled the most often (routinely sampled during most or all of the quarterly sampling events), and wells with at least some detectable PCE concentrations, were chosen for review.

One water well (total depth unknown) that had a GAC filter installed since the beginning of the quarterly monitoring program is located at 11535 Jones Road. This well is on property directly across Jones Road and west of the Cypress Shopping Center. In August 2003, groundwater samples taken from the well had a PCE concentration of 121 µg/L, and the concentration has varied between 45 and 140 µg/L since then, with one anomalous undetected result in February 2004. The accumulated results indicate that the plume is present and has steady PCE concentrations at this well. There are 12 wells at the site with similar records of PCE exceeding the MCL for all or most monitoring events. These wells are all located within 1000 feet of the Cypress Shopping Center, primarily to the south and west. The screened intervals, where known, range from 185 to 260 feet bgs. Table 10 lists the quarterly groundwater monitoring PCE results for these wells with steady PCE concentrations. The average concentration at these 12 wells shows steady PCE values ranging between 49 and 89 µg/L with no clear upward or downward trend.

One water well (total depth unknown) that had a GAC filter installed after the beginning of the quarterly monitoring program (October 2006) is located at 11130 Timber Crest Drive. This well is on a property approximately 1,100 feet west of Jones Road on the north side of Timber Crest. Groundwater samples taken from the well in August 2003 had a PCE concentration of 1.9 µg/L, and subsequent results ranged between 1.4 and 4.4 µg/L until August 2006, when the PCE concentration reached 7.3 µg/L. Since then the results have ranged from 10.8 µg/L in November 2006 to 4.2 µg/L in February 2008. The results indicate that the plume migrated to the well. There are 12 wells with similar records of PCE concentrations increasing from below the MCL to above the MCL. These wells are all located within 1250 feet of the Cypress Shopping Center, primarily to the south and west. The screened intervals, where known, range from 208 to 259
feet bgs. **Table 11** lists the quarterly groundwater monitoring PCE results for these wells with unsteady PCE concentrations. The average concentration at these 12 wells shows PCE values ranging between 2.5 and 30.3 µg/L with a clear upward trend.

One water well (total depth of 225 feet bgs) located at 11102 Tall Timbers had detectable PCE concentrations, but the PCE concentrations were below the MCL. This well is on a property approximately 650 feet west of Jones Road on the north side of Tall Timbers. At this well, the August 2003 concentration was estimated at 0.4 µg/L. Since then, PCE concentrations have ranged from concentrations below the detection limit to 1.5 µg/L. The accumulated results indicate that the plume is affecting the well, but has not exceeded the MCL. The fluctuations in PCE concentrations indicate either migration or attenuation of PCE. There are 14 wells with similar records of detectable PCE concentrations that remain below the MCL. These wells are all located within 1500 feet of the Cypress Shopping Center, primarily to the south and west. The screened intervals, where known, range from 104 to 262 feet bgs. **Table 12** lists the quarterly groundwater monitoring PCE results for these wells at the edge of the plume. The average concentration at these 14 wells shows PCE values ranging between 0.39 and 1.36 µg/L with a slight upward trend.

### 5.4.2 Review of PCE Concentrations Based on Well Screened Intervals

#### 5.4.2.1 PCE Concentrations in Groundwater – November 2007

Several maps were prepared for the November 2007 sampling event to illustrate the concentrations of PCE relative to the total depths of water wells installed on residential and commercial lots at the site (**Figures 17 through 21**). It should be mentioned that during the February sampling event, 173 wells were sampled, but the total depths of only 62 wells were known from available well records, so the distribution of PCE relative to water well depths is relatively undefined (**Table 2** presents a summary of well information). The maps were color-coded to identify the relative concentrations:

- No color representing lots with wells that were not sampled during the sampling event.
- Green representing lots with wells that have PCE concentrations less than 0.5 micrograms per liter (µg/L; equivalent to 0.0005 mg/L).
- Yellow representing lots with wells that have PCE concentrations greater than or equal to 0.5 µg/L but less than or equal to 5.0 µg/L.
- Red representing lots with wells that have PCE concentrations greater than 5.0 µg/L (MCL).

Each map follows the color scheme described above, and is based on the total depth intervals for which the area water wells are screened:

- **Figure 17** illustrates November 2007 PCE concentrations in monitor wells and water wells screened less than 200 feet bgs. Nine monitor wells at the Bell Facility lot, and nine water wells were sampled having total depths in this range. Two lots were green, one lot was yellow, and seven lots were red. Five more water wells in this depth interval were not sampled.
• **Figure 18** illustrates November 2007 PCE concentrations in water wells screened from depths of 200 to 230 feet bgs. Forty-three wells having total depths in this range were sampled, and thirty-four lots were green, two lots were yellow, and seven lots were red. Twenty-two more water wells in this depth interval were not sampled.

• **Figure 19** illustrates November 2007 PCE concentrations in water wells screened from depths of 231 to 260 feet bgs. Two monitor wells and twenty-one water wells having total depths in this range were sampled, and the monitor wells and thirteen lots were green, two lots were yellow, and six lots were red. Eighteen more water wells in this depth interval were not sampled.

• **Figure 20** illustrates November 2007 PCE concentrations in water wells screened from depths of 261 to 300 feet bgs. Seven monitor wells and eight water wells having total depths in this range were sampled, and all the monitor wells and lots were green. Four more water wells in this depth interval were not sampled.

• **Figure 21** illustrates November 2007 PCE concentrations in water wells screened from depths of 301 to 535 feet bgs. One monitor well and five water wells having total depths in this range were sampled, and the monitor well and all five lots were green. Two more water wells in this depth interval were not sampled.

The maps show an expected distribution of PCE concentrations relative to individual screened intervals (sand units), with the PCE concentrations decreasing away from the source area laterally and vertically, generally toward the southwest. The closest domestic well to the source is located at 11014 Forest Valley, and is screened from 240 to 260 feet bgs. This well has historically had the highest concentration of PCE seen in the domestic wells and is located west of the source area.

### 5.4.2.2 PCE Concentrations in Groundwater – November 2006

Several maps were prepared for the November 2006 sampling event to evaluate changes in PCE concentrations in groundwater relative to recent (February 2008) PCE concentrations (**Figures 22 through 26**). For the November 2006 sampling event, 171 wells were sampled, but the total depths of only 62 wells were known from available well records.

• **Figure 22** illustrates November 2006 PCE concentrations in monitor wells and water wells screened less than 200 feet bgs. Eight monitor wells at the Bell Facility lot and eight water wells having total depths in this range were sampled, and two lots were green, one lot was yellow, and six lots were red. No significant change in the number of lots, or relative concentration of PCE in their respective wells was observed compared to the November 2007 PCE map.

• **Figure 23** illustrates November 2006 PCE concentrations in water wells screened from depths of 200 to 230 feet bgs. Thirty-eight wells having total depths in this range were sampled, and twenty-nine lots were green, three lots were yellow, and six lots were red. The mapping results showed a decrease of five green lots, an increase of one yellow lot, and an increase of one red lot on the November 2007 PCE Map compared to November 2006. No apparent lateral migration of PCE was observed, with the farthest westerly impact (yellow) occurring in Lot 11611 Timber Hollow Drive, which remained unchanged (concentration) compared to the November 2007 PCE map. The comparison showed the source area lot (11600 Jones Road) change from yellow to red. The
additional yellow lot and red lot from November 2006 to November 2007, indicates a slight concentration increase within the plume.

- **Figure 24** illustrates November 2006 PCE concentrations in monitor wells and water wells screened from depths of 231 to 260 feet bgs. Two monitor wells and twenty-three water wells having total depths in this range were sampled, and the monitor wells and fifteen lots were green, four lots were yellow, and four lots were red. The mapping results showed an increase of two green lots and an increase of two yellow lots and an increase of two red lots on the November 2007 PCE Map compared to November 2006. The comparison showed a decrease of two green lots, a decrease of two yellow lots, and an increase of two red lots on the November 2007 PCE Map compared to November 2006. The apparent southerly leading edge of the plume (11127 Tall Timbers Drive) change from yellow to red, indicating downward migration in the source area, and some minor lateral movement of the plume in a southerly direction.

- **Figure 25** illustrates November 2006 PCE concentrations in monitor wells and water wells screened from depths of 261 to 300 feet bgs. Seven monitor wells and eight water wells having total depths in this range were sampled, and all the monitor wells and lots were green. No change in the relative concentrations of PCE in their respective wells was observed compared to the November 2007 PCE map.

- **Figure 26** illustrates November 2006 PCE concentrations in monitor wells and water wells screened from depths of 301 to 535 feet bgs. One monitor well and four water wells having total depths in this range were sampled, and the monitor well and all the lots were green. No change in the relative concentrations of PCE in their respective wells or monitor wells was observed compared to the November 2007 PCE map.

### 5.4.2.3 VC Concentrations in Groundwater – November 2007

Several maps were prepared for the November 2007 sampling event to compare concentrations and distribution of VC to November 2007 PCE concentrations (**Figures 27 through 31**). PCE can degrade naturally to TCE, DCE, and VC, with VC being the last degradation product in the series. The presence of VC is an indicator of natural degradation, but it is also an indicator of the leading edge of the plume, since it is more soluble and mobile than PCE and the other daughter products. The same number of samples was analyzed for VC as was analyzed for PCE during the November 2007 sampling event; 173 wells were sampled, but the total depths of only 62 wells were known from available well records. The same color scheme was used to identify the concentration ranges for VC as was used for PCE: only the PCL for VC is 2.0 µg/L, and the quantitation limit used for the study was 0.5 µg/L. Water wells were analyzed by the CLP laboratories, with a quantitation limit of 0.5 µg/L, whereas monitor wells were analyzed by the RPA Region 6 laboratory with a quantitation limit of 1.0 µg/L.

The maps were color-coded to identify the relative concentrations:

- No color representing lots with wells that were not sampled during the sampling event.
- Green representing lots with wells that have VC concentrations less than 0.5 µg/L.
- Yellow representing lots with wells that have VC concentrations greater than or equal to 0.5 µg/L but less than or equal to 2.0 µg/L.
- Red representing lots with wells that have VC concentrations greater than 2.0 µg/L (MCL).
The results of mapping were presented below:

- **Figure 27** illustrates November 2007 VC concentrations in monitor wells and water wells screened less than 200 feet bgs. Nine monitor wells at the Bell Facility lot and nine water wells having total depths in this range were sampled, and seven monitor wells and nine lots were green, and two monitor wells at the Bell Facility were red.

- **Figure 28** illustrates November 2007 VC concentrations in water wells screened from depths of 200 to 230 feet bgs. Forty-three wells having total depths in this range were sampled, and all the lots were green.

- **Figure 29** illustrates November 2007 VC concentrations in monitor wells and water wells screened from depths of 231 to 260 feet bgs. Two monitor wells and twenty-one water wells having total depths in this range were sampled, and all lots were green, one monitor well was yellow and the other monitor well was red.

- **Figure 30** illustrates November 2007 VC concentrations in monitor wells and water wells screened from depths of 261 to 300 feet bgs. Seven monitor wells and eight water wells having total depths in this range were sampled, and one monitor well and eight lots were green, three monitor wells were yellow, and three monitor wells were red. The VC concentrations may be an indication of natural degradation process occurring.

- **Figure 31** illustrates November 2007 VC concentrations in monitor wells and water wells screened from depths of 301 to 535 feet bgs. One monitor well and five water wells having total depths in this range were sampled, and the monitor well and all five lots were green.

5.4.2.4 VC Concentrations in Groundwater – February 2008

One map was prepared for the February 2008 sampling event to compare concentrations and distribution of VC to the November 2007 VC concentrations in water wells screened from depths of 261 to 300 feet bgs. (Figure 32). All VC concentrations in water wells and monitor wells were green (less than 0.5 µg/L), possibly indicating that VC has completely degraded.

5.5 Groundwater Chemical Trend Analysis – Refer to Section 4.1.3.2 (Nature and Extent of Groundwater Contamination)

5.6 Conceptual Site Model

Two CSMs have been prepared for the study area, including a Source Area CSM, and a Local Area CSM.

5.6.1 Source Area Conceptual Site Model (Former Bell Facility)

Shaw prepared a *Final Source Area Conceptual Site Model* (Shaw, May 29, 2008), to understand the contamination source area geology using new recent investigation data, and to aid in preparation of a pilot scale treatment study work plan. The Source Area CSM *(Appendix A)* included cross sections and a fence diagram in the Cypress Shopping Center area, showing the local geology and distribution of PCE in soil and groundwater. The report noted primary
downward migration of PCE immediately near the Bell facility and horizontal movement of PCE in groundwater-bearing units below the facility.

The Source Area CSM concluded that the subsurface geology was deposited in a fluvial depositional environment, as supported by discontinuous silt and sand units deposited under high to medium energy flow regimes, and thick clay units deposited under low energy flow regimes. The Source Area CSM supported previous geologic interpretations that the site is generally underlain by high plasticity clay (CH) from the ground surface to a depth of approximately 20 feet bgs. An interbedded zone consisting of sand (SP), silt (ML), and silty clay (CL) underlies the high plasticity clay, and extends from a depth of approximately 20 feet to 35 feet bgs. The interbedded zone appears to be laterally continuous at the site. High plasticity clay underlies the interbedded zone, and extends from a depth of approximately 35 feet to 60 feet bgs. The high plasticity clay includes randomly distributed discontinuous sand lenses comprising less than ten percent of the high plasticity clay zone. A thick, major sand (SP) unit was encountered while installing soil boring RS-1, which extended from a depth of approximately 60 feet to 107 feet bgs (107 feet is the total depth of RS-1).

Soils directly below the former Bell facility contained PCE concentrations greater than 5 ppb. However, PCE concentrations in shallow soil and groundwater decrease in a radial manner from the facility and in most cases were below the laboratory quantitation limit (detection limit) near the Source Area CSM Boundary. Some shallow lateral and downward vertical movement (down-gradient movement) of PCE was indicated by concentrations greater than 5 ppb detected in groundwater samples collected from monitor well MW-07 (CPT-32) located south of Barely Lane. Relatively short vertical migration in shallow surface soils and groundwater is contrasted by deep vertical migration of PCE within soil samples collected from soil boring RS-1 (Figure 5), indicating that PCE has migrated primarily downward in the immediate area of the facility and has impacted the first major water-bearing sand unit, and likely others below it, as supported by routine quarterly groundwater monitoring in the Jones Road area.

5.6.2 Regional Conceptual Site Model

Two cross sections (Figures 10 and 11) were prepared using geophysical well logs obtained during installation of the deep monitor wells at the site (deepest well drilled approximately 430 feet bgs), and from deep municipal water wells drilled into the Evangeline Aquifer (deepest well drilled approximately 1,845 feet bgs). The figures also include projections of regional water wells and their screened intervals within the cross section.

Preliminary work performed on the Regional CSM revealed that the subsurface geology is comprised of laterally discontinuous, complex fluvial sediments, comprised primarily of paleo river channels and over-bank deposits. During previous investigations, the depth to the bottom of the Chicot Aquifer/top of top of the Evangeline Aquifer was estimated to be approximately 400 feet bgs, although no apparent physical division between the Chicot Aquifer and Evangeline Aquifer was observed during preparation of the Regional CSM. At the site, five major groundwater bearing units have been identified within the Chicot Aquifer.
A municipal well log for Harris County Municipal Utility District No. 130 (State Well No. 65-04-7; TNRCC Code G1012097A) was drilled to a total depth of 1,845 feet bgs, and multiple well screens were installed from a depth of 592 feet to 959 feet bgs. This well represents the deepest known water well drilled near the study area. The quality of the geophysical logging was poor, and identification of the sand and clay units was not readily apparent. Another municipal water well (G1010016) was drilled to a total depth of 1,455 feet bgs, and at least 12 major water bearing units were identified that could have potential for municipal use.

Four of the upper Chicot Aquifer sands have been impacted by PCE. However, the deepest Chicot Aquifer sand and the Evangeline sands have not been impacted by PCE. Rough estimates of the plume size based on surface distance measurements to impacted water wells at the site suggest that the width is approximately 2,000 feet, the length is approximately 3,000 feet, and the depth is approximately 300 feet. The observed dissolved-phase plume has a complex nature which appears to be controlled by the interaction of regional groundwater flow with water supply wells located around the source area. The varying pumping rates, variable screened intervals, and variation in sand thickness associated with the depositional environment all appear to control the lateral and vertical distribution of the dissolved-phase plume.
6.0 **Baseline Risk Assessment Levels**

Previous investigations have shown that potential use of groundwater and inhalation of indoor air are potential exposure pathways that could contribute to human health risk. The physical characteristics of the chlorinated hydrocarbons being investigated at the site enable them to be classified as volatile organic chemicals (VOCs), as they will evaporate, or volatilize, when in contact with air. The risk assessment focused on PCE and its major degradation products, including TCE, DCE (cis-1,2-DCE and trans-1,2-DCE), and VC at concentrations that have been measured in groundwater and indoor air media.

6.1 **Human Health Evaluation**

6.1.1 **Exposure Assessment**

To evaluate exposure over a range of possible conditions that may exist at the site, two hypothetical degrees of exposure are normally considered in a risk assessment: reasonable maximum exposure (RME) and central tendency exposure (CTE). While the RME does not represent the maximum exposure expected at a site, it does represent the highest exposure that is reasonably expected to occur. The CTE is intended to represent more typical (i.e., central tendency or average) exposure conditions. Because all COPCs identified in groundwater at the site have MCLs, they were designated as COCs and exposures were not evaluated in the BLRA.

Because only two indoor air samples were analyzed, no statistical analysis of the vapor concentration values was made; the exposure assessment was made using the maximum concentration of each COPC.

6.1.1.1 **Groundwater**

To determine the initial COPCs for groundwater, the maximum positively detected value for each contaminant was compared to its risk-based screening level. The risk-based used values are the Medium-Specific Screening Levels (MSSLs) for groundwater provided in USEPA (2007) guidance and the groundwater ingestion (GW\textsubscript{Ing}) protective concentration level (PCL) as specified in 30 Texas Administrative Code (TAC) §350.71(k). The screening levels are associated with a cancer risk of 1E-06 and a systemic non-cancer hazard index (HI) of 1. Where a chemical has risk-based values for cancer and non-cancer endpoints, the lower (i.e., more stringent) value was used for the screen.

If the maximum concentration of a chemical is below the lower of the MSSL and GW\textsubscript{Ing} values, the chemical was removed from consideration in the BLRA. If the maximum concentration of a chemical is above the lower of the MSSL and GW\textsubscript{Ing} values, the chemical was identified as a COPC for groundwater, and the risk from exposure to that chemical was assessed. If a chemical is shown to present either a carcinogenic risk of one-in-one-million (1E-06) to one-in-ten-thousand (1E-04) or greater, or a noncancer HQ greater than one, it is considered a chemical of concern (COC).
At chlorinated solvent sites, PCE and its degradation products are commonly identified as COCs, and their MCLs are selected as cleanup levels in the Record of Decision. The basis for this approach is Office of Solid Waste and Emergency Response (OSWER) Directive 9355.0-30, Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions (USEPA, 1991a), which states that chemical-specific standards that define acceptable risk levels (e.g., MCLs) may be used to determine whether an exposure is associated with an unacceptable risk to human health or the environment and whether remedial action is warranted.

Groundwater screening values are the MSSLs provided in USEPA Region 6 (2004a) guidance and the TCEQ PCL (GWGWIng) value. The MSSL is a risk-based value that corresponds to a cancer risk of 1E-06 or Hazard Index of 1 (USEPA, 2004a). If an MSSL is available for cancer and non-cancer toxic effects, the lower of the two values is used for the screening. Because the risk-based MSSL Residential Water values for PCE, TCE and VC screening values are less than the detection limits for these chemicals in water, the GWGWIng values for these chemicals were used in the screening step to identify COPCs. The MSSL value for cis-1,2-DCE is less than the GWGWIng, and was used in the screening step for cis-1,2-DCE. The GWGWIng value for trans-1,2-DCE is less than the MSSL, and was used in the screening step for trans-1,2-DCE. A summary of the screening values selected is presented in Table 13.

6.1.1.2 Indoor Air

Concentrations of vapor measured indoors at the site were compared to Draft USEPA (2002) air screening levels and Draft TCEQ screening levels based on residential or commercial risk-based exposure levels (AirRBELInh) based on the TRRP rule [30 TAC §350.74]. Site-related contaminants (PCE, TCE, and cis-1,2-DCE) were detected, with PCE and TCE measured above conservative Draft USEPA screening levels in both indoor air samples. None of the compounds in indoor air exceed conservative Draft TCEQ screening levels based on residential or commercial AirRBELInh levels from the TRRP rule.

The VOCs detected in sub-slab soil vapor were PCE, TCE, and cis-1,2-DCE, the same site-related VOCs detected in indoor air. PCE and TCE were detected in both sub-slab soil vapor samples at concentrations well above Draft USEPA and Draft TCEQ screening values for sub-slab soil vapor designed to be protective of indoor air. Shaw examined these sub-slab soil vapor concentrations along with their co-located indoor air samples to calculate site-specific attenuation factors, which ranged from 0.0002 to 0.0009, indicating very low migration of vapors from the sub-slab to indoor air. The comparison for these site-related compounds indicates that, although intrusion of vapor through the slab is potentially a complete pathway, very little vapor is currently migrating from the sub-slab soil into indoor air.

6.1.2 Toxicity Assessment

6.1.2.1 PCE

High concentrations of PCE (particularly in closed, poorly ventilated areas) can cause dizziness, headache, sleepiness, confusion, nausea, difficulty in speaking and walking, unconsciousness, and death. Irritation may result from repeated or extended skin contact. These symptoms occur
almost entirely in work (or hobby) environments when people have been accidentally exposed to high concentrations or have intentionally used PCE to get a "high." In industry, most workers are exposed to levels lower than those causing obvious nervous system effects. The health effects of breathing in air or drinking water with low levels of PCE are not known. Results of animal studies, conducted with amounts much higher than those to which most people are exposed, show that PCE can cause liver and kidney damage (source of the RfDo). Exposure to very high levels of PCE can be toxic to the unborn pups of pregnant rats and mice. Changes in behavior were observed in the offspring of rats that breathed high levels of the chemical while they were pregnant.

The Texas Department of State Health Services (TDSHS) has determined that PCE may be reasonably anticipated to be a carcinogen. PCE has been shown to cause liver tumors in mice and kidney tumors in male rats. The slope factor used in the BLRA is from the California Environmental Protection Agency (Cal-EPA).

### 6.1.2.2 TCE

Breathing small amounts of TCE may cause headaches, lung irritation, dizziness, poor coordination, and difficulty in concentration. Breathing TCE for long periods may cause nerve, kidney, and liver damage. Drinking TCE for long periods may cause liver and kidney damage, impaired immune system function, and impaired fetal development in pregnant women, although the extent of some of these effects is not yet clear. Skin contact with TCE for short periods may cause skin rashes.

Some studies with mice and rats have suggested that high levels of TCE may cause liver, kidney, or lung cancer. Some studies of people exposed over long periods to high levels of TCE in drinking water or in workplace air have found evidence of increased cancer. Although there are some concerns about the studies of people who were exposed to TCE, some of the effects found in people were similar to effects in animals. In its 9th Report on Carcinogens, the National Toxicology Program (NTP) determined that TCE is “reasonably anticipated to be a human carcinogen.” The International Agency for Research on Cancer (IARC) has determined that TCE is “probably carcinogenic to humans.”

Two inhalation slope factors are used for TCE in the BLRA: a low-end SFi from Cal-EPA, and a high-end SFi from the National Center for Environmental Assessment (NCEA).

### 6.1.2.3 cis-1,2-DCE

Cis-1,2-DCE is not classifiable as to human carcinogenicity. The basis for its Class D designation is the lack of data in humans or animals and generally nonpositive results in mutagenicity assays. This liquid can act as a primary irritant producing dermatitis and irritation of mucous membranes, and is toxic by ingestion, inhalation, and skin contact. Inhalation causes nausea, vomiting, weakness, tremor, cramps, and central nervous depression. Repeated exposure of cats and rabbits to vapor concentration of 0.16 to 0.19% in air showed loss of appetite, decrease in body weight, and pathological changes in lung, liver, kidney tissue.
Cis-1,2-DCE is not mutagenic to E. Coli K-12 or salmonella typhimurium when incubated in presence of metabolically active mouse liver enzymes. Cis- and trans-1,2-dichloroethylene were tested for mutagenic effects in a diploid strain (D7) of yeast Saccharomyces cerevisiae in suspension tests with and without a mammalian microsomal activation system, a S9 mouse liver fraction, and by an in vivo intrasanguineous host-mediated assay. The effects of the same agents on other enzyme systems showed that only the cis-isomer showed evidence of mutagenic activity. Such mutagenic activity was found after acute and chronic doses and in the liver, kidney, and lung tissue. The mutagenicities of organic chemical contaminants in city water and related compounds were examined by the Salmonella/microsome test (Ames test). Cis-1,2-DCE was not mutagenic in the test system.

6.1.2.4 trans-1,2-DCE

Trans-1,2-DCE is toxic by ingestion, inhalation, and is a skin contact irritant inhalation of at high levels causes nausea, vomiting, weakness, tremor, and central nervous depression contact. 1,2-DCE has been used as a general anesthetic in humans. Exposure to the trans-isomer at 2200 ppm caused burning of the eyes, vertigo, and nausea. Occupational exposure to trans-1,2-dichloroethylene may occur through inhalation and dermal contact with this compound at workplaces where trans-1,2-dichloroethylene is produced or used. Monitoring data indicate that the general population may be exposed to trans-1,2-dichloroethylene via drinking water.

The mutagenicity of several chlorinated ethylenes was tested on E. Coli strain K-12 in culture medium containing mouse liver microsomes metabolic activation system. 1,2-trans-DCE was not mutagenic in this test and was not mutagenic in tests using salmonella typhimurium strains in vitro without metabolic activation, or in vivo with a cytogenetic analysis of bone marrow cells from female mice.

Inhalation studies were performed on both mature female SPF Wistar rats and mature female NMRI mice. Histopathological organ changes were observed after single or repetitive doses of trans-1,2-DCE at 200 ppm including slight to severe fatty degeneration of the hepatic lobules and Kupffer cells over the controls.

6.1.2.5 VC

Breathing high levels of VC can cause dizziness or drowsiness, and breathing very high levels can cause unconsciousness or even death. Some people who are repeatedly exposed to high levels of VC have developed changes in liver structure, nerve damage, and immune reactions. The lowest levels that produce these effects in people are not known. The effects of drinking high levels of VC are unknown. When in contact with the skin, it can cause numbness, redness, and blisters. Animal studies have shown that long-term exposure to VC can damage the sperm and testes, as well as cause changes in liver structure (source of the RfDo).

VC is a known carcinogen (Class A). Studies in workers who have breathed VC over many years showed an increased risk of liver cancer. Brain cancer, lung cancer, and some cancers of the blood also have been observed in workers.
6.1.3 Risk Characterization

6.1.3.1 Carcinogenic Risk Results

Indoor Air

These risk results for inhalation of indoor air are not modeled, but are based on direct measurements of indoor air. Because they do not account for any possible background sources of VOCs, the cancer risks and noncancer hazards are expected to be overestimated. Risk from inhalation of indoor air was calculated for the adult and child resident, and the adult on-site worker. Carcinogenic risk from exposure to indoor air is presented as a range, due to the use of “high-end” and “low-end” slope factors (SFs) for vinyl chloride, as well as evaluation of cancer risk for VC based on the ages at which exposure would theoretically begin.

Estimated cancer risk for the hypothetical resident at the Center Room location ranged from 3.6E-05 to 7.2E-05 in the case of the adult resident. For the child resident, the estimated inhalation risk is 1.7E-05. The estimated cancer risk for a hypothetical indoor worker at the Center Room location was 1.4E-05. All cancer risk estimates are within the acceptable range of 1E-06 to 1E-04 established by USEPA (1989) guidance.

6.1.3.2 Non-Carcinogenic Risk Results

Indoor Air

Hazard from inhalation of indoor air was calculated for the adult and child resident, and the adult on-site worker. The estimated non-cancer hazard for the hypothetical resident at the Center Room location was 9.1E-02, well below the acceptable HI of 1. For the child resident, inhalation hazard was estimated as 2.0E-01, which is below the acceptable HI value established by USEPA (1989) guidance. The estimated non-cancer hazard for the hypothetical indoor worker at the Center Room location was 3.9E-02.

6.2 Environmental Evaluation

Potential ecological risks for the site were evaluated according to the Tier 1 Ecological Criteria Checklist specified in Title 30 of the Texas Administrative Code [30 TAC §350.77(b)]. Based on this checklist, no action is required at the Jones Road site to protect ecological receptors. The completed Tier 1 Tier 1 Ecological Criteria Checklist is shown in Appendix D.
7.0 Interim (Emergency) Remedial Action for Protection of Human Health

7.1 Installation of Granular Activated Carbon Filtration Units

The TCEQ installed GAC filtration units on all water wells (including water supply systems) as soon as they were confirmed (through quarterly groundwater monitoring) to be impacted with PCE at concentrations equal to or above the MCL (5 µg/L). The GAC filtration systems generally include a flow meter, two cartridge-type particulate filters, two GAC vessels connected in series, three sample ports, all contained within a small weather-proof shed. Following installation of the GAC units, routine servicing and maintenance was performed by Culligan Ultrapure Industrial Services (previous contractor was Carbonair), and quarterly sampling was performed by Shaw to ensure that they continued to remove PCE from groundwater. Quarterly GAC filtration unit sampling was performed by collecting a sample before the first GAC unit sample port for raw water analysis, sample port between the GAC vessels to determine if the first GAC vessel is effectively capturing PCE and break-through from the first GAC unit, and from the sample port after the second GAC vessel, which is installed to capture PCE in case of breakthrough. In the event that PCE is detected past the second sample port, the first GAC vessel is removed from service, and the second GAC is moved to the first position. A new GAC vessel is subsequently installed in the second GAC position. A labeled photograph of a typical GAC unit is presented on Figure 33.

7.2 Installation of Waterline

The USEPA and TCEQ are currently funding a project to install a waterline at the site to provide municipal water to the area, which is intended to replace individual water wells used for potable water consumption. The installation of the waterline is scheduled to be completed in July 2008, and connections to individual businesses and residences in the area are expected to be finished by November 2008. A map showing the boundaries of the waterline service to be provided at the site is presented on Figure 34.

Since the initiation of the water line effort in 2005, property owners have been provided information about the water line and have had the opportunity to voluntarily participate in the government-funded water line project. The TCEQ developed a legal document, entitled Alternative Water Connection Agreement (Agreement) which defined the terms for property/well owners to participate in the government-funded water line project. A copy of the Agreement is presented in Appendix G.

In 2007, the USEPA and the TCEQ signed a Removal Action Contract (RAC) with the specified purpose of constructing a water line to eliminate risks to human health and the environment from the groundwater plume. The RAC was a time critical removal action which initiated/funded the construction of water mains and connections to homes and businesses within the designated water service boundaries (Figure 34). The primary actions of this project under the RAC include 1) acquisition of a sufficient water supply with enough capacity to serve the general Jones Road site area; 2) the survey, design, installation and testing of water supply line(s) from a
water supply authority to the general Jones Road site area; and 3) the design, installation and testing of supply lines connecting individual residences or businesses to the area supply lines.

The number of eligible properties/tracts within the designated water service boundaries is approximately 240 (+/- 10% due to property transactions). Below is a summary of water line/participation information, as of August 2008:

- There are approximately 240 (+/- 10%) properties/tracts within the designated water line service boundaries.
- There are 35 wells with filtration systems in the designated water line service boundaries.
- 158 well owners have signed TCEQ Agreements.
- There are 28 water wells equipped with filtrations systems with signed TCEQ Agreements from the owners.
- There are seven water wells with filtration systems without signed TCEQ Agreements from the owners.
- There are ten well owners that have signed with the water service provider, but did not sign the TCEQ Agreement.
8.0 Summary and Conclusions

8.1 Summary

PCE has impacted soils and groundwater in the immediate vicinity of the former Bell facility, located within the Cypress Shopping Center at 11600 Jones Road. The PCE-impacted soils and groundwater at the Bell facility are the source of an extensive dissolved-phase groundwater plume that has impacted the Chicot Aquifer (used as a source of drinking water) below the adjacent neighborhood primarily west and southwest of the Bell facility. GAC filtration units were installed on wells screened within the aquifers as a temporary precaution to prevent consumption of impacted groundwater, and quarterly sampling of wells and GAC filtration systems in the area was implemented to identify any new detections of PCE in water wells and monitor the operation of the GAC filtration units.

8.1.1 Nature and Extent of Contamination

PCE was likely discharged as DNAPL directly behind the Bell facility and into a floor drain using unauthorized disposal practices, and was transported vertically to soils below the site. Contact between the PCE DNAPL and groundwater resulted in a dissolved-phase PCE plume with a width of approximately 2,000 feet, length of approximately 3,000 feet, and a depth of approximately 300 feet. The dissolved-phase PCE plume appears to be relatively stable in the neighborhood areas. PCE impact to soils in the source area is relatively small, with an aerial extent approximately 300 feet long and 120 feet wide. Groundwater in the shallow GBU (<35 feet bgs) appears to be moving in a southwesterly direction (as indicated by increasing PCE concentrations in one down-gradient well), which indicates that DNAPL or high-concentration dissolved-phase PCE may still remain below the Bell facility. PCE is the predominant compound detected in the groundwater samples taken from the domestic wells, with little evidence of biodegradation into its daughter products. The biodegradation of PCE into its daughter products is more evident in the on-site monitor wells.

8.1.2 Fate and Transport

PCE within soils below the former Bell facility provide a continuous source of contamination to shallow WBUs. The fluvial nature of subsurface strata may provide preferential pathways for contaminant transportation from the shallow WBUs to the deeper aquifers through coalescing paleo river channels or overbank deposits. Groundwater withdrawals through water wells may also influence the direction of plume movement toward the neighborhood, especially during seasons of high water demand. Migration to deeper WBUs in the Chicot Aquifer and upper Evangeline Aquifer may be limited by aquitards that separate the sand units.

8.1.3 Risk Assessment

PCE and daughter product concentrations in groundwater exceed federal MCLs and pose a risk to human health if consumed.
8.2 **Conclusions**

Unauthorized disposal of waste PCE behind the former Bell facility has resulted in contamination of soils and the Chicot Aquifer, which is a source of drinking water in the area. The waste likely still remains and may continue to provide a source of contamination to underlying groundwater-bearing units. The contaminants, if not treated with GAC filtration units, would be an immediate threat to human health. The dissolved-phase PCE plume appears to be relatively stable, but threatens down-gradient drinking water wells and deeper drinking water aquifers.

8.2.1 **Data Limitations and Recommendations for Future Work**

Sufficient groundwater and soil analytical results of useable quality have been obtained for proper evaluation of the study area, and the study area is sufficiently defined except for the following:

- The vertical extent of soil and groundwater impact in the source area is relatively unknown, as an attempt to install a deep well in the source area failed. Installation of one or more wells in the area, and collection of soil and groundwater samples during the installation is recommended.

- A groundwater pump test has not been conducted to determine site-specific characteristics of the Chicot Aquifer, although some well yield information is available from well tests performed following installation of private water wells.

- Aquifer testing of the shallow groundwater zone will be performed during the feasibility study phase of work to define the groundwater classification.

- Groundwater modeling specifically at the site is recommended to determine the nature of current (pumping) and future (non-pumping or reduced pumping) conditions related to installation of the municipal water line and subsequent de-commissioning of water wells. The modeling is equally important for evaluation of potential remedial options at the site.

8.2.2 **Recommended Remedial Action Objectives**

The remedial action objectives for the site are based on the guidance document *Presumptive Response Strategy and Ex-Situ Treatment Technologies for Contaminated Ground Water at CERCLA Sites* (USEPA, October 1996). The remedial action objectives, listed in the sequence in which they should generally be addressed for the site would be:

- Prevent exposure to contaminated groundwater, above acceptable risk levels;
- Prevent or minimize further migration of the contaminant plume (plume containment);
• Prevent or minimize further migration of contaminants from source materials to groundwater (source control); and
• Return groundwater to the expected beneficial use wherever practicable (aquifer restoration).
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Figures
Tables
Appendix A

Technical Memorandum and Referenced Reports
Appendix B

State of Texas Well Reports
Appendix C

Geophysical Logs
Appendix D

TCEQ Tier 1 (Ecological) Exclusion Criteria Checklist
Appendix E

Analytical Data and QA/QC Evaluation Results
(including data validation reports)
Appendix F

Waste Manifests
Appendix G

Alternative Water Connection Agreement