GROUNDWATER MODEL IDENTIFICATION REPORT
Jones Road Groundwater Plume Superfund Site
Houston, Texas

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Acronyms and Abbreviations

ASTM	American Society for Testing and Materials
Bell facility	Bell Dry Cleaners site
bgs	below ground surface
CSM	conceptual site model
DCE	1-,2-dichloroethylene
DNAPL	dense nonaqueous phase liquid
EPA	U.S. Environmental Protection Agency
ft/d	foot (feet) per day
g/cm^3	gram(s) per cubic centimeter
GPS	global positioning system
K_{ow}	octanol-water partition coefficient
MCL	maximum contaminant level
PCE	tetrachlorothylene
PWS	public water supply
Shaw	Shaw Environmental & Infrastructure, Inc.
SOP	Standard Operating Procedure
TCE	trichloroethene
TCEQ	Texas Commission on Environmental Quality
USGS	U.S. Geological Survey
VC	vinyl chloride

1.0 Introduction

The Texas Commission on Environmental Quality (TCEQ), through a Cooperative Agreement with the U.S. Environmental Protection Agency (EPA), is undertaking a remedial investigation in the residential and commercial area surrounding the former location of the Bell Dry Cleaners site (Bell facility). The Bell facility was located at 11600 Jones Road, Houston, Texas. The Jones Road Groundwater Plume Site (Jones Road site) is located approximately one-half mile north of the intersection of Jones Road and FM 1960, outside the Houston city limits in northwest Harris County (Figure 1). The groundwater is contaminated with tetrachlorothylene (PCE), trichloroethene (TCE), cis-1-,2-dichloroethylene (DCE), trans-1-,2-DCE, and vinyl chloride (VC). The extent of the plume has been documented from the southern end of Echo Spring Lane to Tower Oaks Boulevard and from Timber Hollow Drive to the eastern side of Jones Road. PCE concentrations measured in November 2007 are presented in Figure 2.

1.1 Site History

The contaminants PCE, DCE, and chloromethane were first detected in a public water supply (PWS) well (PWS Number 1012358) in December 2000; this PWS well has supplied Finch's Gymnastics USA and Childcare for nearly 22 years. PWS well samples collected in January and May of 2001 showed PCE, cis-1-,2-DCE, trans-1-,2-DCE, and chloromethane at concentrations exceeding the EPA maximum contaminant level (MCL) for drinking water. The MCLs are:

- PCE – 5 parts per billion (ppb)
- TCE – 5 ppb
- cis-1-,2-DCE – 70 ppb
- trans-1-,2-DCE – 100 ppb
- VC – 2 ppb

In March 2002, PCE was confirmed in residential wells. During the 2001–2002 timeframe, shallow monitoring wells were installed by the owner of the former Bell Cleaners while in the TCEQ Voluntary Cleanup Program. The groundwater sampling results at these monitoring wells indicated that shallow groundwater (approximately 30 feet below ground surface [bgs]) was contaminated with PCE, TCE, DCE, and VC, all of which were detected at concentrations above their respective MCLs.

Approximately 231 PWS and private wells have been identified within a one-half-mile radius of the former Bell facility. Filtration systems have been installed on wells where PCE has been detected at levels exceeding the MCL; an additional filtration system was installed on a well where PCE concentrations are below the MCL, at the request of the owner. Between 100 and 150 residential wells are monitored on a quarterly basis.

1.2 Approach

A 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 for the Jones Road site. Relevant American Society for Testing and Materials (ASTM) standards, as outlined in the Shaw Environmental & Infrastructure, Inc. (Shaw) Standard Operating Procedure (SOP) EI-GS063 (Appendix A) will be followed. The Shaw SOP EI-GS063 outlines the scope of the groundwater model, as well as the process for review and approval of the modeling results.

Calibration of the model will be conducted by trial and error methods (Anderson and Woessner, 1992), the automatic calibration routines available in current versions of MODFLOW, or some combination of both approaches. Calibration of the model will meet the ASTM standards.

2.0 Conceptual Site Model

Two primary hydrostratigraphic units have been defined for the Jones Road site based on geologic and hydrogeologic information available. The Chicot Aquifer comprises one of the hydrostratigraphic units and is composed of the youngest water-bearing unit in the Coastal Plain of Texas. The unit is laterally discontinuous and includes fluvial-deltaic deposits of gravel, sand, silt, and clay. The presence of the Chicot Aquifer in the subsurface can be delineated by a higher sand-clay ratio relative to the underlying Evangeline Aquifer (Baker, 1979). A thick sequence of laterally discontinuous, interbedded sand and clay layers separates the shallow sediments of the Chicot Aquifer from the deeper layers (Kasmarek and Strom, 2002). This sequence of interbedded sand and clay layers results in a weak hydraulic connection between the Chicot Aquifer and the land surface. The Chicot Aquifer is commonly differentiated from the Evangeline Aquifer on the basis of its contrasting, relatively lower transmissivity. A weak hydraulic connection exists between the Chicot and Evangeline Aquifers, allowing for water to move vertically between the two hydrostratigraphic units.

The second hydrostratigraphic unit identified for the Jones Road site is the Evangeline Aquifer that underlies the Chicot Aquifer. The top of the Evangeline Aquifer is located at a depth of 300 to 400 feet bgs in the vicinity of the Jones Road site. This second aquifer is geologically similar to the Chicot Aquifer in that it is composed of fluvial-deltaic deposits of gravel, sand, silt, and clay. The Evangeline Aquifer is one of the more productive aquifers in the Houston area (Baker, 1979).

Both the Chicot and Evangeline Aquifers outcrop inland of the coast. All of Harris County lies within the Chicot Outcrop Area, as mapped by the U.S. Geological Survey (USGS) (Figure 3). The Evangeline Outcrop Area is situated immediately north of Harris County

(Figure 4). 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, updip sections of the Chicot Aquifer. Towards the south, the Chicot Aquifer acts as a confined system, with exchange to and from the shallow sediments impeded by the interbedded sand and clay layers. In the area of the Jones Road 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 (Figure 4). South of the outcrop area, the aquifer acts as a confined system. The Jones Road site lies approximately 25 miles south of the Evangeline Outcrop Area and is therefore believed to be a confined system (Kasmarek and Strom, 2002).

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 recharge and discharge in the area of the Jones Road site is also affected by water withdrawal from the aquifers due to groundwater development (e.g., commercial and residential water supply wells). Harris County is one of the principal areas of groundwater withdrawal, along with 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 Houston and Galveston Counties Service District.

The regional groundwater flow direction in Harris County is generally south-southeast (Kasmarek and Strom, 2002). The large number of PWS and private wells within Harris County and, more specifically, the Jones Road site, may locally affect the local groundwater flow directions. Data logger information obtained from five wells within the Jones Road site indicates that the local groundwater flow direction varies from south, southeast, and southwest in the Chicot Aquifer. However, more recent and complete data collected from deeper wells completed in the Chicot (Shaw, 2007) indicate that flow is more to the southeast. This is consistent with other published reports of groundwater flow in the area (Kasmarek and Houston, 2007).

Shallow groundwater and soil boring samples indicate that the former Bell Dry Cleaners is the most likely source of contamination at the Jones Road site. The contaminant PCE has been detected very close to the former Bell facility, which is assumed to be the primary discharge area. Due to the fact that the specific gravity of PCE (1.62 grams per cubic centimeter [g/cm^3])

is greater than that of water (1.0 g/cm^3), it is believed that PCE migrated downward through the geologic strata to the deeper groundwater as a dense nonaqueous phase liquid (DNAPL).

In the subsurface, movement of the DNAPL is due to gravity and groundwater flow, with secondary lateral migration. Lateral movement of the plume most likely occurs as the dissolved phase from the DNAPL source. The weak hydraulic connection between the Chicot and Evangeline Aquifers may result in migration of the contaminant between the two aquifers.

Figure 5 shows a simplified geologic cross section for the site. Figure 6 illustrates a simple conceptual site model (CSM) for the Jones Road site. More detailed CSMs are being prepared separately for (1) the contaminant source area and (2) the entire site (i.e., on the scale of Figure 2).

The remainder of this report focuses on data and site-specific parameters that will be input to the numerical model. For reference, Appendix B contains a memo from Shaw to the TCEQ dated December 17, 2007. This memo lists parameters required for the model and was reviewed and approved by the TCEQ.

3.0 Model Design

The following sections describe the primary design elements of the groundwater flow model for the Jones Road site. The elements described include the model code selected, assumptions made during CSM and modeling design, the model grid and layering, boundary conditions, and the properties assigned to the aquifer.

The Jones Road 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.

3.1 Model Code

The Jones Road site model will be developed using a recent version of the code MODFLOW (McDonald and Harbaugh, 1988) 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). The code 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. In addition, MT3D is capable of modeling advection-dominated transport problems as well as assessment of natural attenuation and degradation in groundwater systems. MT3D does not consider DNAPL migration.

3.2 Model Grid

The long axis of the model grid will be oriented parallel to the dominant direction of groundwater flow. Figure 7 illustrates the approximate model domain with respect to PWS wells that have been identified within a 3-mile radius of the Jones Road site. The model domain will be defined by a 298-row by 280-column, uniformly spaced, finite-difference grid. Each cell will be no more than 100 feet long in the x direction and 100 feet long in the y direction. The number of rows and columns may be adjusted during the actual implementation of the model. The long axis of the model grid has a total length of 5.6 miles. The width of the grid along the shorter axis is 5.3 miles. The model grid will be oriented parallel to the primary direction of groundwater flow, which is believed to be approximately southwest, within the model domain.

3.3 Model Grid Layers

The number of layers used in the model design may be between 8 and 10, depending on which number of layers results in a numerically stable model. The subsurface geology will also be taken into consideration when designing the number of model layers, and a grid block size ratio of horizontal to vertical will be maintained at no more than 2:1.

3.4 Wells

A total of 367 wells have been identified within a 3-mile radius of the Jones Road site (TCEQ, 2007a and 2007b). This number includes the private wells shown in Figure 8 and the PWS wells shown in Figure 7. Each active well will be incorporated into the model as sink terms where water is withdrawn from the groundwater flow system. Pumping rates, screened intervals, and water levels will all be input into the model in order to simulate current flow conditions at the Jones Road site. Considerable uncertainty exists regarding the location, screened interval, and pumping rate for many of the wells.

3.4.1 Public Water Supply Wells

Numerous PWS wells are located within the proposed model domain for the Jones Road site (Figure 7). Each of the active PWS wells that have been identified to exist in the model domain will be included in the model simulations as sink terms. The pumping rates used for each of the wells will be based on either information available in the well logs or estimations of typical pumping rates for a given application (e.g., commercial water use).

Data Gaps

Table 1 lists the PWS wells that are known to exist within the model domain and those wells for which key parameters are not known, such as the coordinates, screened interval, or pumping rate. The pumping rate applied at each of these wells may have a significant effect on the ability to accurately describe plume dynamics at the Jones Road site. Shaw will use the information in TCEQ (2007b) to obtain as much well-specific data as possible.

In addition to the pumping rates, it is imperative that the wells are accurately placed in the model. Figure 7 was developed from a four-page map included in the well logs that were provided to Shaw. A list of each of the well locations from this map with the associated latitude and longitude is required to incorporate the wells into the model grid. If the coordinates are not readily available, it is suggested that a global positioning system (GPS) be used to obtain coordinates (see Section 3.4.2 for a discussion of preferred GPS technology). In the absence of any new well location data collected by GPS, Shaw proposes to use coordinates from the Harris County appraisal district base maps.

3.4.2 Private Wells

Approximately 310 private wells are known to be located within the Jones Road site (Figure 8). In November 2007, samples were collected from 176 of these wells and analyzed for organic compounds, including PCE. Filtration systems have been installed on 33 of the private wells. Groundwater data from the most recent quarterly sampling event will be used in the model. Each of the private wells that are actively used by the property owners will be included as sink terms in the model. A pumping rate will be assigned to the wells based on either available information for the well or estimations of typical pumping rates.

Data Gaps

Of the 176 wells that were sampled in November 2007, 78 of these wells are not shown on the maps provided. Table 2 summarizes the private wells in the model domain that are not indicated on maps available at the time of this report. Values for the latitude and longitude of all the private wells are necessary in order to accurately place the wells in the model domain.

Although there is a dense canopy over much of the Jones Road area where private wells and monitoring wells exist, current GPS technology can be successfully used to obtain one centimeter accuracy in the X and Y direction and near two centimeter accuracy in the Z direction in most instances where previous and now outdated GPS systems have failed.

Shaw would use a Topcon GR-3 Real Time Kinematic (RTK) GPS to complete this task. Topcon's GR-3 incorporates G3 tracking technology that supports access to the United States' based satellite GPS network along with the Russian Glonass and European Galileo signals.

Initially, a temporary base station would be set up at a known permanent benchmark in the area of the site. If a benchmark is unavailable, Shaw is capable of establishing a benchmark for the site using this system setup. Once the base station and/or benchmark(s) have been established, a Topcon GR-3 Rover would be utilized to establish X, Y, and Z coordinates at each private/monitoring well that requires survey activities.

If access to private property is not attainable, Shaw would utilize a TruPulse 360 laser rangefinder. This system is fully compatible with Topcon's GR-3 RTK GPS. The use of this laser rangefinder will eliminate the need to physically enter private property to survey a well. This system has limitations and is highly site dependent. Typically a clear, unobstructed view from the rover to the intended survey target is required (e.g., a clear view from the street to the homeowner well).

Data would be collected in the field and made available for uploading into GIS by means of exporting the collected data as shape files. Survey grade site maps could be generated as a result of these activities.

As stated in Section 3.4.1, if it is not possible to collect new GPS data, then Shaw recommends the use of the Harris County Appraisal District maps as the most accurate and consistent base map for the model.

The screened interval for many of the private wells is currently unknown, though some data have been provided by the TCEQ. Knowing screened intervals for each of the wells will ensure that the water extracted from the wells comes from the correct aquifer (e.g., Chicot verses Evangeline); most wells are less than 400 feet bgs and are assumed to be completed in the Chicot Aquifer. It is acknowledged that some well construction details may be present in the TCEQ well data base (TCEQ, 2007b). All of this information will help to develop a more thorough understanding of the PCE plume. Information on the household usage (gallons per month) and filtration systems is also requested for model completion. The usage rates for each of the private wells are expected to have a considerable effect on plume dynamics for the Jones Road site; therefore, it is preferable to obtain as much information as possible for this parameter. Calculations by the TCEQ put estimated pumping rates in the range of 30–50 gallons per minute (M.C. Long, Memo to USEPA, October 17, 2007).

3.5 Flow Conditions

Flow conditions for the Jones Road site groundwater flow and solute transport model will be simulated initially as an unconfined, homogeneous, and isotropic aquifer under steady-state conditions. In addition, simulations will be completed as unconfined in a heterogeneous and isotropic aquifer under steady-state conditions. Two zones of hydraulic conductivity in the model represent the fluvial-deltaic deposits observed in both the Chicot and Evangeline

Aquifers. A third hydraulic conductivity zone will be applied to the model domain to simulate the interfingering and laterally discontinuous clay and caliche layers that separate the shallow aquifer materials from the deeper layers of the Chicot Aquifer. The transmissivity of the model grid varies during the model simulation period and is calculated from the saturated thickness and the hydraulic conductivity specified (McDonald and Harbaugh, 1988).

3.6 Boundary Conditions

3.6.1 Wells

Each well in the model domain that is used to supply water to commercial and residential areas will be treated as constant flux boundary conditions. Constant flux boundary conditions are assigned to the grid cell(s) containing a well at a pumping rate such that the grid cell will represent a drain on the groundwater system. A more detailed discussion of the wells in the vicinity of the Jones Road site and the identified data gaps is provided in Section 3.4.

3.6.2 Constant-Head and No-Flow Boundaries

The upper boundary of the model grid will be simulated as a free-surface boundary to simulate the water table within the Chicot Aquifer. The free-surface elevation is varied during the simulation period and is calculated during the solution of the model (McDonald and Harbaugh, 1988).

The lower boundary is simulated as a no-flow boundary because it is assumed that the vertical flow of groundwater in the Evangeline Aquifer to the underlying aquifer material is negligible.

The eastern and western boundaries of the model domain will be treated as constant hydraulic head boundaries. The constant-head boundaries will simulate the observed horizontal gradients at the Jones Road site. The head values will be calculated from observed heads in wells along both boundaries using an assumed constant gradient.

The model grid will be oriented such that it is parallel to the primary direction of groundwater flow. Therefore, the northern and southern grid boundaries will be no-flow boundaries.

Water level monitoring data collected from wells within the Jones Road site will be used to calculate the average head values and the hydraulic gradient. Groundwater gradients were monitored at 19 monitoring wells, starting in August of 2003. The average head for each monitoring well over time will be calculated. The average head calculations will then be used to determine the hydraulic gradient for the Jones Road site and constant-head boundary values.

Data Gaps

Shaw currently has water level data collected in August 2007 at nine of the monitoring wells located within 1 mile of the Bell facility (Figure 8) as well as contour maps for water levels

measured between March and August 2007. Water level data for additional wells throughout the model domain are requested as these will lead to a more thorough understanding of groundwater conditions within the model domain and also help to develop a more robust, calibrated model. Kasmarek and Strom (2002) indicate that the USGS regularly monitors water levels in 480 wells in Harris, Galveston, and surrounding counties that are screened within the Chicot and Evangeline Aquifers. It is recommended that the USGS water level data be obtained for wells within the study area for inclusion in the groundwater model.

4.0 Aquifer Properties

4.1 Recharge

Recharge will be included in the groundwater flow and transport model for the Jones Road site. In an effort to reflect actual recharge conditions across the model domain, recharge will not be uniform across the entire surface area and instead will be modeled as recharge zones. In areas where extensive concrete/pavement surfaces are present, recharge will be considered negligible and set to a value of zero. In areas immediately adjacent to the concrete/pavement surface areas, the recharge value will increase to reflect the combined factors of precipitation and surface runoff. A third recharge value will be assigned to areas of predominant vegetation where precipitation is considered to be the primary factor affecting recharge rates. The values input for each of the three recharge zones will be based on mean annual precipitation values for Harris County, collected from the National Oceanic and Atmospheric Administration climate database. The assignment of recharge zones will be addressed when the model domain is fixed and justified during model calibration.

4.2 Hydraulic Conductivity

The Chicot Aquifer is a heterogeneous unit consisting of fluvial-deltaic deposits of gravel, sand, silt, and clay (Kasmerek and Strom, 2002). The hydraulic conductivity for the Chicot Aquifer in the vicinity of the Jones Road site will be modeled as two zones. Zone 1 will represent the fluvial sand material found predominantly in the region, and Zone 2 will represent the lenses of clay. The values for the aquifer will be estimated from the analysis of aquifer tests conducted at eight PWS wells that are located within a 1- to 3-mile radius of the Bell facility (Figure 7). In addition, hydraulic conductivity values reported in published literature sources will also be referenced to develop the hydraulic conductivity zones.

The spatial distribution of the hydraulic conductivity zones will be based on geologic cross sections developed using available well logs for the area. Hydraulic conductivity values range from 14 to 35 feet per day (ft/d) in the Chicot Aquifer within Harris County (Young et al., 2006). The hydraulic conductivity of the Evangeline Aquifer varies between 20 to 100 ft/d (LDEQ, 2003).

Data Gaps

Geologic cross sections that localize the model domain, and therefore the Jones Road site, are necessary in order to accurately simulate the relationship between the Chicot Aquifer; the interbedded sand, clay, and caliche horizons; and the Evangeline Aquifer. Slug tests conducted in wells that are located within 1 mile of the Bell facility would be beneficial for estimating hydraulic conductivity values for the model.

4.3 Porosity

Porosity values will be determined from published literature sources for the Chicot Aquifer; the interbedded sand, silt, and caliche horizons; and the Evangeline Aquifer. Three separate porosity zones may be established to simulate the three material types that are believed to exist in the subsurface around the Jones Road site. The spatial distribution of porosity will be based on geologic cross sections developed using available well logs for the area.

5.0 Transport Properties

5.1 Initial Conditions

Initial conditions for the Jones Road plume dynamics model will be equal to the concentration distribution of the existing plume, as indicated by the most recent groundwater sampling results available when modeling begins. The PCE concentration 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.

Data Gaps

The May 2007 groundwater sampling analytical results will be contoured in order to obtain an understanding of the current size and shape of the PCE plume for the Jones Road site. Coordinates for the wells where groundwater samples have been collected are required for accurately simulating the initial conditions of the PCE plume. If well coordinates are not available and cannot be obtained, then approximate locations indicated on a site map would suffice.

Data for the daughter products of PCE (e.g., TCE, DCE, and VC) are also requested for use in transport simulations.

5.2 Boundary Conditions

Specified concentration conditions (constant concentration conditions) will be defined at depths where PCE has been detected in both soil and groundwater samples. Soil samples collected during the installation of monitoring wells and Geoprobe boreholes at the Jones Road site will be used to determine the depth of the PCE plume. The contaminant PCE is considered a DNAPL

and therefore will be modeled as a constant concentration in a specific node, due to the fact that dissolved concentrations of PCE in groundwater near the PCE plume can be expected to remain relatively high and essentially constant.

5.3 Chemical Parameters

The octanol-water partition coefficient (K_{ow}) of PCE will be estimated from values available in the literature. Linear sorption will be incorporated into the model through the input of a retardation factor. The value for the retardation factor will be estimated by matching the observed plume movement documented during quarterly groundwater sampling events to what is calculated during model simulations run with zero retardation. This approach for estimating retardation factors has been documented by Roberts et al. (1986). Contour plots will be generated for groundwater sampling results. Over a fixed period, concentrations of PCE daughter products for the same time period will also be examined. This method (analyzing PCE and daughter product concentrations at fixed wells over a fixed time period) will allow for the estimation of the retardation factor for each of the daughter products for use in the transport model simulations.

5.4 Diffusion and Dispersion

Initial approximations of dispersivity values for the model domain will be obtained from literature resources such as Gelhar et al. (1992). The research conducted by Gelhar et al. (1992) relates the scale of field aquifer conditions that are being simulated to values of longitudinal dispersivity. The horizontal dispersivity will be set to a value that is one order of magnitude smaller than the longitudinal dispersivity used in the simulations. The values of the dispersivity used in the model will be justified during model calibration.

6.0 Evaluation of PCE Plume Dynamics

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.

During the preliminary, simplified simulations it will be assumed that adsorption of PCE in the aquifer materials is negligible. A value of 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

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 will be based on model results and discussions with the TCEQ.

7.0 Data Gap Summary

The following information is still required for both the PWS and private wells that are within a 3-mile radius of the former Bell facility:

- Well coordinates obtained either by measurement with a GPS unit or estimation from map data. The locations of 78 wells that were sampled in February 2007 are not indicated on available maps. At a minimum, well locations need to be approximated on a map and geographic coordinates estimated.
- Current pumping rates and household usage values are estimated. If possible, actual pumping rates should be acquired. Table 1 summarizes the PWS wells that require additional information. Shaw recognizes that some well yield data may be available in TCEQ, 2007b.

The USGS has a network of wells within Harris County that are regularly measured for water levels. This data from the USGS would greatly increase the ability to accurately calibrate the flow and transport model for the Jones Road site.

In order to better understand the subsurface geology, geologic cross sections for the study area will need to be generated. In addition, it is requested that slug tests be conducted in the monitoring wells within a 1-mile radius of the Bell facility. The slug tests will assist in the estimation of the hydraulic conductivity of the aquifer.

Contouring of contaminant concentrations for the Jones Road site will need to be completed in order to determine the initial conditions for input into the transport model. The 2004 to 2007

groundwater sampling results are requested for the PCE daughter products TCE, DCE, and VC. This data will be contoured and potentially used as initial conditions for models evaluating the migration of daughter products through the aquifer.

8.0 References

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Figures

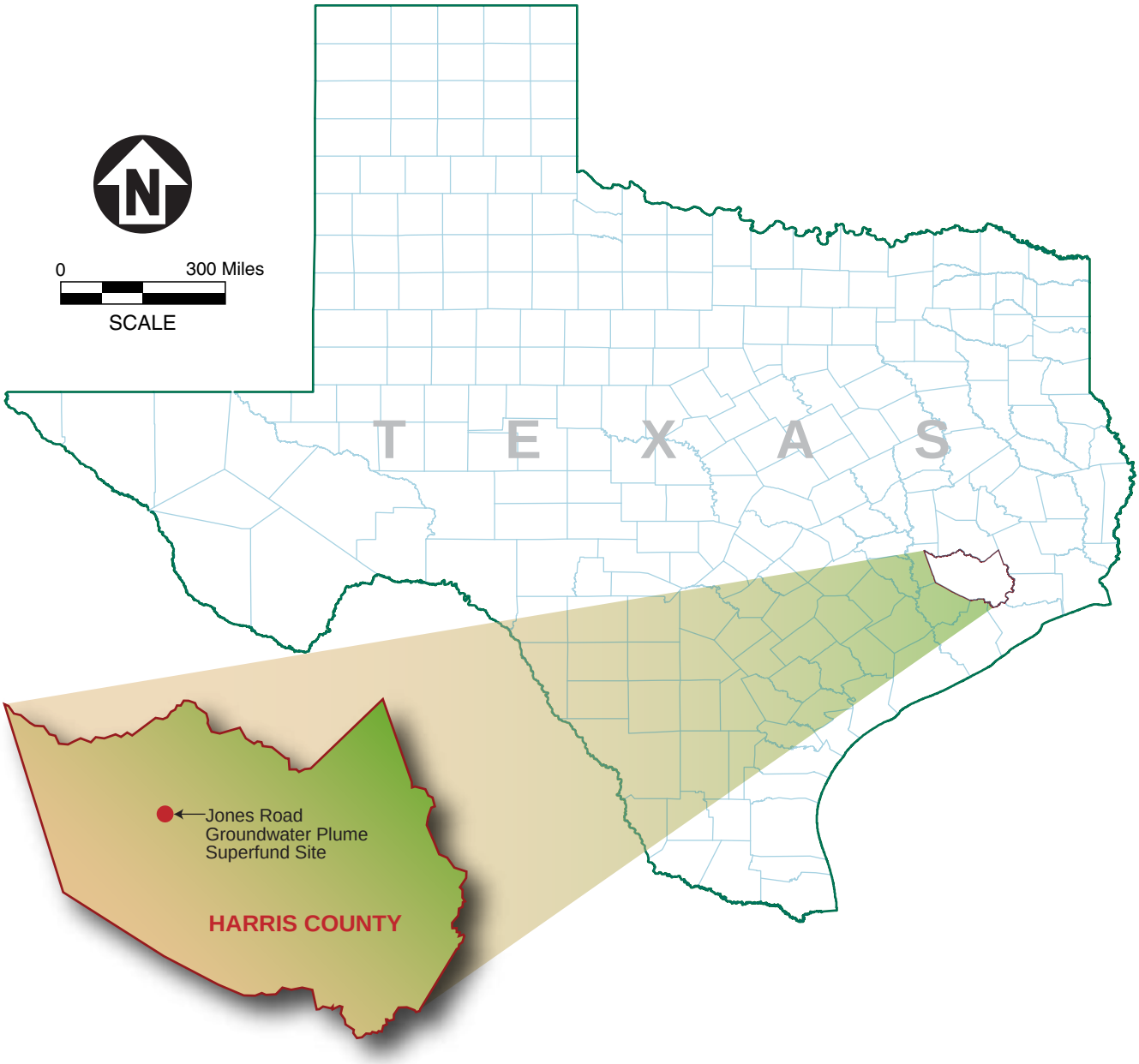
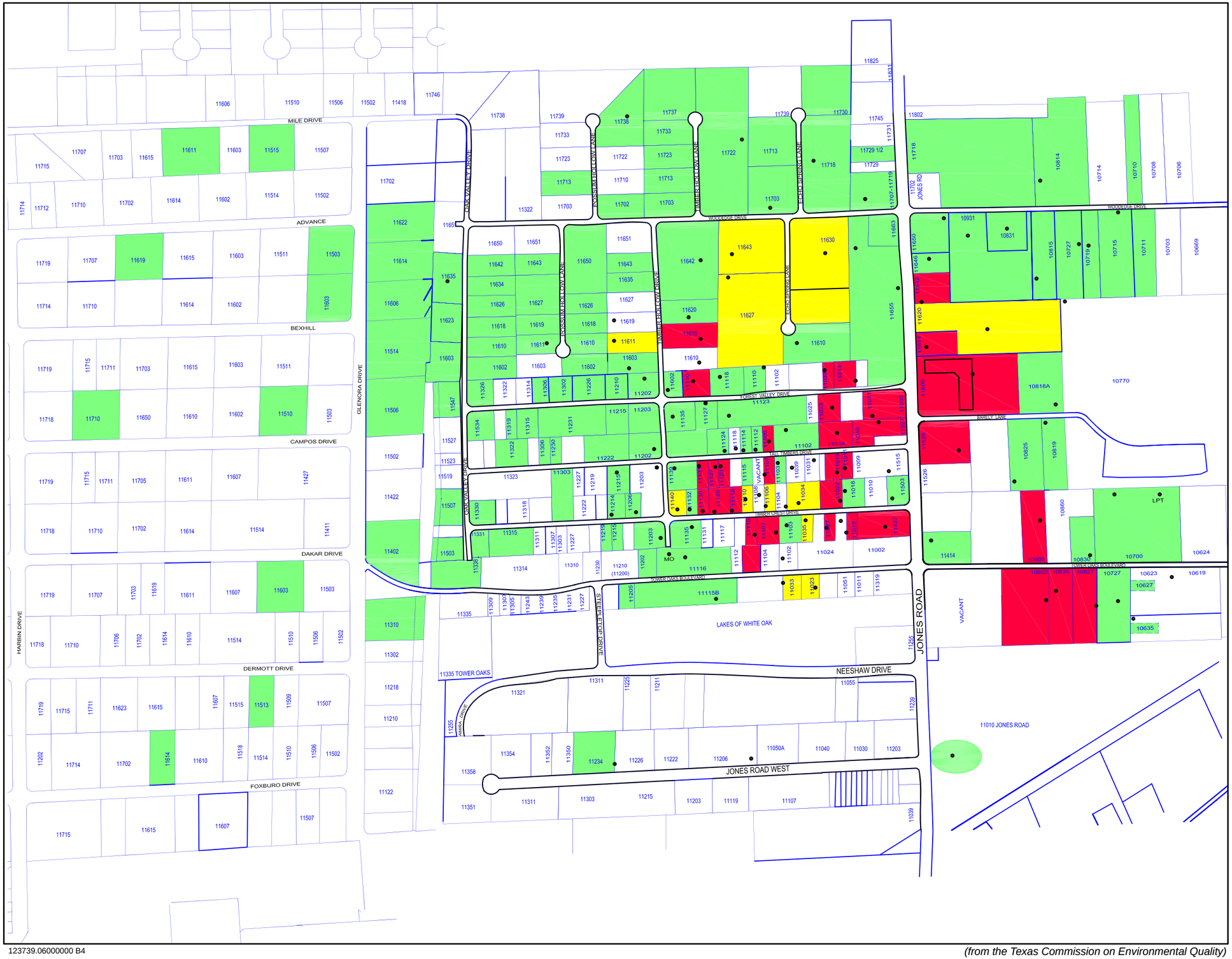


Figure 1
Site Location Map
Jones Road Groundwater Plume Superfund Site
Houston, Texas

123739.06000000 A5



LEGEND

- Property boundary
- Approximate private well location
- Not sampled
- PCE < 05.ppb (Quantitation limit)
- PCE >= 0.50ppb TO <= 5.0ppb
- PCE > 5.0ppb (MCL)

N

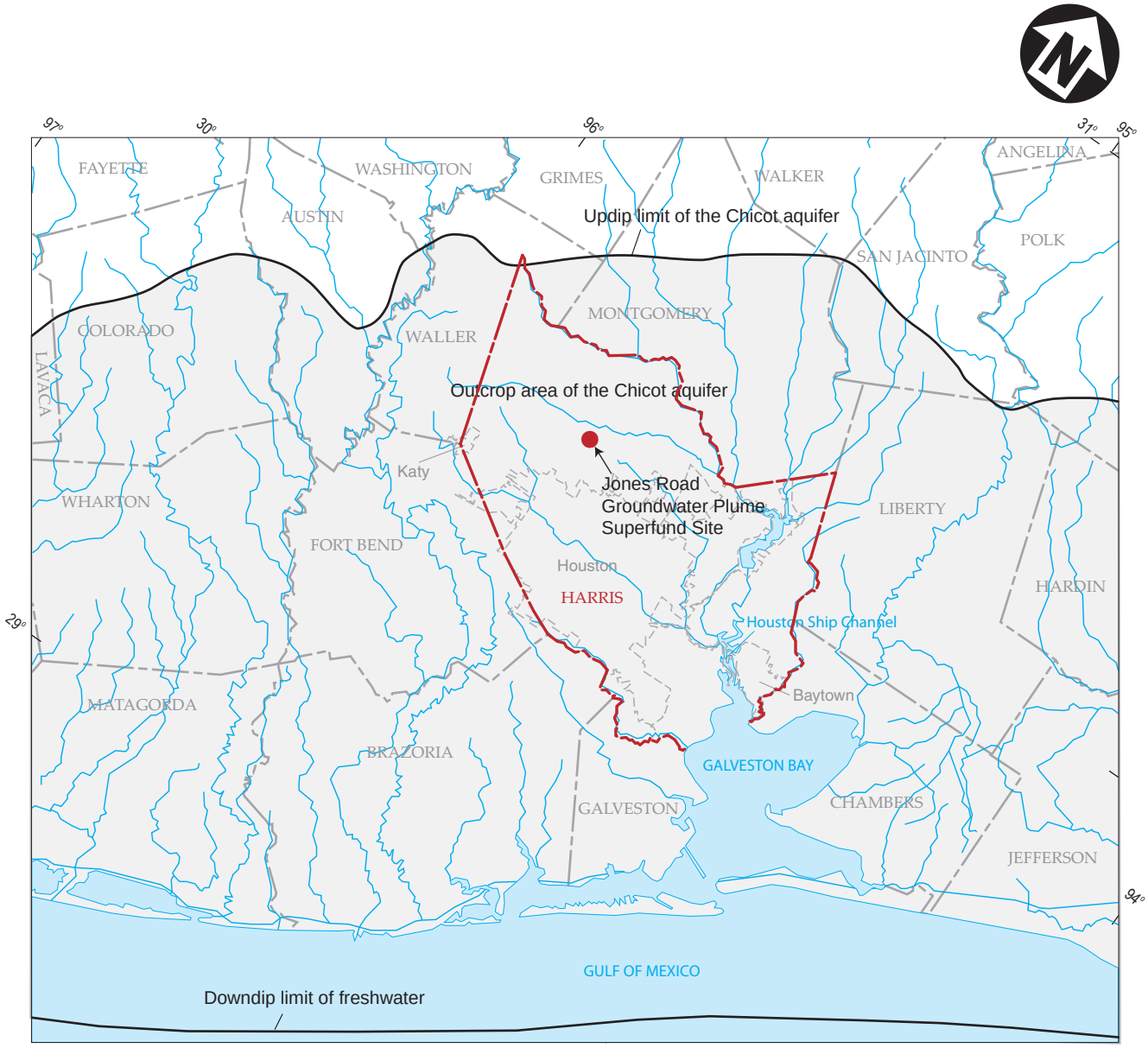
0 250 500 FT

SCALE

Figure 2
Quarterly Sampling Results
November 2007
Jones Road Groundwater Plume
Superfund Site
Houston, Texas

123739.06000000 B4

(from the Texas Commission on Environmental Quality)



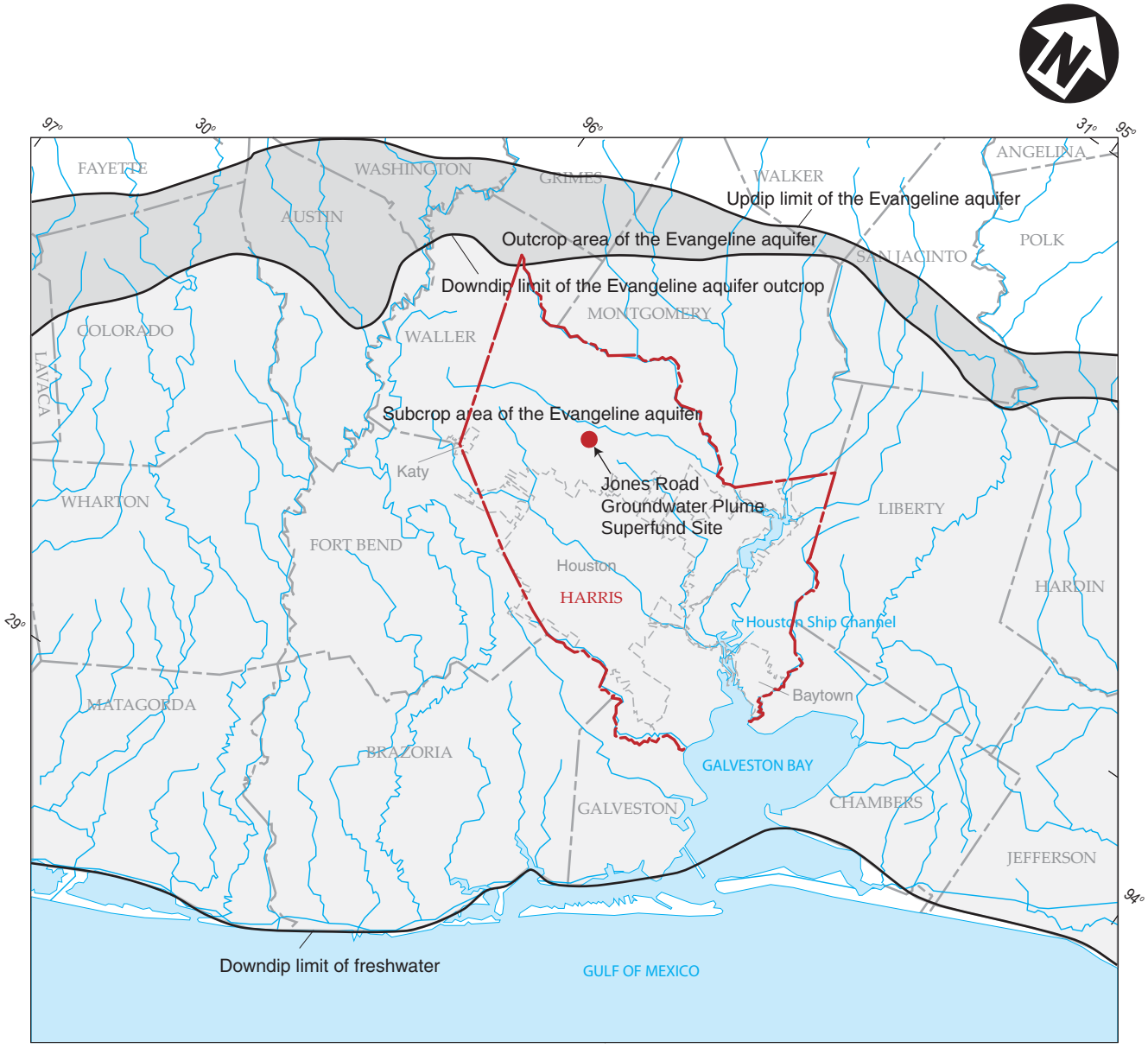
Base modified from U.S. Geological Survey digital data
1:250,000, 1972
Lambert Conformal Conic projection
Standard parallels 29˚30' and 45˚30', central meridian -96˚

0 5 10 15 20 MILES

(from Kasmerek and Strom, 2002)

Figure 3
Chicot Outcrop Area Relative to Harris County
Jones Road Groundwater Plume Superfund Site
Houston, Texas

123739.06000000 A3

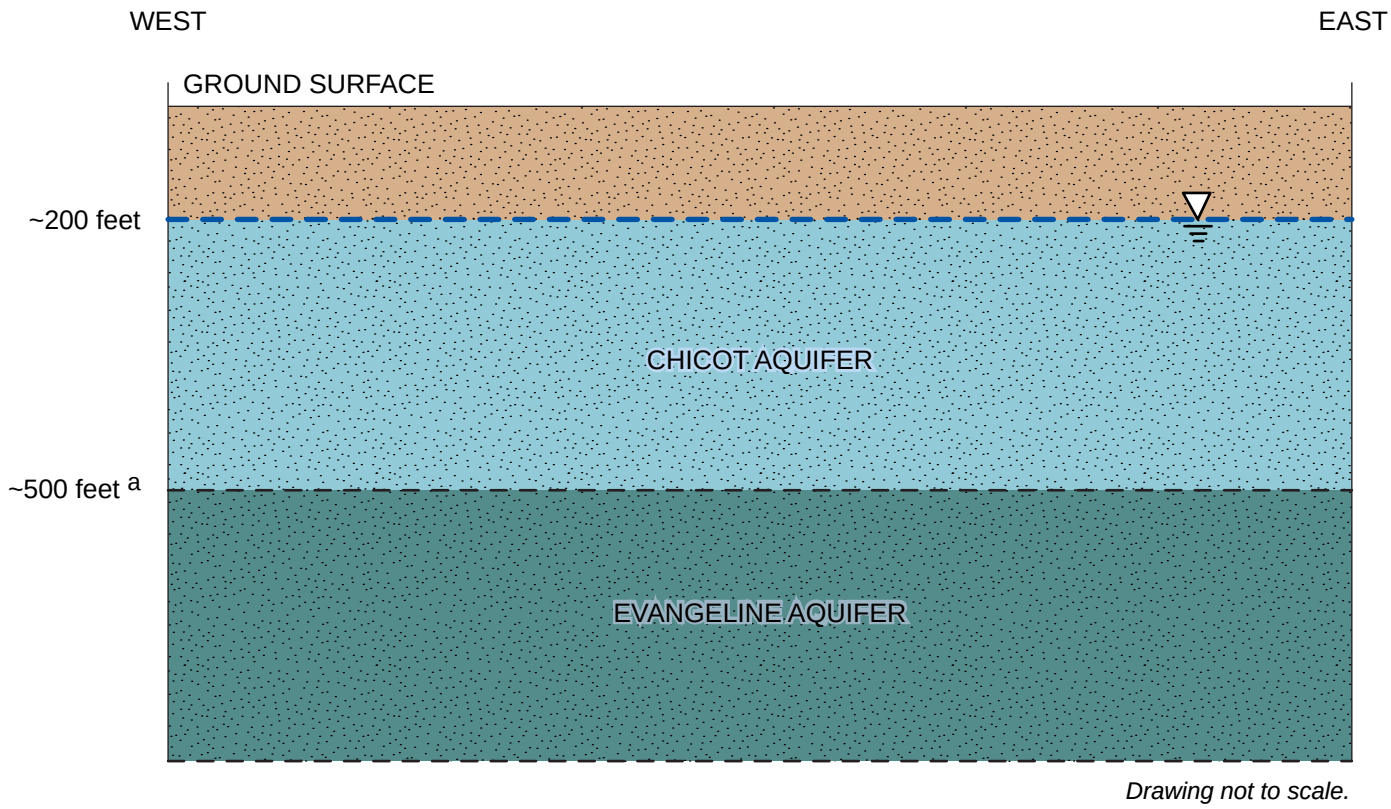


Base modified from U.S. Geological Survey digital data
1:250,000, 1972
Lambert Conformal Conic projection
Standard parallels 29°30' and 45°30', central meridian -96°

0 5 10 15 20 MILES

(from Kasmerek and Strom, 2002)

Figure 4
Evangeline Outcrop Area Relative to Harris County
Jones Road Groundwater Plume Superfund Site
Houston, Texas



LEGEND

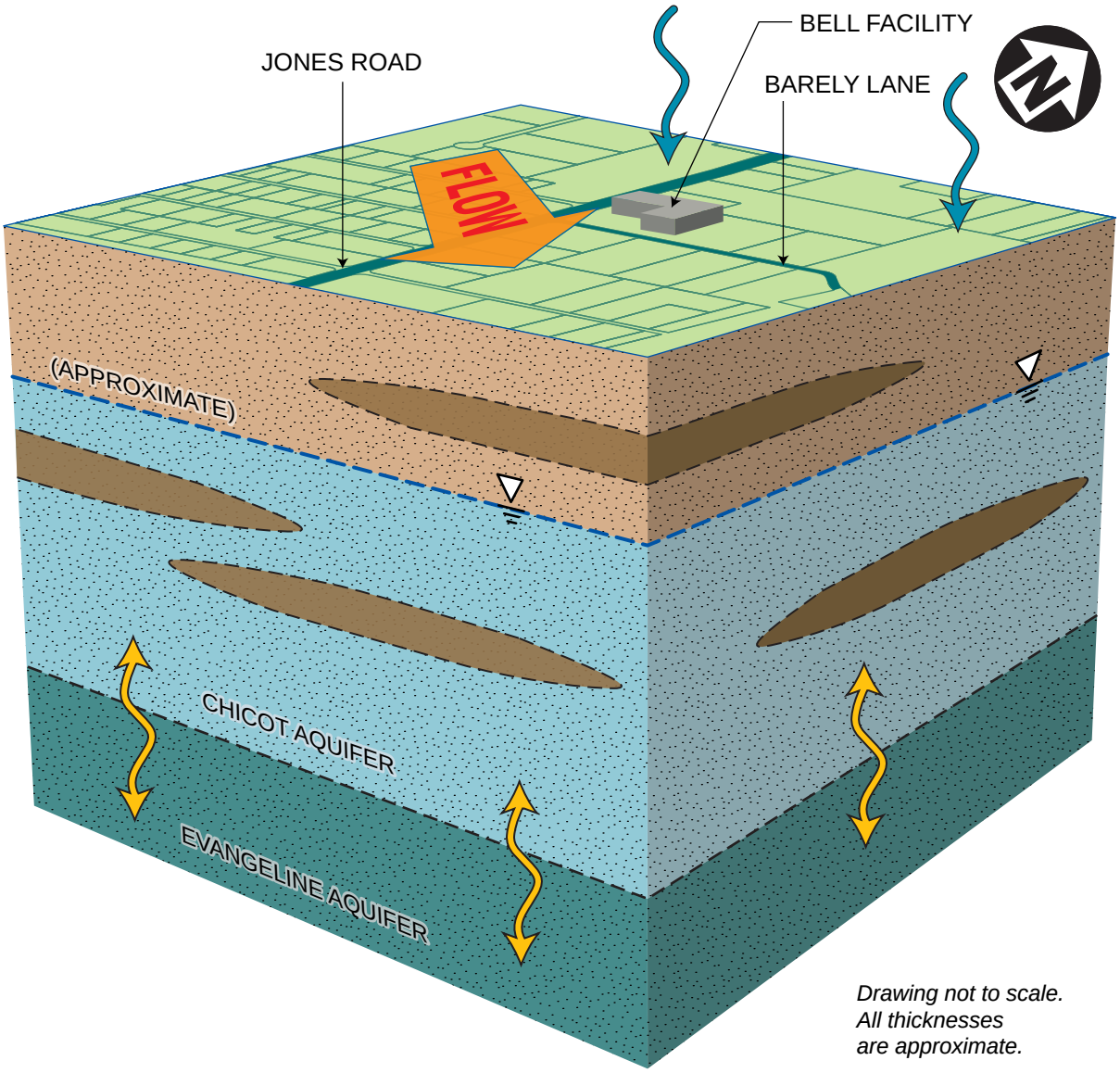
Approximate water level

Approximate boundary

Approximate water table

[a] Depth estimated from information provided in E.T. Baker, 1979, Stratigraphic and Hydrogeologic Framework of Part of the Coastal plain of Texas, Texas Department of Water Resources, Report 236, Austin, Texas.

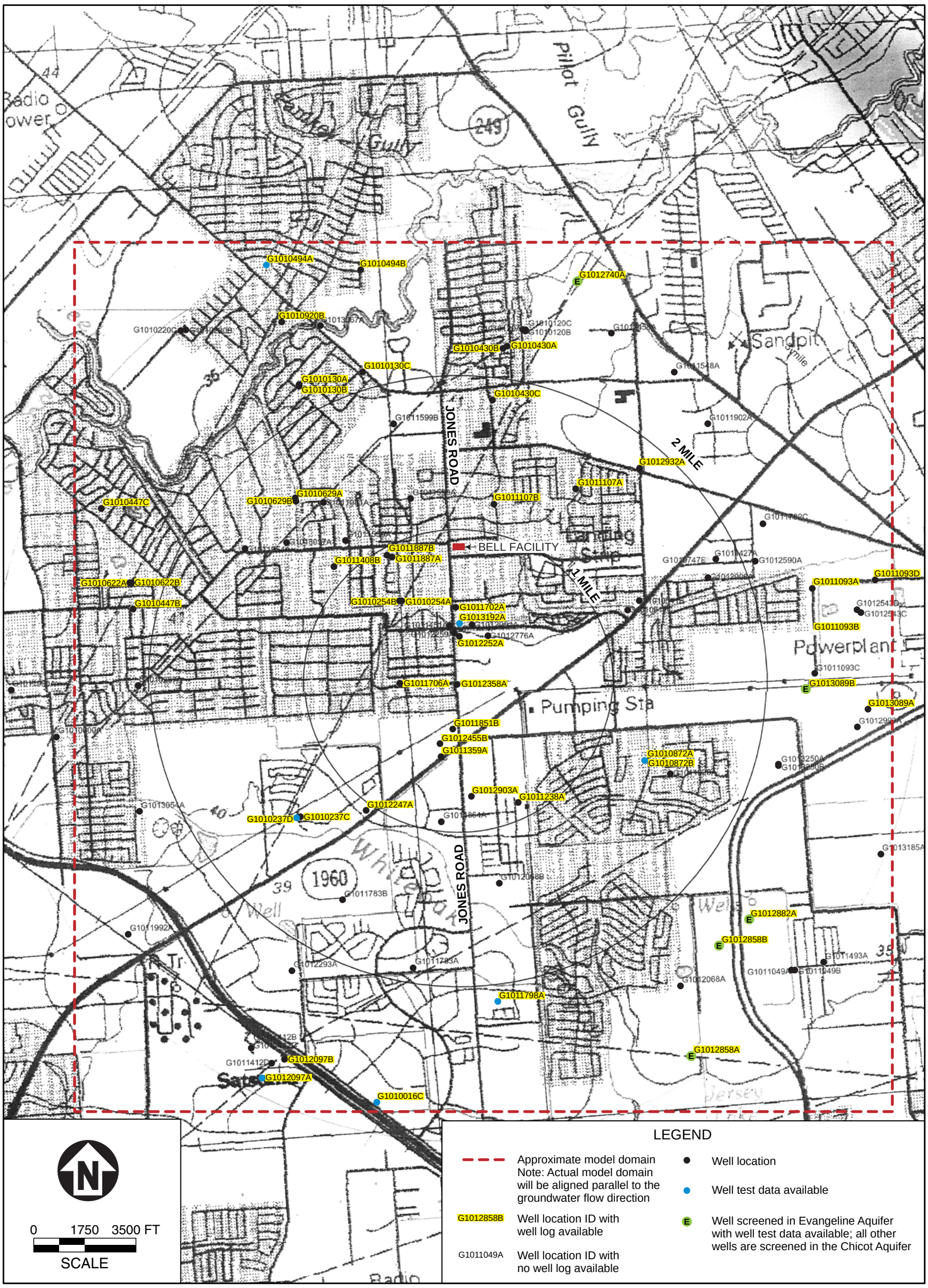
Figure 5
Simplified Cross Section for the Jones Road Site
Jones Road Groundwater Plume Superfund Site
Houston, Texas



LEGEND

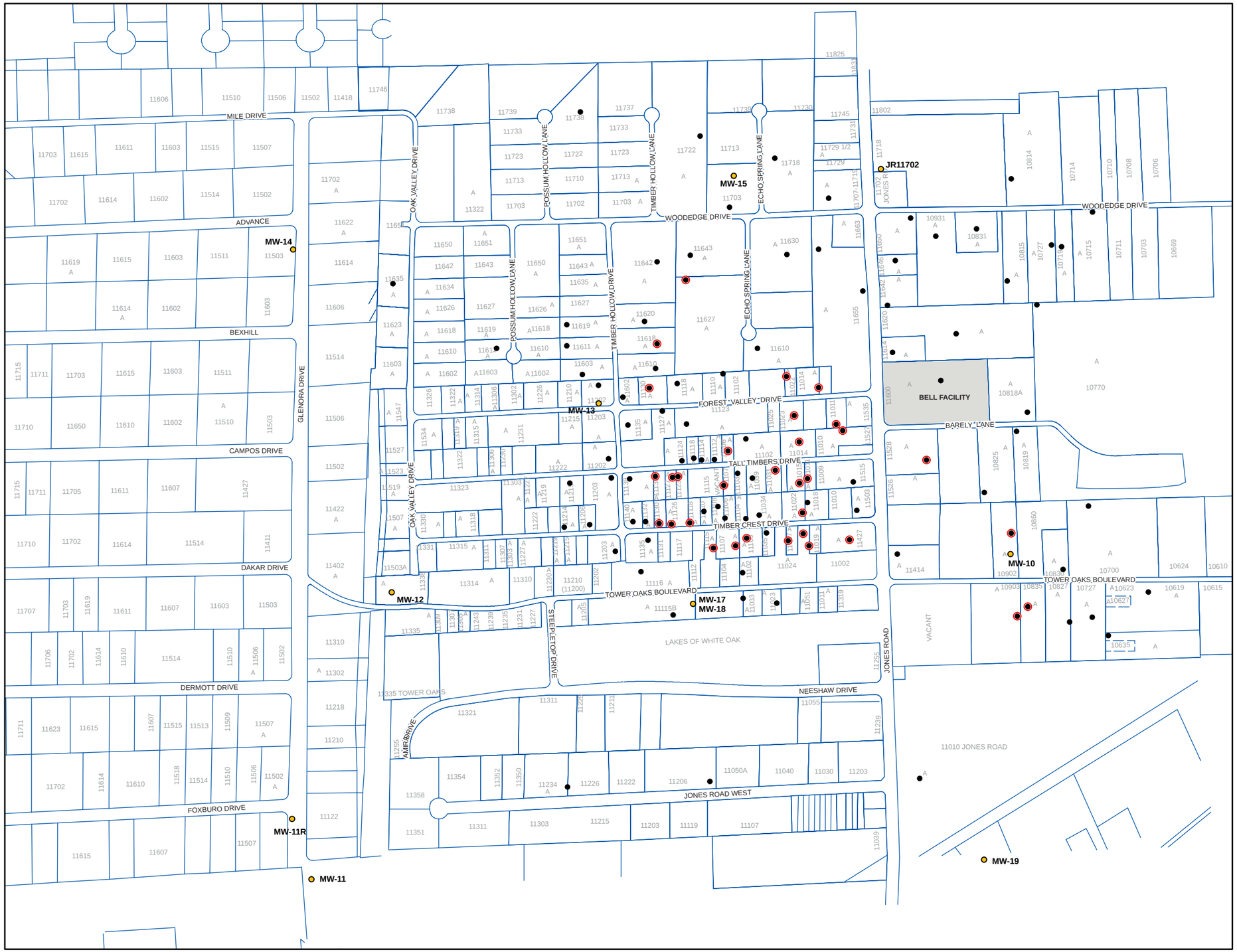
- Approximate water table
- Approximate boundary
- Water table elevation
- Unsaturated aquifer conditions
- Saturated aquifer conditions
- Low permeability
- Leaky aquifer zone
- Aquifer recharge from northern outcropping of Chicot Aquifer
- Approximate direction of groundwater flow

Figure 6
Illustration of the Conceptual Site Model
Jones Road Groundwater Plume Superfund Site
Houston, Texas



123739.06000000 B2

Figure 7
Public Water Supply Wells
Jones Road Groundwater Plume Superfund Site
Houston, Texas



LEGEND

- Well location
- Monitoring well
- Wells with filtration system installed
- A Access agreement
- Property boundary
- 10770 Property number

N

0 250 500 FT
SCALE

Figure 8
Private Well Locations
Jones Road Groundwater Plume
Superfund Site
Houston, Texas

123739.06000000 B1

(from the Texas Commission on Environmental Quality)

Tables

Table 1
Public Water Supply Wells Missing Key Parameters
Jones Road Groundwater Plume Superfund Site
Houston, Texas

PWS ID		Latitude	Longitude	Screened Interval (ft bgs)	Pumping Rate Known?	Notes
G1010016		NK	NK	934–1390.38	Yes	Screened in the Evangeline Aquifer
G1010920		NK	NK	265–345	Yes	
G1011093	Well A	NK	NK	NK	Yes	
	Well B	NK	NK	NK	No	
	Well C	NK	NK	NK	No	
	Well D	NK	NK	NK	No	
G1011798		NK	NK	NK	Yes	
G1012097		NK	NK	290–346	Yes	
G1012740		NK	NK	745–814	Yes	Screened in the Evangeline Aquifer
G1012858	Well A	NK	NK	766–1191	Yes	Screened in the Evangeline Aquifer
	Well B	NK	NK	777–1340	No	Screened in the Evangeline Aquifer
G1012882		NK	NK	515–984	Yes	Screened in the Evangeline Aquifer
G1013089	Well #1	NK	NK	645–750	Yes	Screened in the Evangeline Aquifer
	Well #2	NK	NK	850–909	No	Screened in the Evangeline Aquifer
G1010254		NK	NK	383–406	Yes	
G1010887		NK	NK	240–260	Yes	
G1011238		NK	NK	440–730	Yes	Screened in the Evangeline Aquifer
G1011359		NK	NK	NK	Yes	
G1011851		29°55'58"	95°35'9"	355–375	Yes	
G1012455		29°55'55"	95°35'13"	282–302	Yes	
G1012903		NK	NK	NK	Yes	
G1010430	Well 2	29°58'14"	95°34'40"	NK	Yes	
	Well 3	29°57'55"	95°34'45"	NK	Yes	
G1010541	Well A	NK	NK	770–1060	Yes	Screened in the Evangeline Aquifer
	Well B	NK	NK	NK	No	
	Well C	29°56'43"	95°33'57"	455–876	Yes	Screened in the Evangeline Aquifer
G1010629		NK	NK	240–260	Yes	
G1010872		NK	NK	NK	No	

Table 1 (Continued)
Public Water Supply Wells Missing Key Parameters
Jones Road Groundwater Plume Superfund Site
Houston, Texas

PWS ID		Latitude	Longitude	Screened Interval (ft bgs)	Pumping Rate Known?	Notes
G1011107	Well A	NK	NK	778–1116	Yes	
	Well B	NK	NK	NK	Yes	
G1011408		29°57'01"	95°35'53"	265–285	Yes	
G1012247		NK	NK	360–380	Yes	
G1012932		NK	NK	275–291	No	
G1010130		NK	NK	365–375	No	
		NK	NK	NK	No	
		NK	NK	NK	No	
G1010447		NK	NK	580–890	No	Screened in the Evangeline Aquifer
G1010600		NK	NK	NK	Yes	
G1010622		29°57'00"	95°37'06"	211–239	No	
G1010237	Well A	29°56'24"	95°37'08"	291–1108	No	
	Well C	NK	NK	NK	No	
G1010494		29°58'42"	95°36'12"	429–982	Yes	Screened in the Evangeline Aquifer

bgs = *Below ground surface.*
° = *Degree(s).*
ft = *Foot (feet).*
ID = *Identification.*
NK = *Not known.*
PWS = *Public water supply.*

Table 2
Private Wells Not Indicated on Maps
Jones Road Groundwater Plume Superfund Site
Houston, Texas

Well ID	Well Address
AD11603	11603 Advance
AD11619	11619 Advance
BH11603	11603 Bexhill
CP11510	11510 Campos
CP11710	11710 Campos
CP11711	11711 Campos
DK11703	11703 Dakar Drive
DM11507	11507 Dermott Drive
ES11713	11703 Echo Springs
ES11730	11730 Echo Springs
FV11203	11203 Forest Valley Drive
FV11210	11210 Forest Valley Drive
FV11215	11215 Forest Valley Drive
FV11226	11226 Forest Valley Drive
FV11302	11302 Forest Valley Drive
FV11306	11306 Forest Valley Drive
FV11315	11315 Forest Valley Drive
FV11319	11319 Forest Valley Drive
FV11322	11322 Forest Valley Drive
FV11326	11326 Forest Valley Drive
GL11310	11310 Glenora Drive
GL11402	11402 Glenora Drive
GL11506	11506 Glenora Drive
GL11514	11514 Glenora Drive
GL11606	11606 Glenora Drive
GL11614	11614 Glenora Drive
GL11622	11622 Glenora Drive
JR11403	11403 Jones Road
JR11526	11526 Jones Road

Table 2 (Continued)
Private Wells Not Indicated on Maps
Jones Road Groundwater Plume Superfund Site
Houston, Texas

Well ID	Well Address
JR11655	11655 Jones Road
JR11663	11633 Jones Road
JR11729 1/2	11729 1/2 Jones Road
MI11507	
OV11503	11503 Oak Valley Drive
OV11507	11507 Oak Valley Drive
OV11534	11534 Oak Valley Drive
OV11547	11547 Oak Valley Drive
OV11602	11602 Oak Valley Drive
OV11603	11603 Oak Valley Drive
OV11610	11610 Oak Valley Drive
OV11618	11618 Oak Valley Drive
OV11623	11623 Oak Valley Drive
OV11634	11634 Oak Valley Drive
OV11642	11642 Oak Valley Drive
PH11602	11602 Possum Hollow
PH11610	11610 Possum Hollow
PH11618	11618 Possum Hollow
PH11619	11619 Possum Hollow
PH11626	11626 Possum Hollow
PH11627	11627 Possum Hollow
PH11643	11643 Possum Hollow
PH11650	11650 Possum Hollow
PH11702	11702 Possum Hollow
PH11713	11713 Possum Hollow
TC11215	11215 Timber Crest
TC11219	11219 Timber Crest
TC11315	11315 Timber Crest
TC11330	11330 Timber Crest
TC11331	11331 Timber Crest

Table 2 (Continued)
Private Wells Not Indicated on Maps
Jones Road Groundwater Plume Superfund Site
Houston, Texas

Well ID	Well Address
TH11635	11635 Timber Hollow Drive
TH11643	11643 Timber Hollow Drive
TH11703	11703 Timber Hollow Drive
TH11713	11713 Timber Hollow Drive
TH11723	11723 Timber Hollow Drive
TH11733	11733 Timber Hollow Drive
TH11737	11737 Timber Hollow Drive
TO10700LPT	
TO11116MO	
TO11205	11205 Tower Oaks Blvd
TO11230	11230 Tower Oaks Blvd
TT11222	11222 Tall Timbers Drive
TT11230	11230 Tall Timbers Drive
TT11303	11303 Tall Timbers Drive
TT11306	11306 Tall Timbers Drive
TT11322	11322 Tall Timbers Drive
WE10710	10710 Woodedge Drive
WE10711	10711 Woodedge Drive
WE11322	11322 Woodedge Drive

Blvd = Boulevard.
ID = Identification.

Appendix A
Shaw Environmental & Infrastructure, Inc.
Standard Operating Procedure EI-GS063

STANDARD OPERATING PROCEDURE

Subject: Standards for Conducting Groundwater Flow and Solute Transport Modeling

1. PURPOSE

This procedure provides the standard practice for generating groundwater flow and solute transport models and includes the minimum required steps and quality checks that employees and subcontractors are to follow when performing the subject task.

This procedure may also contain guidance for recommended or suggested practice that is based upon collective professional experience. Recommended practice goes beyond the minimum requirements of the procedure, and should be implemented when appropriate.

2. SCOPE

Geosciences Standard Operating Procedure (SOP) EI-GS063 describes standards for groundwater flow and solute transport modeling and how such modeling will be conducted and documented for projects executed by Shaw Environmental & Infrastructure, Inc. (Shaw E & I). The SOP addresses technical requirements and required documentation. Responsibilities of individuals performing the work are also detailed.

3. REFERENCES (STANDARD INDUSTRY PRACTICES)

Computer modeling shall follow accepted industry practices for model construction, calibration, evaluation, verification, uncertainty analysis, and reporting. These are as defined by the latest version of various ASTM Standards:

ASTM D 5447	Standard Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem
ASTM D 5610	Standard Guide for Defining Initial Conditions in Ground-Water Flow Modeling
ASTM D 5609	Standard Guide for Defining Boundary Conditions in Ground-Water Flow Modeling
ASTM D 5611	Standard Guide for Conducting a Sensitivity Analysis for a Ground-Water Flow Model Application
ASTM D 5490	Standard Guide for Comparing Ground-Water Flow Model Simulations to Site-Specific Information
ASTM E 978	Standard Practice for Evaluating Mathematical Models for the Environmental Fate of Chemicals
ASTM D 5981	Standard Guide for Calibrating a Ground-Water Flow Model Application
ASTM D 5880	Standard Guide for Subsurface Flow and Transport Modeling
ASTM D 5718	Standard Guide for Documenting a Ground-Water Flow Model Application
ASTM D 6170	Standard Guide for Selecting a Ground-Water Modeling Code
ASTM D 6025	Standard Guide for Developing and Evaluating Ground-Water Modeling Codes
ASTM D 6033	Standard Guide for Describing the Functionality of a Ground-Water Modeling Code

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ASTM E 1689	Standard Guide for Developing Conceptual Site Models for Contaminated Sites
ASTM D 6171	Standard Guide for Documenting a Ground-Water Modeling Code

Additional reference materials that are useful for conducting modeling include the following:

- Anderson, M.P. and W.W. Woessner, 1992, *Applied Groundwater Modeling, Simulation of Flow and Advective Transport*.
- Committee on Fracture Characterization and Fluid Flow, U.S. National Committee for Rock Mechanics, 1996, *Rock Fractures and Fluid Flow, Contemporary Understanding and Applications, National Academy Press*, Specifically Chapter 6, "Field-Scale Flow and Transport Models."
- McDonald, M.G., and A.W. Harbaugh, 1988, "A Modular Three-Dimensional Finite-Difference Ground-Water Flow Model," *Techniques of Water-Resources Investigations of the United State Geological Survey*, Book 6, Chapter A1, 576 pp.
- U.S. Environmental Protection Agency (EPA), *Quality Assurance and Quality Control in the Development and Application of a Groundwater Model*, EPA/600/R-93/011.
- U.S. Environmental Protection Agency, 1993, *A Manual of Instructional Problems for the U.S.G.S. MODFLOW Model*, EPA/600/R93/010, EPA.
- Zheng, C., and G.D. Bennett, 1995, *Applied Contaminant Transport Modeling*, Van Nostrand Reinhold, New York, NY, 440 pp.

4. DEFINITIONS

The following definitions are applicable to the generation of groundwater flow and solute transport models and are used in this SOP.

- **Calibration**—The process of refining the model representation of the hydrogeologic framework, hydraulic properties, boundary conditions, and solute transport (if sufficient data are available) to achieve a desired degree of correspondence between the model simulations and actual observations or measurements of the groundwater flow and transport systems.
- **Conceptual Model**—An interpretation or working description of the characteristics and dynamics of the physical system.
- **Groundwater Flow Model**—An application of a mathematical model to represent a groundwater flow system.
- **Mathematical Model**—Mathematical equations expressing the physical system (site conceptual model) including simplifying assumptions. The representation of a physical system by mathematical expressions from which the behavior of the system can be deduced with known performance.
- **Model**—An assembly of concepts and site-specific data in the form of mathematical equations that portray understanding of a particular hydrogeologic system.
- **Model Code (Computer Program)**—The assembly of numerical techniques, bookkeeping, and control language that represents the model from acceptance of input data and instructions to delivery of output.
- **Sensitivity (Model Application)**—The degree to which the model result is affected by changes in a selected model input parameter representing hydrogeologic framework, hydraulic properties, and boundary conditions.

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- **Simulation**—In groundwater flow modeling, one complete execution of a groundwater modeling computer program, including input and output.
- **Verification**—Using the set of parameter values and boundary conditions from a calibrated model to acceptably approximate a second set of field data measured under similar hydrologic conditions.

5. RESPONSIBILITIES

5.1 Procedure Responsibility

The Geosciences Discipline Lead is responsible for the development, maintenance, and revision of this procedure. Any questions, comments, or suggestions regarding this technical SOP should be directed to the Geosciences Discipline Lead. The Geosciences Discipline Lead's location and associated contact information can be found on the Shaw Group intranet site, ShawNet.

5.2 Project Responsibility

Employees conducting groundwater flow or solute transport modeling, or any portion thereof, are responsible for meeting the requirements of this procedure. Employees conducting technical review of company groundwater flow or solute transport modeling efforts are also responsible for following appropriate portions of this SOP. Project participants are responsible for documenting information in sufficient detail to provide objective documentation (checkprints, calculations, reports, etc.) that the requirements of this SOP have been met. Such documentation shall be retained as project records.

6. PROCEDURES (TECHNICAL REQUIREMENTS AND STANDARDS)

Groundwater flow and solute transport models are constructed to represent the physical and geochemical system of a site. The degree of representativeness of the modeling results depends on the complexity of the site setting, the amount of available site data, the complexity of the model, and the effort necessary to adjust the model to site conditions. Modeling results are used for decision-making, design efforts, and other evaluations (such as risk analysis). Consequently, it is important that the modeling effort be technically defensible and conducted following consistent requirements, standards, and/or procedures. The requirements, standards, and/or procedures for conducting groundwater flow and solute transport modeling are provided in the subsequent text.

6.1 Methodology

The model development process consists of many individual steps, which include the following:

- Definition of the problem
- Development of a conceptual model
- Selection of the model code
- Verification of the model code
- Parameterization of the model input
- Model construction
- Model calibration
- Model sensitivity analysis

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- Model application
- Model validation (if data set is available)

These steps are common to all models regardless of their size or scope, and all require documentation of their approaches and conclusions to complete the modeling process. The documentation process is described in the following sections.

6.2 Initial Model Documentation

Modeling is conducted to address a site-specific issue or problem. All models have application limitations, and the degree of model representativeness to site conditions will depend on the planned model use. Consequently, the site-specific problem for which the modeling will be constructed must be defined, and the conceptual model and description of the scope of the modeling program must also be compiled and documented.

These steps are usually addressed in a project work plan or proposal. If so, a copy of this document must be included in the modeling records. If they are not, documentation must be created which clearly defines the modeling objectives and concepts. Any changes to the modeling program's scope and/or conceptual model must be documented and approved by an appropriate level of management (Project Manager or designee), with a reference to the original documentation.

The model's scope will include the following:

- A basic description of the problem
- Site background information
- Regulatory framework
- Definition of the size of the area to be modeled
- Calibration criteria
- Model sensitivity analysis and/or validation
- Special factors that may influence the modeling program

The conceptual model description will include the following:

- A definition of the system to be modeled
- Definition of parameters needed for model input
- Description of the conceptual flow system
- Definition of the conceptual solute transport system (if applicable)
- Any and all assumptions used in the development of the conceptual model

The conceptual model, initial model input parameters, and model results shall be reviewed and approved by the Project Hydrogeologist. The Project Hydrogeologist is the individual responsible for providing technical oversight of the site conceptualization, determining site aquifer parameters and other hydrologic parameters (i.e., model input parameters), and verifying that the model output is consistent with site conditions.

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6.3 Model Code Selection

Code selection is an important step in modeling. It essentially consists of matching the modeling needs of the project and known hydrogeologic site conditions to the key characteristics or capabilities of existing computer codes. The selected code should possess essential characteristics or capabilities to effectively address the problem to be answered while representing known site conditions. In addition, the model code selection shall be documented and maintained as project records.

Selection of the model code, and documentation of model code selection, shall follow guidelines contained in the industry standards listed in Section 3. Those individuals needing assistance in model code selection and documentation may consult internal Shaw technical listings for experts in groundwater flow and solute transport modeling.

6.4 Model Parameter Input

Model input parameters should be derived from site-specific studies and investigations covering site geology, hydrogeology, and geochemistry. If site-specific parameter data are not available, data from local and regional geologic studies that are suitable for the application may be used as model input parameters. If neither site-specific nor local or regional data are available, non-site-specific literature values may be used. Initial input values for parameters should closely approximate literature values and should not be changed until model calibration is begun. Literature sources and their values must be documented and included in the modeling documentation files.

6.5 Model Calibration

Model calibration is the mid-step between model selection and development and model application. Documentation of the calibration process is important. The documentation provides an unbroken record of the input parameters used in the calibration of the model, beginning with the initial input parameters and ending with the parameters used for the final calibrated model. For manual calibration, each model calibration run should be limited by changing only one parameter at a time; if multiple parameters are changed, their effects may mask each other, and the results may be unclear. Each parameter changed during calibration should be changed only within the range of possibilities defined during conceptual model development and model input parameterization. The first calibration run of any modeling program should be a baseline run using all initial input parameters. Sufficient documentation of calibration runs will be made and will include the following:

- Modeler's name and date
- Calibration run number
- Input filename(s)
- Output filename(s)
- Program name and version
- Purpose of the calibration run
- Parameter(s) changed during the run and their values
- Results of the calibration run
- Plans for the next calibration run based on the present results, if necessary

For model calibration using codes such as PEST, UCODE, MODFLOWP, MODAC, or similar software, documentation shall be sufficient to describe the process and results.

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Documentation for calibration runs shall be filed in the project modeling records. Such documentation shall include both a hardcopy and an electronic copy of the model input and output files for the final calibration run, and other runs, if necessary.

6.6 Other Modeling Documentation

Model application or simulation runs, sensitivity analysis, and validation runs are conducted as the modeling effort progresses. These runs require identical documentation as used in calibration runs and also require documentation of their basic purpose as related to the scope of the modeling program. Sensitivity analyses should consider key parameters that were not well defined during the input parameterization step and should reference the parameterization documentation. Model validation runs should describe the new data sets to be used and should reference the original model calibration. In all cases, both paper and electronic copies will be made for each modeling run. These copies and accompanying run descriptions will be included in the modeling documentation files. An expanded report outline is shown in Attachment 1 (Section 7) as an example means of providing appropriate information and documentation.

6.7 Potential Modeling Errors

The following is a list of potential modeling errors. The most appropriate method for eliminating modeling errors is to apply good hydrogeologic judgment and to effectively question the model simulations.

Model Conceptualization Errors:

- Lack of understanding of site hydrogeological processes
- Inappropriate model code selection
- Selection of inappropriate boundary conditions
- Excessive discretization
- Lack of far-field data
- Oversimplification of the problem, including complexity of the groundwater flow system and equivalent porous media assumptions for fractured rock
- Placing model boundaries too close to the area of interest, especially pumping centers

Data Input Errors:

- Inconsistent parameter units
- Incorrect sign (+/-) for pumping or recharge
- Inappropriate use of model code modules (e.g., MODFLOW, DRAIN, or RIVER, and ET)
- Extraction well not specified correctly
- Aquifer stresses not specified correctly over entire transient simulation period
- Use of interpolated or extrapolated data
- Forcing questionable data to fit
- Misinterpreting mass balance data

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Simulation Results Errors:

- Deviations from standard industry practices without proper justification and documentation
- Improper or insufficient model calibration
- Omitting results inconsistent with conceptual model
- Blind acceptance of model output
- Insufficient modeling documentation

If model results do not make physical sense or are not consistent with observed site conditions, the model should be checked for potential errors or other causal factors. The model should then be revised appropriately before formally presenting the results and generating conclusions.

6.8 Review & Approval

All models and modeling results shall undergo technical review. The technical reviewer should be a person capable of conducting the modeling and also understanding and comparing observed field data to the conceptual and numerical models. The technical reviewer should not have developed or conducted the particular modeling to be reviewed. For state-of-the-art or highly sensitive models, the technical reviewer should be carefully selected and may be a qualified person outside the project team. Individuals needing assistance in finding qualified technical reviewers may consult internal Shaw technical listings for experts in groundwater flow and solute transport modeling. Experts outside of Shaw may be used, if necessary, for highly sensitive projects after internal Shaw reviews have been performed.

The technical review, at a minimum, should consider and evaluate the following items:

- Definition of the problem—The basic description of the problem is provided as well as the basic scope of the modeling to be conducted.
- Site conceptual model—The hydrogeologic system to be modeled as well as the conceptual flow and solute transport system (if applicable) are appropriately defined and are supported by site data; parameters needed for model input are appropriately identified; the conceptual model is approved by the Project Hydrogeologist.
- Applicability of selected code—The code selected for use is optimum for the described conceptual model and supported by observed site conditions.
- Model input parameters—Input parameters are clearly specified and their values are appropriately documented; parameters are technically supportable.
- Model calibration—The calibration is complete or sufficient, and the results and conclusions generated are compatible with standard industry practice; change in calibration is conducted and documented.
- Model sensitivity analysis—The conducted sensitivity analysis and results and conclusions generated are compatible with standard industry practice and are technically supportable.
- Model validation and agreement with field data—Model validation is conducted appropriately, reflects standard industry practice, and is technically supported by the field data.
- Model documentation—All documentation has been completed according to this SOP and any other applicable procedures.

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- Model results—In general, all modeling results are supported by the field data and all errors are identified as to root cause and corrected.
- Modeling assumptions—Any and all assumptions used for the modeling are appropriately documented and justified.

Any issues raised during the technical review shall be resolved between the reviewer and staff conducting the modeling before external (i.e., outside of Shaw) submission of the model and modeling results. The technical review comments and issues, and corresponding resolution, shall be documented and filed with the project records. If a modeling report is prepared (such as in Attachment 1), documentation of the report review may also be included with the project records.

7. ATTACHMENTS

- Attachment 1, Suggested Modeling Report Sections

8. FORMS

None.

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Attachment 1
Suggested Modeling Report Sections
(As Applicable)

List of Tables
List of Figures
List of Acronyms
1.0 Introduction
- 1.1 Objectives
- 1.2 Scope of Work
- 1.3 Organization of Document

2.0 Geology and Physiography of the Model Area
- 2.1 Physiography
- 2.2 Subsurface Geology
- 2.3 Surface Soils

3.0 Hydrology of the Model Area
- 3.1 Precipitation
- 3.2 Evapotranspiration
- 3.3 Base Flows of the Rivers and Tributaries
- 3.4 Groundwater Recharge
- 3.5 Hydraulic Properties of Geologic Materials
- 3.6 Subdivisions of the Groundwater Flow System
- 3.7 Groundwater Elevations
- 3.8 Vertical Hydraulic Gradients
- 3.9 Groundwater Discharge

4.0 Conceptual Groundwater Flow System and Modeling Assumptions
- 4.1 Groundwater Flow System and Modeling Assumptions
- 4.2 Hydraulic Conductivity Values
- 4.3 Groundwater Flow Directions and Gradients
- 4.4 Groundwater Discharge
- 4.5 Seasonal Variability in the Groundwater System

5.0 Selection of the Model Code
- 5.1 Model Requirements
- 5.2 Models Evaluated
- 5.3 Model Selection
- 5.4 Additional Consideration

6.0 Construction of the Groundwater Flow Model
- 6.1 Model Domain
- 6.2 Layers and Stratigraphic Zonation
- 6.3 Groundwater Recharge
- 6.4 Groundwater Discharge
- 6.5 Boundary Conditions
- 6.6 Hydraulic Conductivity Values
- 6.7 Porosity, Storage Coefficient, and Specific Yield
- 6.8 Hydraulic Head Values
- 6.9 Fluid Densities
- 6.10 Simplifying Assumptions

7.0 Calibration of the Groundwater Flow Model
- 7.1 Approach and Procedures
- 7.2 Criteria for Judging Calibration
- 7.3 Adjustment of K Values
- 7.4 Adjustment of Boundary Conditions
- 7.5 Adjustment of Recharge Rates
- 7.6 Adjustment of Stream Bed Conductance Values
- 7.7 Residual Heads and Groundwater Flow

7.8 Water Budget
7.9 Areas of Uncertainty
7.10 Comparison of Initial Model to Final Calibrated Version
8.0 Flow Model Simulation Results and Discussion
9.0 Flow Model Sensitivity Analyses
9.1 Approach and Procedures
9.2 Variations in River Stage and Bed Conductance
9.3 Variations in Precipitation Recharge Rate
9.4 Variations in Horizontal and Vertical Hydraulic Conductivity Values
9.5 Variations in Boundary Conditions
10.0 Model Validation
11.0 Particle Tracking
12.0 Water Budget Analysis
12.1 Flux Through Model Boundaries
12.2 Groundwater Discharge to the Streams
13.0 Solute Transport Modeling
13.1 Objectives
13.2 Scope of Work
13.3 General Approach and Modeling Assumptions
13.4 Sources of Contaminants Entering the Model Domain
13.4.1 Loading Rates From Leachate Sources
13.4.2 Loading Rates from Potential DNAPL Sources
13.5 Physical Attenuation Processes
13.5.1 Hydrodynamic Dispersion
13.5.2 Adsorption and Desorption Processes
13.6 Biodegradation Processes
13.7 Simulation Solute Transport
13.7.1 Initial Distribution
13.7.2 Predicted Changes in Concentrations Over X Years
13.7.3 Mass Budgets
14.0 Sensitivity of the Solute Transport Models
14.1 Adsorption and Desorption
14.2 Biodegradation
14.3 Dispersion
15.0 Quality Control and Peer Review
15.1 Quality Assurance/Quality Control
15.2 Internal Peer Review
15.3 External Peer Review
15.4 Numerical Dispersion Analysis
15.5 Permanent Loading Source Areas
16.0 Conclusions
16.1 Groundwater Flow Model
16.2 Transport Modeling
17.0 References

Note: All main topics covered in the modeling work plan (if prepared) need to be addressed as topics in the report.

Appendix B
Memo from Shaw to the TCEQ, December 17, 2007
"Groundwater Model Required Parameters"

Memo

To: Subhash Pal

From: Diane Agnew and Michael Goodrich

Copy: Marilyn Long and Russell Perry

Date: December 17, 2007

Re: Groundwater Model Required Parameters

We evaluated the input parameters required to construct, calibrate and run the flow and transport model for the Jones Road Superfund Site. This memorandum has been written to meet one of the action items outlined during the December 11th and 12th, 2007 meeting and the December 13th site visit. Table 1 summarizes the required input parameters for the groundwater flow aspect of the Jones Road Superfund Site model. The required input parameters relevant to the contaminant transport aspect of the model are included in Table 2.

Flow Model

The first phase of the model setup and calibration will focus on the hydrologic relationships and flow within the Site. The parameters listed in Table 1 are those that will be required during model setup, as well as during model calibration. Suggestions for where to obtain the input parameter values are also included in Table 1. If values for a given parameter can not be obtained from available site data, values will be estimated from literature or material experts. A neighborhood-scale conceptual model will be developed from relevant information and incorporated into the model.

Transport Model

The second phase of model setup and calibration will involve chemical transport at the Site. Given the known information and the existing conceptual chemical transport site model, it will be assumed that the PCE is behaving as a dense, non-aqueous phase liquid (DNAPL) at or near the ground surface that is slowly degrading and releasing dissolved-phase PCE to the aquifer. The DNAPL will be simulated as a constant source term in the model; dissolved-phase concentrations will be imported directly from recent site measurements. Table 2 summarizes the required input parameters for the transport model, as well as possible sources for the requested information.

If you have any questions or need additional information, please feel free to contact me at (505) 262-8940 or by email at diane.agnew@shawgrp.com. Michael Goodrich is also available to provide additional information and/or answer questions at (505) 262-8908 or by email at michael.goodrich@shawgrp.com.

Table 1 Required Input Parameters - Groundwater Flow Model

Input Parameter	Description	Possible Sources
Hydraulic Conductivity (K_x, K_y, K_z)	Horizontal (K_x and K_y), vertical (K_z), and/or effective conductivity values are required for the flow model.	❖ Geotechnical data from boreholes within the model domain. ❖ Data published in reports summarizing previous modeling efforts. ❖ Analysis of data collected during specific capacity tests conducted at water supply wells within the model domain. ❖ Analysis of data collected from slug tests conducted in on-site wells.
Storage (S)	The input values for storage will depend on if the aquifer is being simulated under confined and unconfined conditions and the type of aquifer material. For a confined aquifer, the storage coefficient reflects the compressibility of the aquifer and the expansion of water. Under unconfined aquifer conditions, the specific yield of the aquifer depends on porosity, grain size, and sorting of the aquifer material. Multiple storage zones can be set up in the model domain.	❖ Data published in reports summarizing previous modeling efforts. ❖ Values published in scientific journals for equivalent aquifer conditions. ❖ Data from multi-well aquifer tests conducted nearby, if available.
Recharge	Recharge can be estimated from the total precipitation received within the model domain. For the purpose of this model, recharge will initially be assumed to be 5% of the precipitation. Multiple recharge zones maybe used to simulate parking lots verses private plots of land. Recharge will be treated as an independent variable during calibration.	❖ National climatic data for the Jones Road Superfund Site and/or the general Houston, TX region. ❖ Published recharge values for the surrounding area.

Subsurface geology/lithology	Lithologic information will be used to determine number and location of hydraulic conductivity zones and water bearing units. The lithology can also be used to determine the relative thickness of layers used in the model. The direction and angle of dip of major units will also be incorporated into the model.	❖ Geologic classification logs for wells and boreholes within the model domain. ❖ Geophysical data from boreholes within the model domain. ❖ Subsurface geology information published from previous studies in the area.
Well location and screen intervals	The coordinates for each well within the model domain would aid in the accurate placement of the wells. In addition, screened intervals for wells within the model domain will ensure that the simulated pumping will draw from the correct water bearing units.	❖ Some coordinates can be obtained from well logs registered with the state of Texas. ❖ GPS locations can be attempted with a Trimble XH in areas not limited by a thick canopy cover.
Aquifer thickness	The thickness of water bearing units will be important during the construction of layers and boundary conditions in the model domain.	❖ Geologic cross-sections for the Jones Road Superfund Site. ❖ Well logs and screening information for wells located in the model domain. ❖ Geophysical data from boreholes within the model domain.
Initial hydraulic head (h_1, h_2)	Input values for the hydraulic head boundary conditions must be input into the model as a starting point for water levels in the simulations. The Groundwater Availability Model (GAM) developed for the Houston area may provided the best approximations for initial heads for the model domain.	❖ Water levels collected directly from wells within the model domain. ❖ Values of initial head published from previous modeling efforts for the area (e.g., GAM).

Table 2 Required Input Parameters - Groundwater Transport Model

Input Parameter	Description	Possible Sources
Adsorption Coefficient (K_D)	This parameter will help account for partitioning for the contaminant between the groundwater, the aquifer matrix, and vapor phases. This parameter is material dependent and therefore, will most likely need to be estimated from published values for similar materials.	❖ Published values for PCE, TCE, and DCE in published reports.
Solubility	The solubility of a compound in water is temperature dependent, so standard temperature will be assumed for the model (25 ^{o}C).	❖ Published chemical data for PCE, TCE, and DCE.
Initial Concentrations (C_o)	Initial concentrations include what is currently detected in the soil and groundwater, as well as the concentration for the DNAPL source term.	❖ Site-specific groundwater sampling data for PCE, TCE, and DCE.
Dispersivity	The dispersivity input term will account for the fact that there is mixing along the flow path of a solute in the aquifer matrix. This value accounts for mechanical dispersion of the solute, as well as diffusion.	❖ Published values from scientific journals for an equivalent material. ❖ Published values in reports from previous modeling efforts.
Porosity (n)	The porosity values must be correlated with the storage values input into the model. The porosity vales represent the interconnectedness of the aquifer material and therefore, are related to the specific yield of an unconfined aquifer. Multiple zones of porosity can be used in the model domain to reflect changes in material, vertically and horizontally.	❖ Geotechnical data from boreholes within the model domain. ❖ Data published in reports summarizing previous studies and modeling efforts. ❖ Values published in scientific journals for equivalent aquifer materials.