SANBORN HEAD
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*1 Technology Park Drive*
*Westford, MA 01886*

June 6, 2016
File No. 3888.03

Mr. Steve Senna
BPR Development, LLC
c/o National Development
2310 Washington Street
Newton Lower Falls, MA 02462

Re: Fate and Transport of CVOCs – Sanitary Wastewater System to Raymond Road Well Field
526 & 528 Boston Post Road
Sudbury, Massachusetts

Dear Steve:

On behalf of BPR Development, LLC (Client), Sanborn, Head & Associates, Inc. (Sanborn Head) has prepared this letter to evaluate the potential impact to groundwater quality from the 528 Boston Post Road property in Sudbury, MA (Site) to the Raymond Road well field and direct abutters east and south of the Site given that low levels of chlorinated volatile organic compounds (CVOCs) have been observed in groundwater at the Site. A Locus Plan is provided as Figure 1.

**Existing Conditions and Project Description**

The Site is located at 526 & 528 Boston Post Road (Route 20) in southern central Sudbury, Massachusetts and consists of approximately 50 acres of land previously owned and operated by the Raytheon Company (Raytheon) since 1958. Up until January 2016, an active wastewater treatment plant (WWTP) consisting of treated wastewater discharging to three (3) open sand leaching beds has been in operation in the northern portion of the Site as shown on Figure 2. The Site is located within the Zone II Public Water Supply Protection Area for the Sudbury Water District Raymond Road water supply well field, which is located approximately 0.3 miles southeast of the Site as shown on Figure 1.

The WWTP is currently permitted to treat and discharge 50,000 gallons per day (gpd) under its current Groundwater Discharge Permit and has historically been treating as much as 30,000 gpd. Redevelopment plans for the WWTP include a proposed upgrade of the current WWTP to support an increase of the maximum daily flow to 90,000 gpd. Based on data from similar facilities (size and use) the daily flow from the WWTP would be much less (80% or less).

Approximately 40 groundwater monitoring wells have been advanced at the Site by Raytheon. Currently, only three of these monitoring wells contain concentrations of constituents above applicable Massachusetts Contingency Plan (MCP) standards. The on-Site concentrations have been monitored by Raytheon since 1990 under the MCP program. The years of monitoring data show that the concentrations present in groundwater are decreasing over time. The groundwater containing concentrations of CVOCs above MCP standards represents about 5% of the total Site area.

Specifically, the CVOC trichloroethylene (TCE) was detected in two deep monitoring wells in March 2015 at concentrations above the MCP Method 1, GW-1 standard, which is protective of drinking water exposures. TCE was detected in on-Site monitoring wells GZ-10D and GZ-202 at concentrations of 36 and 23 micrograms per liter (µg/L) respectively, which are above the MCP Method 1, GW-1 standard of 5 µg/L. Freon was also detected in shallow monitoring well GZ-106 at a concentration of 45 µg/L. There is no MCP Method 1, GW-1 standard or other published drinking water standard for Freon. The Freon concentration of 45 µg/L detected at GZ-106 was compared to a previously derived MCP Method 2, GW-2 standard of 13 µg/L, which is protective of the potential for vapor intrusion into a building.

The locations of monitoring wells GZ-10D, GZ-202 and GZ-106 are shown on Figure 2. As shown on the Figure, the closest well to the WWTP is GZ-10D, which is the location where the highest concentration of TCE was detected during the March 2015 sampling round. A conceptual hydrogeologic model was created using Visual MODFLOW with the MODPATH and MT3DMS packages to evaluate potential downgradient impacts of TCE, the primary contaminant of concern, from the proposed WWTP upgrade and expansion. The conceptual hydrogeologic model and the subsurface information/assumptions used to generate the model are discussed further below. The existing WWTP conditions are shown on Figure 2 and the proposed conditions are shown on Figure 3.

**Subsurface Soil Conditions**

In conjunction with the expansion and upgrade of the WWTP, Sanborn Head observed and documented the advancement of 12 official deep observation holes (test pits), six percolation tests, and four Guelph permeameter/infiltration tests in March and May 2016 at the Site. The results from the subsurface explorations indicated that in landscaped areas, the surface topsoil is generally 6 to 24 inches thick. Below the topsoil, there is a combination of discontinuous layers of subsoil, fill materials, and buried topsoil on the order of 0 to 8 feet thick. The fill generally consists of sand with varying amounts of silt and trace amounts of gravel.

Below the surface materials and fill material, the Site is underlain by natural glacial outwash deposits composed of sands and silts in discontinuous layers and strata. Based on our understanding of subsurface conditions across the overall development from subsurface exploration logs by Sanborn Head and others, these deposits are greater than 25 feet thick. The materials vary from sand with trace to little amounts of silt and trace amounts of gravel to non-plastic silts and sand. At isolated locations near the top of the deposits, very few root particles and organic matter were encountered and are likely an indication of former grade and subsoil that was left in-place. The organic content is estimated to be less than one percent by weight. The material is typically very loose to medium dense.

Based on extensive Site-wide explorations (approximately 62 explorations of depths ranging between approximately 15 and 108 feet below ground surface [bgs]), we understand the sand and silty sand deposits are underlain by glacial till at depths greater than 35 feet bgs within the existing leaching field area.

Subsurface information for the Raymond Road aquifer was obtained from the Sudbury Groundwater Model Supplement[1] and surficial geology maps provided by the Massachusetts Office of Geographic Information (MassGIS). These reports indicate the Raymond Road aquifer consists of sand and gravel and fine-grained soil deposits approximately 25 to 110 feet thick and underlain by glacial till. Additionally, near surface organic soils can be found along depressions near streams within the Landham Brook watershed. For the purposes of creating a conceptual hydrogeologic model, we have assumed the subsurface conditions at the Raymond Road aquifer consist of loamy sand.

## Travel Time Analysis and Mounding Effects

Based on the subsurface conditions observed at the Site and our review of the Sudbury Groundwater Model Supplement for the Sudbury Water District Raymond Road drinking water well field, a conceptual hydrogeologic model was created using Visual MODFLOW with the MODPATH package (with particle tracking) to estimate mounding beneath the leaching beds and the travel time from the proposed wastewater discharge area to the well field based on the historical discharge of approximately 30,000 gpd, and a proposed daily design flow of 90,000 gpd. To be more representative of actual conditions, the model used 80% of the maximum daily flow (or 72,000 gpd) which is consistent with *DEP Guidelines for the Design, Construction, Operation, and Maintenance of Small Wastewater Treatment Facilities with Land Disposal*, dated November 2014.

Subsurface conditions at the Site were modeled in accordance with observed conditions during subsurface explorations at the open sand leaching bed area described previously. Subsurface conditions at the Raymond Road aquifer were modeled as loamy sand in accordance with the Sudbury Groundwater Model Supplement and MassGIS. Well construction details and pumping rates were provided by Ms. Rebecca McEnroe, Superintendent at the Sudbury Water District, and were incorporated into the model.

The travel time analysis was performed to estimate the length of time required for groundwater located within the glacial till geological unit at the Site (where TCE concentrations have been observed) to reach the Sudbury Water District Raymond Road drinking water well field. TCE concentrations have not been detected in shallow groundwater at the Site. MODFLOW travel time results are included in Attachment A. Based on the results of the hydrogeologic model, the estimated travel time it takes the groundwater in the deep glacial till groundwater flow regime (at the wastewater disposal field) to reach the nearest Raymond Road drinking water supply well (Well No. 2) is between 25 and 30 years for both the existing and proposed design flow conditions.

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[1] *Groundwater Model Documentation Supplement to Prolonged Pumping Test Report for New Well No. 9, Sudbury, Massachusetts*, H2O Engineering Consulting Associates, Inc., February 1993.

In addition to the travel time analysis, mounding effects for the proposed upgrade were analyzed. Groundwater elevation contours produced from the MODFLOW model are included for the former existing condition of 30,000 gpd discharge rate and the proposed 90,000 gpd discharge rate in Attachment B. Please note that Attachment B shows generalized regional groundwater contours for the purpose of estimating long-term effects and not Site specific groundwater contours. Mounding effects show that groundwater elevations in the immediate vicinity of the open leaching bed area increase slightly when the proposed conditions are applied to the model. However, at the Site boundaries, the groundwater contours stabilize and no significant changes were observed for off-Site groundwater elevations based on the MODFLOW outputs for existing and proposed conditions.

As indicated by the model, the travel time from the Site to the Raymond Road well field and the mounding effects at the Site boundaries are not noticeably altered by the increase in daily flow to the proposed design rate of 90,000 gpd. Based on these results, it is Sanborn Head's opinion that the proposed increase in daily flow is not likely to impact off-Site groundwater flow patterns and/or groundwater quality.

**CVOC Fate and Transport**

The most recent groundwater quality data available for the Site from March 2015 shows the highest concentration of TCE detected at a concentration of 36 µg/L in monitoring well GZ-10D located immediately downgradient of the existing open leaching beds. The location of well GZ-10D is shown on Figure 2. The screened interval for this well is 59 to 69 feet below top of PVC well riser (El. 96 to 86 feet). Based on subsurface soil conditions, this well is screened within the glacial till layer.

The aforementioned parameters were included in a TCE fate and transport model created using the MT3DMS package for Visual MODFLOW. TCE was modeled under the proposed 90,000 gpd discharge rate using a first order decay and linear sorption isotherms based on available published literature, which is representative of the likely natural breakdown in the subsurface. As a conservative estimate, a TCE concentration of 36 µg/L (highest concentration of TCE detected during the most recent sampling round in March 2015) was applied as a constant source (i.e. continuous input) at the location of GZ-10D, which is closest to and immediately downgradient of the leaching fields. The MODFLOW output provided in Attachment C shows estimated TCE concentration contours with a cut-off of the MCP Method 1, GW-1 standard and MA Drinking Water Maximum Contaminant Level (MCL) of 5µg/L. The MODFLOW output shows that, under the proposed discharge rate using a first order decay and linear sorption isotherms, the TCE plume does not reach the Site boundaries after more than 27 years (approximately 10,000 days). As such, based on the model, off-Site impacts to groundwater quality are not anticipated. Note that this scenario is considered conservative based on the assumption of a continuous source of TCE, which has not been identified at the Site.

TCE fate and transport was also modeled as a conservative tracer (i.e. no sorption or decay). TCE in the environment has a tendency to sorb to organics and soil particles, volatilize in soil vapor, and degrade through microbial biodegradation. Therefore, modeling TCE fate and transport as a tracer provides a conservative estimate, but also another means to measure and evaluate our other modeling assumptions. As shown in the MODFLOW output based on this conservative tracer analytical approach, concentrations of TCE greater than the MCP Method 1, GW-1 standard and MCL would not reach the Site boundaries after more than 27 years (approximately 10,000 days). We would anticipate similar results if fate and transport of TCE and Freon were modeled using conditions observed at groundwater monitoring wells GZ-106 and GZ-202, where these CVOCs were also detected.

Sanborn Head also performed independent calculations using Darcy's law and assuming first order decay rates for TCE to support the MODFLOW results. The calculations conservatively ignored the well documented and scientifically accepted dilution affects from dispersion/diffusion and sorption/retardation effects. These calculations are provided in Attachment D and indicate that TCE concentrations would not reach the Raymond Road well field for approximately 30 years, and that the TCE concentration at the well field would be on the order of $10^{-8}$ µg/L (seven orders of magnitude below laboratory detection limits)even though the calculations very conservatively ignored dilution affects. The findings confirm the MODFLOW output and show that detectable TCE concentrations would not reach the Raymond Road well field.

Based on the CVOC fate and transport model and supporting calculations, it is our opinion that TCE and/or other contaminants from the Raytheon site will not be detectable in the public wells with the proposed increase flow of 90,000 gpd at the WWTP. Further, significant impacts to the direct abutters east and south of the Site where CVOCs have been observed in groundwater are not expected.

Very truly yours,
SANBORN, HEAD & ASSOCIATES, INC.

Danielle M. Volpe

Danielle M. Volpe, P.E.
*Senior Project Engineer*

Patricia M. Pinto, P.E., LSP
*Senior Associate/Vice President*

Matthew P. Heil, P.E., LSP
*Associate/Project Director*

DMV/PRM/SSS/MPH/PMP: dmv

Encl.

Figure 1: Locus Plan
Figure 2: Existing Conditions

Figure 3: Proposed Conceptual Subsurface Bed
Attachment A: Travel Time Analysis MODFLOW OUTPUT
Attachment B: Groundwater Elevation Contours MODFLOW OUTPUT
Attachment C: CVOC Fate and Transport MODFLOW OUTPUT
Attachment D: Fate and Transport Calculations

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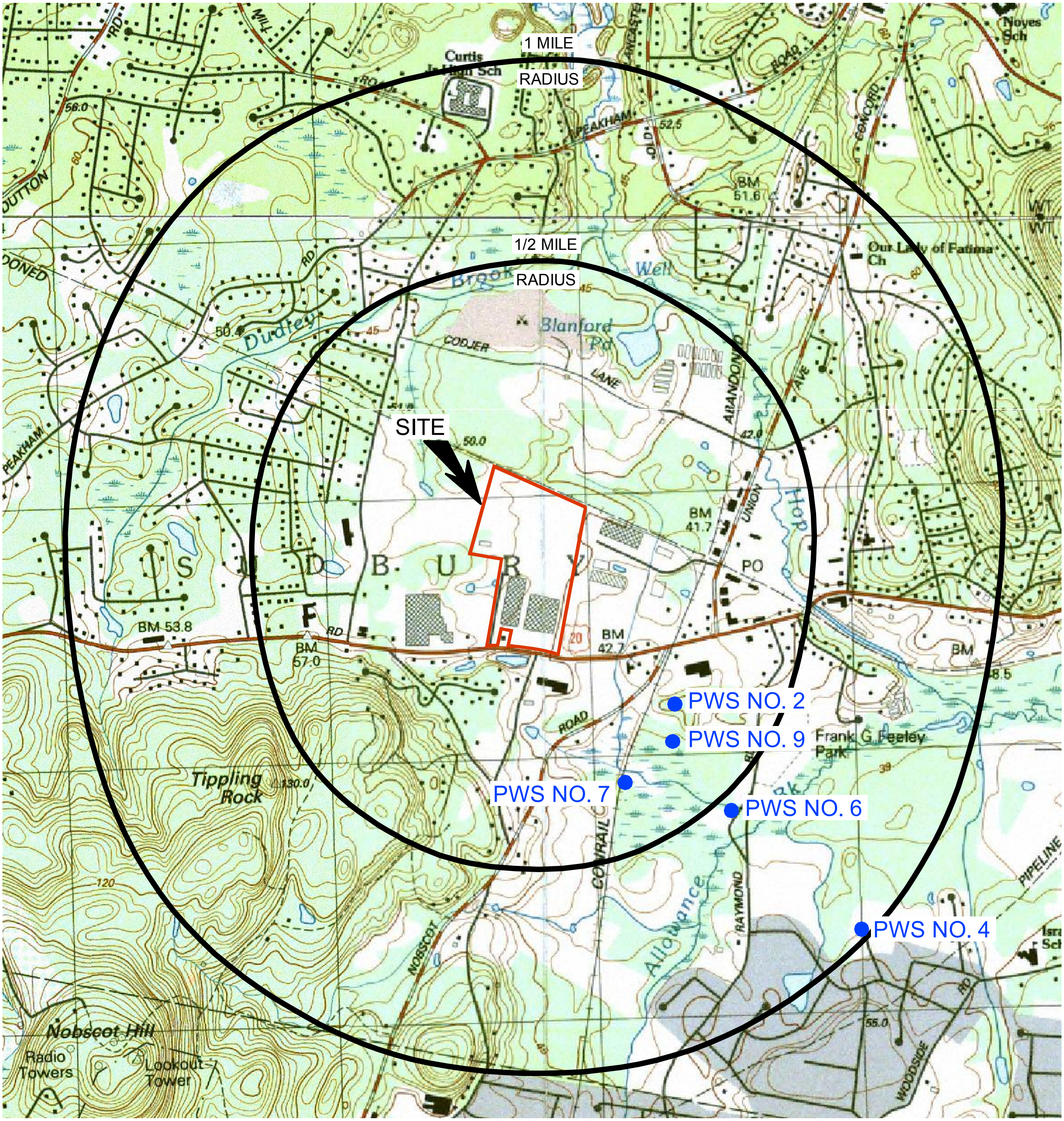
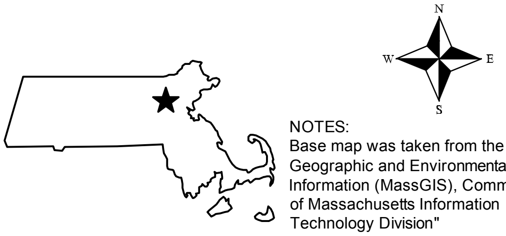
# FIGURES




Legend:

● Community and Non-Community Public Water Supply Well (from MassGIS online database records)



NOTES:
Base map was taken from the "Office of Geographic and Environmental Information (MassGIS), Commonwealth of Massachusetts Information Technology Division"
7.5 minute USGS Quadrangle Maps: Sudbury, Massachusetts, REV: 1987

Drawn By: D.Dombrowsky
Designed By: D.Volpe
Reviewed By: L.Norton
Project No: 3888.03
Date: June 2016

SCALE: 1" = 1,700'

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Figure 1

# Locus Plan

CVOC Fate and Transport Analysis
528 Boston Post Road
Sudbury, Massachusetts

NOTES:

1. THE BASE MAP WAS TAKEN FROM AN ELECTRONIC PLAN ENTITLED, "EXISTING CONDITIONS SITE PLAN", PREPARED BY VANASSE HANGEN BRUSTLIN, INC. (VHB) OF WATERTOWN, MA, RECEIVED MAY 23, 2016 WITH AN ORIGINAL SCALE OF 1" = 100'.


SANBORN HEAD

GRAPHICAL SCALE

100' 50' 0' 100' 200'

| NO. | DATE | DESCRIPTION | BY |
|---|---|---|---|

DRAWN BY: C.GREEN
DESIGNED BY: L.NORTON
REVIEWED BY: S.SADKOWSKI
PROJECT MGR: L.NORTON
PIC: S.SADKOWSKI
DATE: JUNE 2016

CVOC FATE AND TRANPORT ANALYSIS

528 BOSTON POST ROAD

SUDBURY, MASSACHUSETTS

EXISTING CONDITIONS PLAN

PROJECT NUMBER: 3888.03

SHEET NUMBER: 2

NOTES:

1. THE BASE MAP WAS TAKEN FROM AN ELECTRONIC PLAN ENTITLED, "PROPOSED CONCEPTUAL SUBSURFACE BED," PREPARED BY VANASSE HANGEN BRUSTLIN, INC. (VHB) OF WATERTOWN, MA, RECEIVED MAY 23, 2016 WITH AN ORIGINAL SCALE OF 1"=100'.


SANBORN HEAD

GRAPHICAL SCALE

100' 50' 0' 100' 200'

| NO. | DATE | DESCRIPTION | BY |
|---|---|---|---|

DRAWN BY: C.GREEN
DESIGNED BY: L.NORTON
REVIEWED BY: S.SADKOWSKI
PROJECT MGR: L.NORTON
PIC: S.SADKOWSKI
DATE: JUNE 2016

CVOC FATE AND TRANSPORT ANALYSIS
528 BOSTON POST ROAD
SUDBURY, MASSACHUSETTS

PROPOSED CONCEPTUAL SUBSURFACE BED

PROJECT NUMBER: 3888.03

SHEET NUMBER: 3

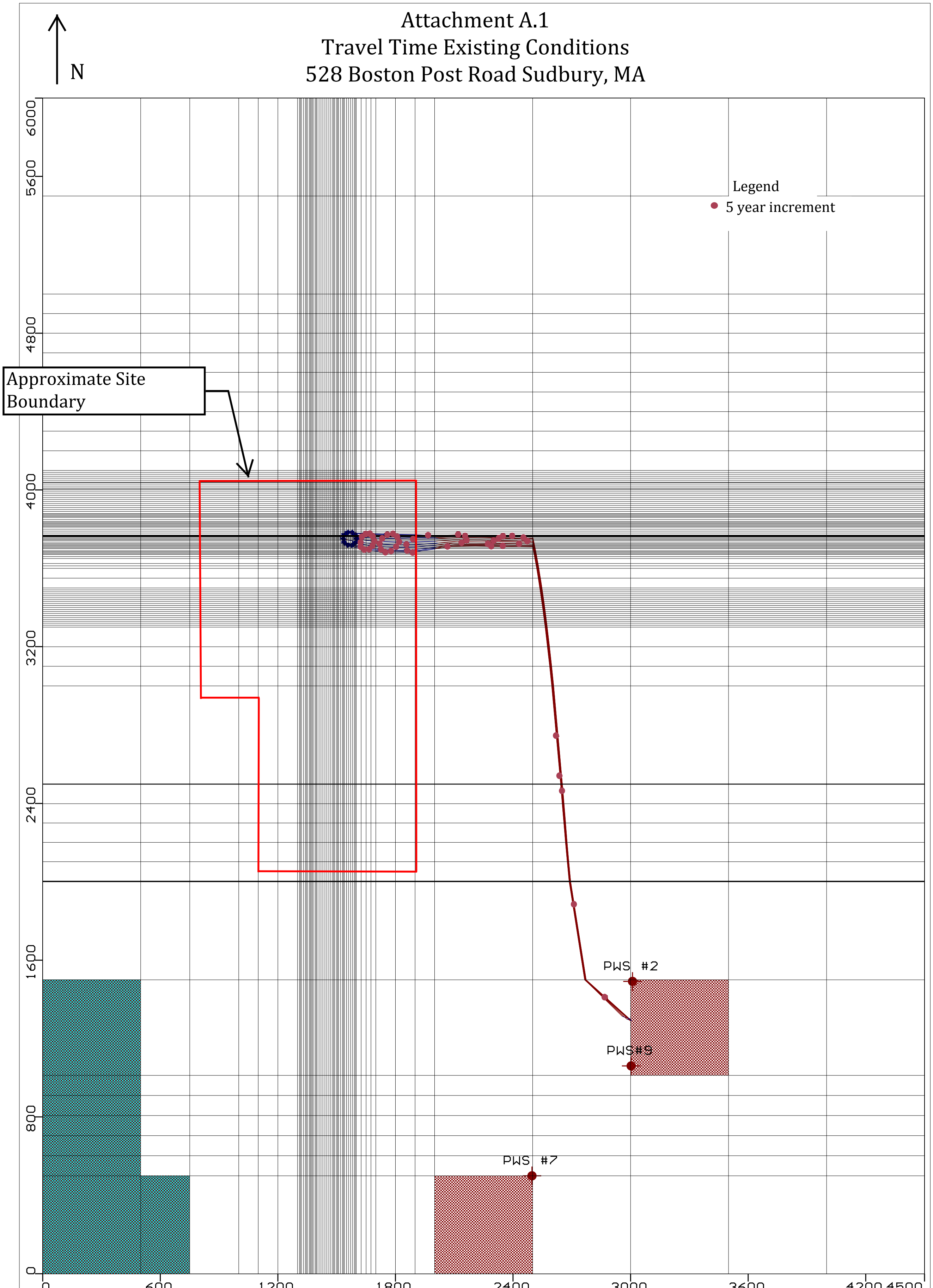
# ATTACHMENT A

# TRAVEL TIME ANALYSIS MODFLOW OUTPUT

Attachment A.1

Travel Time Existing Conditions

528 Boston Post Road Sudbury, MA

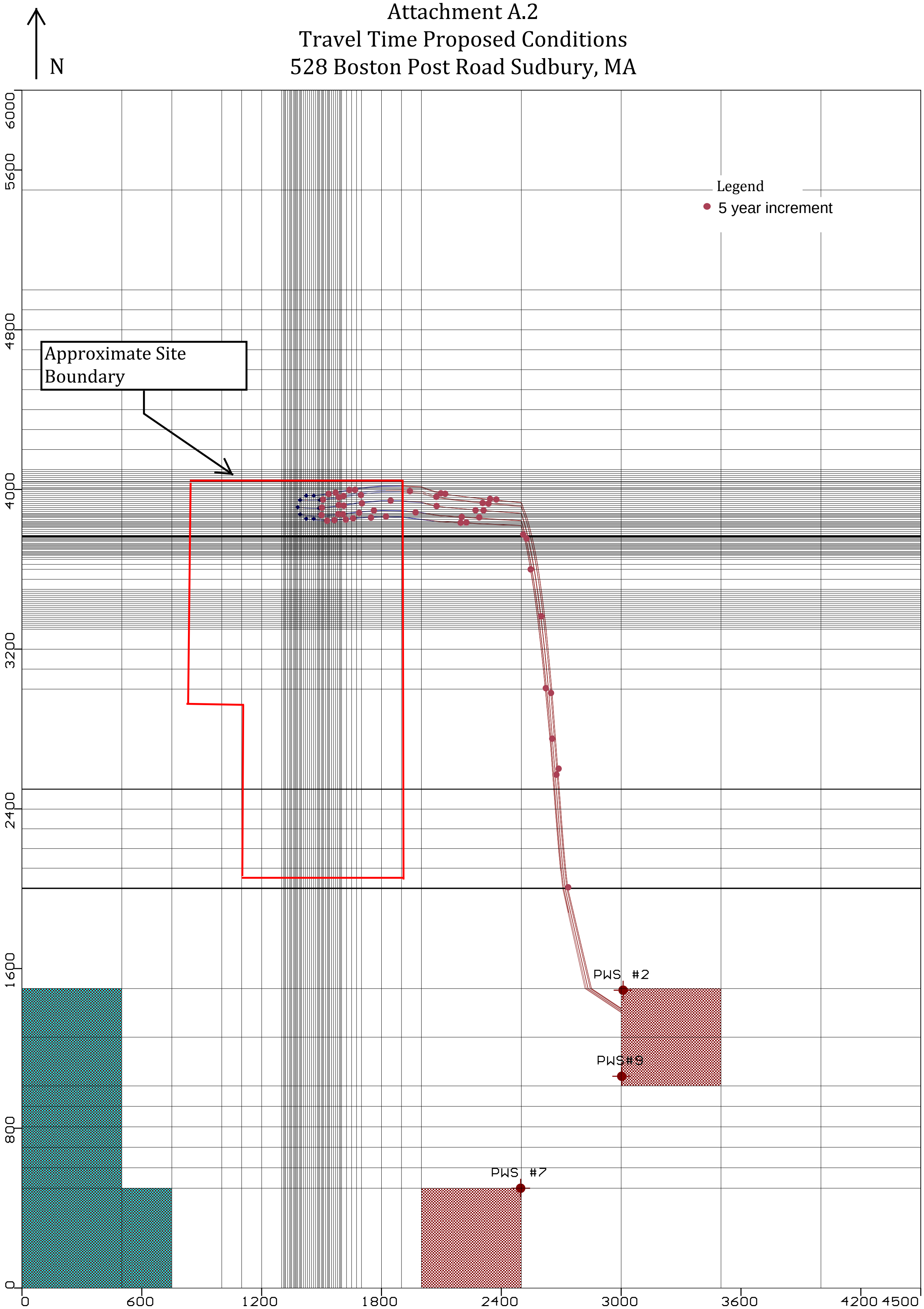



Notes:

Existing Conditions:

30,000 gallons per day applied to Bed No. 2 and Bed No.3. Bed No. 1 on reserve

# Attachment A.2
# Travel Time Proposed Conditions
# 528 Boston Post Road Sudbury, MA




Notes:
Proposed Conditions:
90,000 gallons per day applied to New Bed (22,500 square feet) Bed No. 2 on Reserve

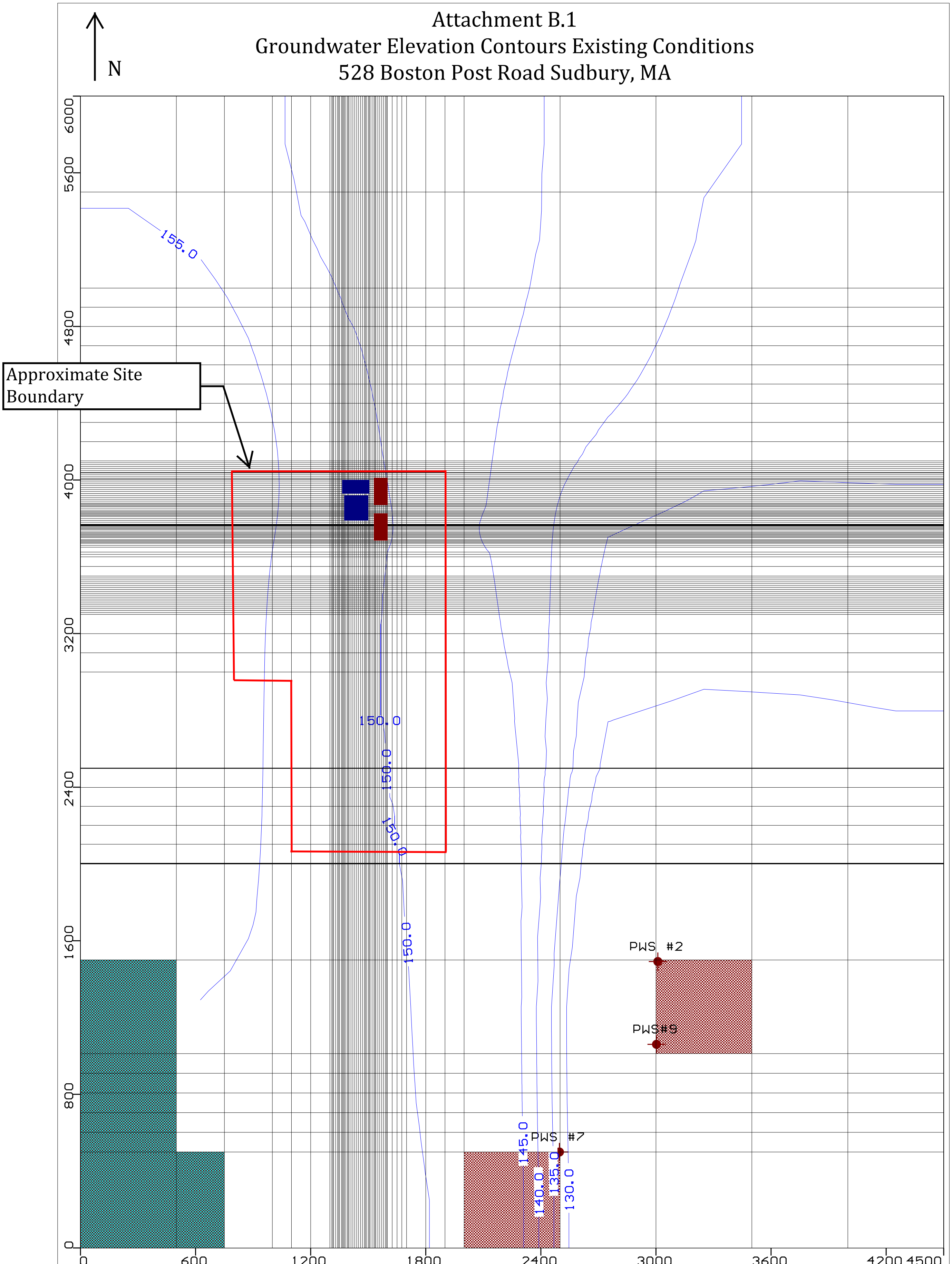
# ATTACHMENT B

# GROUNDWATER ELEVATION CONTOURS MODFLOW OUTPUT

Attachment B.1

Groundwater Elevation Contours Existing Conditions

528 Boston Post Road Sudbury, MA



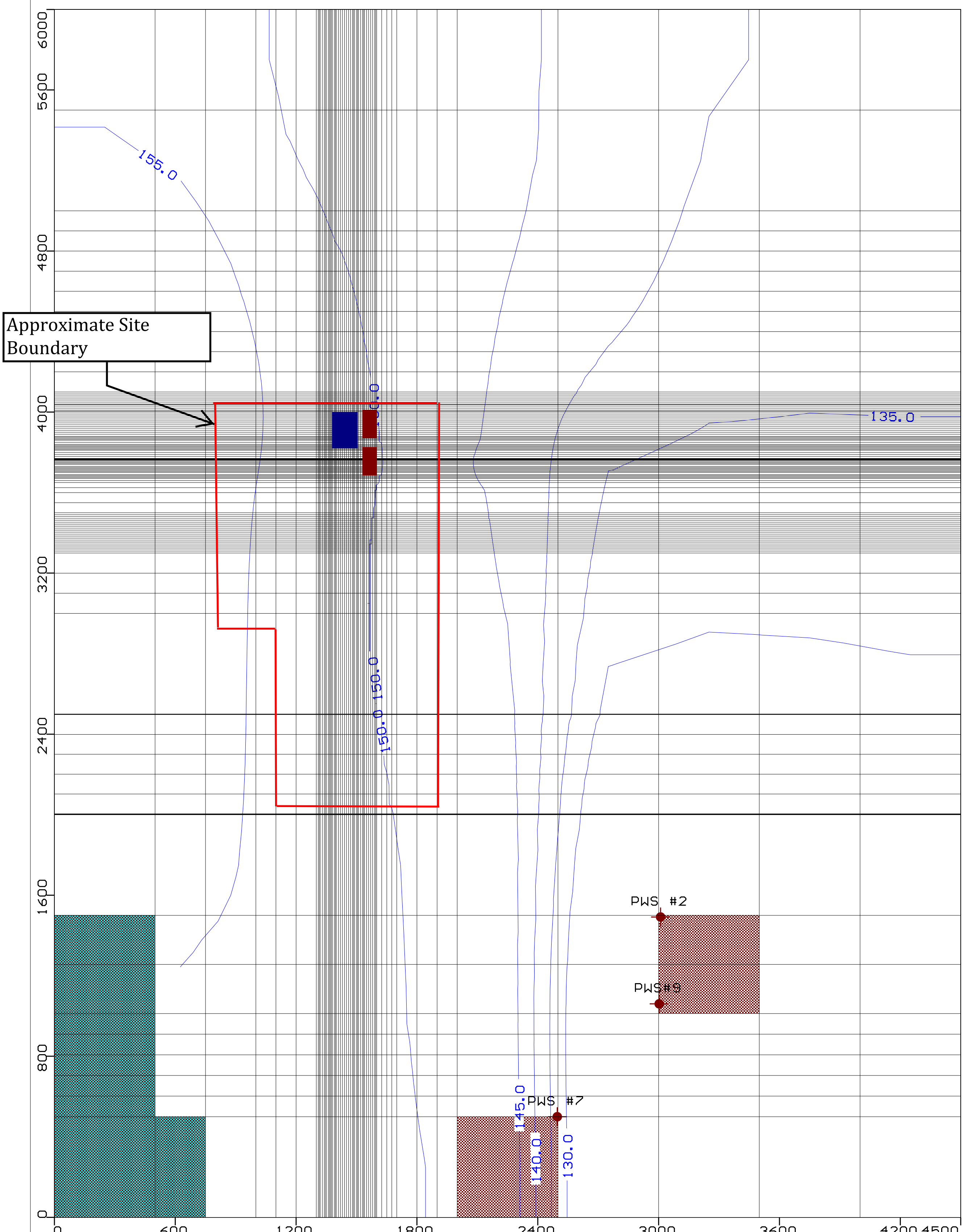

Notes:

Existing Conditions:

30,000 gallons per day applied to Bed No. 2 and Bed No.3, Bed No. 1 on Reserve

N

# Attachment B.2
## Groundwater Elevation Contours Proposed Conditions
## 528 Boston Post Road Sudbury, MA

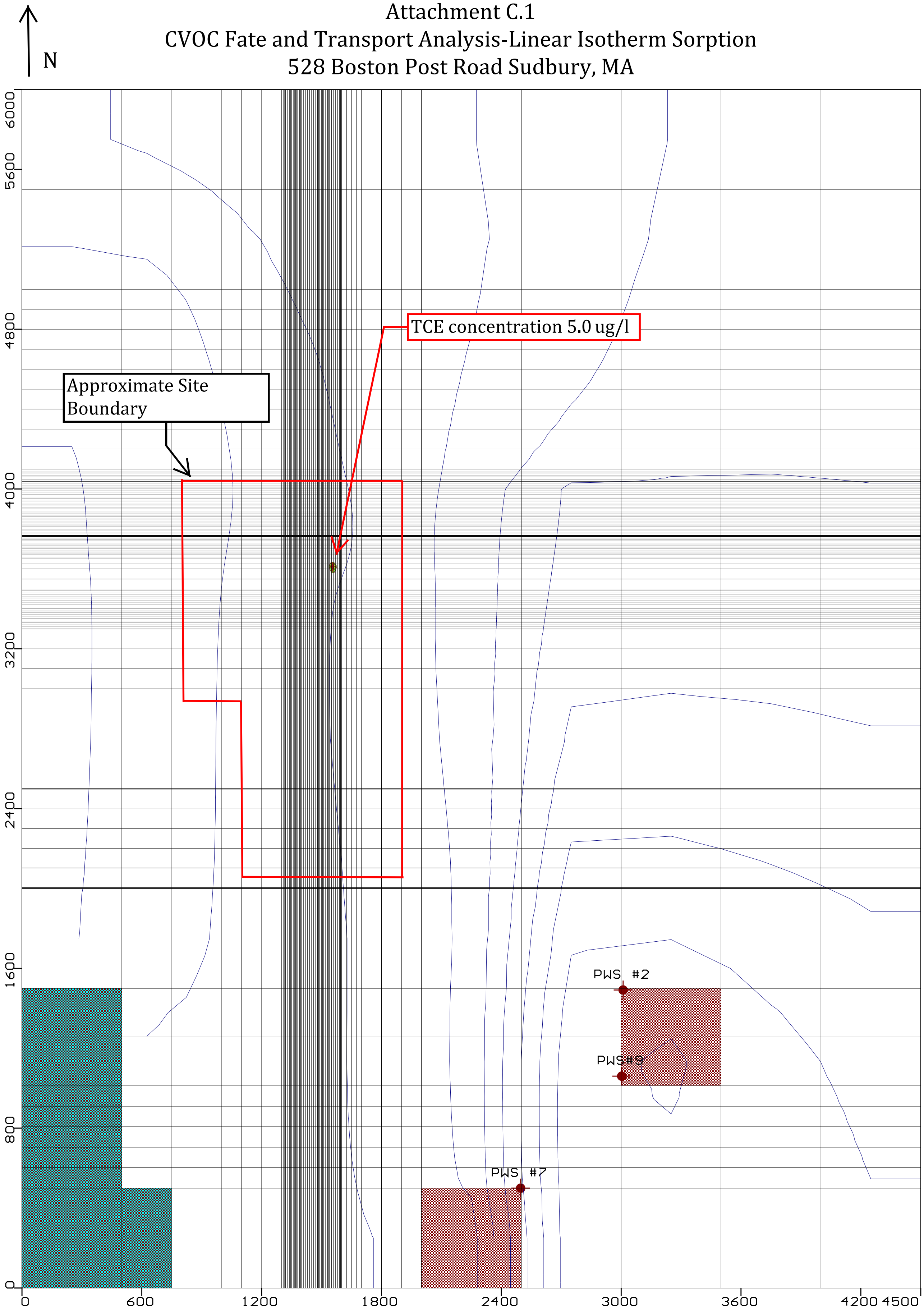



Notes:
Proposed Conditions:
90,000 gallons per day applied to New Bed (22,500 square feet) Bed No. 2 on Reserve

# ATTACHMENT C

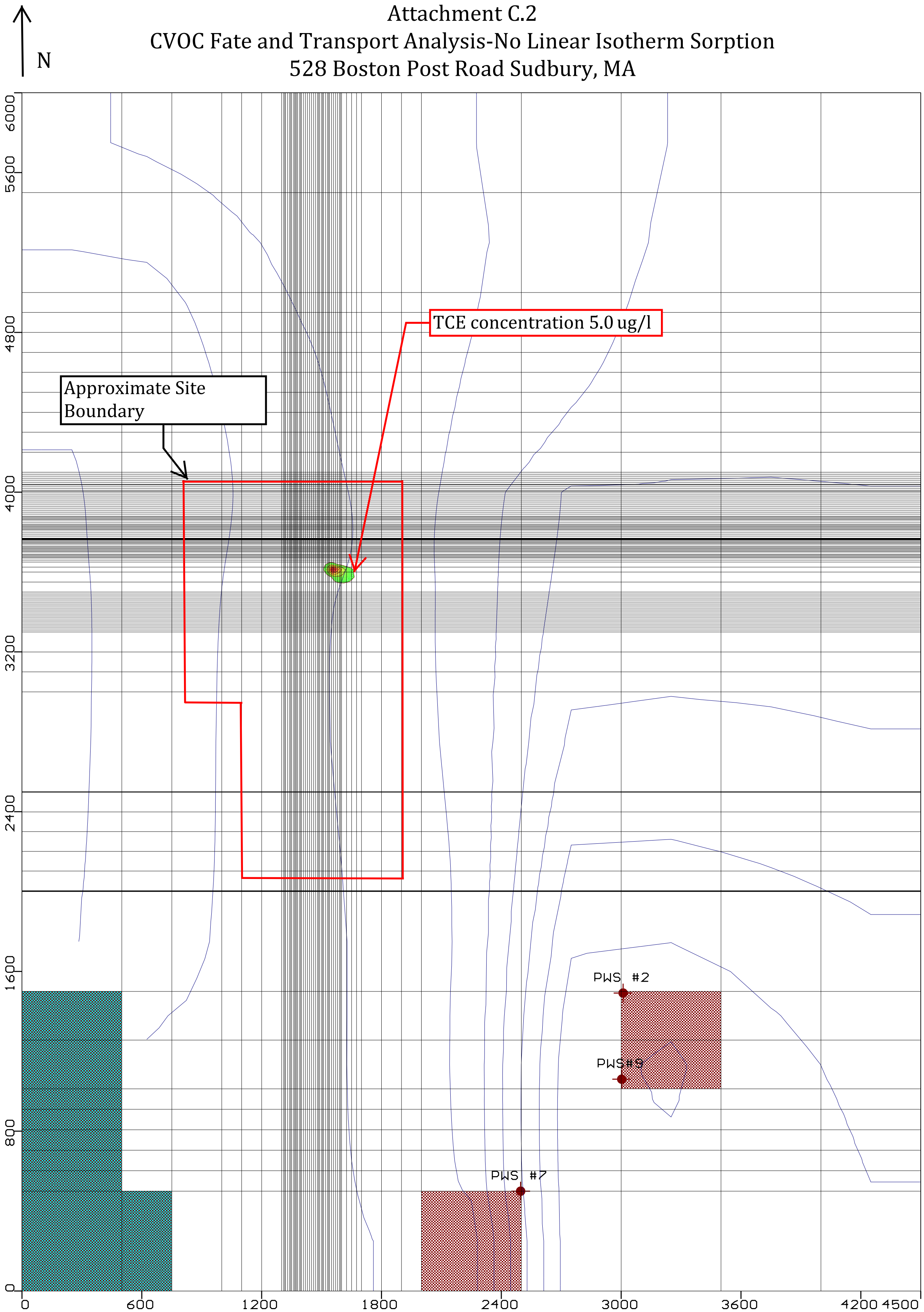
# CVOC FATE AND TRANSPORT MODFLOW OUTPUT

Attachment C.1
CVOC Fate and Transport Analysis-Linear Isotherm Sorption
528 Boston Post Road Sudbury, MA




Notes:
TCE concentration after 27 years

Attachment C.2
CVOC Fate and Transport Analysis-No Linear Isotherm Sorption
528 Boston Post Road Sudbury, MA




Notes:
TCE concentration after 27 years

# ATTACHMENT D

# FATE AND TRANSPORT CALCULATIONS

**PURPOSE:**
To estimate the concentration of TCE at downgradient drinking water wells based on on-Site groundwater concentrations.

**ASSUMPTIONS:**

The following parameters are based on site-specific information or published literature values. The values for hydraulic conductivity and porosity are consistent with deeper aquifer silts, which are conservatively higher than those observed in the glacial till where the TCE is known to reside.

| | | |
|---|---|---|
| GW Elevation On-Site | = | 150 ft |
| GW Elevation Supply Well | = | 120 ft |
| Hydraulic Conductivity (K) | = | 8 ft/day |
| Distance (L) | = | 2,500 ft |
| Porosity (n) | = | 0.42 |
| TCE Concentration (Co) | = | 36 ug/L |
| Decay rate (k) | = | 0.002/day to 0.008/day (USEPA, 2002) |

**METHOD:**
Darcy's Law
First Order Decay

**CALCULATION:**
v=K dh/dx (Darcy)
v=8 x [(150-120)/2500] = 0.096 ft/d

Seepage or linear velocity (vL):
vL=v/n = 0.096/0.42 = 0.23 ft/d

Travel time (t):
t = 2500/0.23 = 10,900 days (30 years)

Based on USEPA guidance, conservatively assume a first order TCE decay rate of 0.002/day.

C = Coe^-kt = 36 e^(-0.002x10,900) = 1.2E-8 ug/L

**RESULTS:**

Simplified fate and transport calculations using Darcy and assumed first order decay indicate TCE concentrations in the downgradient wells of **approximately 1.2E-8 ug/L** resulting from on-site impacts.

**CONCLUSIONS:**

The results indicate that TCE concentrations from the Site would be well below laboratory detection limits at the public wells. Further, the results are based on a simplified calculation conservatively ignores dilution effects from diffusion/dispersion. It also ignores retardation and sorption effects, which if included would result in even lower concentrations.

**REFERENCES:**

- On-site groundwater elevations are based on estimated seasonal high groundwater calculated using the Frimpter Method.
- Hydraulic conductivity was estimated using Hazen and Kozeny-Carmen grain-size analyses on soil samples collected by Sanborn Head during the subsurface investigation.
- Porosity was assumed based on literature and our experience on similar projects.
- TCE decay rate was obtained from:
    - United States Environmental Protection Agency (November 2002). *Ground Water Issue – Calculation and Use of First-Order Rate Constants for Monitored Natural Attenuation Studies*. National Risk Management Research Laboratory, Cincinnati, OH.