An Innovative Approach for Hydraulic Containment of PCB Contamination in Fractured Bedrock

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Abstract

A comprehensive remedy has been proposed to remediate a site contaminated with polychlorinated biphenyls (PCBs) and volatile organic compounds (VOCs) (GeoTrans, Inc. et al., 2001a, 2001b). Two of the principal groundwater-related remedial action objectives for the site are to:

$ prevent or minimize PCB releases to a river next to the western portion of the Site; and
$ prevent or minimize migration of contaminated groundwater from the Site.

A principal component of the proposed groundwater remedy is a tunnel/drain collection system (TDCS) that would be installed in fractured shale beneath the site. The primary objectives of the collection system are to prevent or minimize PCB releases to the river adjacent to the site and to contain the migration of contaminated groundwater from the site. A 20-foot diameter dropshaft would be constructed to a depth of about 200 feet (elevation 40 feet National Geodetic Vertical Datum [NGVD]). Three 10- to 12-foot diameter sloping tunnels would be mined from the shaft. One tunnel would extend a distance of about 500 feet from the shaft to beneath the river bed, a second tunnel would extend about 600 feet south beneath the eastern edge of the river, and the third tunnel would extend about 650 feet north beneath the eastern edge of the river. Vertical drain wells that intersect the tunnels would be installed. In addition, horizontal drain wells would be drilled from the tunnels to create an expanded region of downward hydraulic gradients beneath the river. An alcohol/polymer flood, or other localized supplemental remedial action, is being evaluated for the purpose of removing DNAPL from portions of the periodically exposed bedrock beneath the riverbed, if necessary.

The proposed remedy is based on a site conceptual model that was developed after several years of investigation and characterization. Some of the more significant and informative investigative techniques used to develop the conceptual model were:

- Installation of multi-level FLUTe™ monitoring systems to provide long-term groundwater level and quality monitoring in deep bedrock wells
- Rock core and FLUTe™ swab sampling to identify DNAPL bearing fractures
- Borehole video logging to identify the spatial distribution of DNAPL and bedrock fractures
- Short-term water level monitoring in the dry portion of the falls using removable FLUTe™ systems
- Cross-hole hydraulic monitoring to determine preferred orientations of hydraulically-connected fractures
- DNAPL chemical fingerprint analyses
- DNAPL recovery from selected wells
- Pilot-scale polymer flood in shallow bedrock beneath the Wing Dam area
- Regional groundwater flow modeling
- Discrete fracture network modeling

Regional groundwater flow model analyses indicate that operation of the tunnel/drain collection system, with a water level maintained at 40 feet NGVD, would result in site-wide lowering of the water table including the area beneath the former manufacturing building. The model-calculated capture zone extends about 400 feet beneath the river and about 150 feet downstream of the southerly end of the proposed tunnel. The capture zone extends beyond the area of the river where DNAPL has been detected in the bedrock. Discrete fracture network model analyses were done to evaluate the effect that the hydraulic gradients resulting from the construction and operation of the TDCS would have on DNAPL mobilization and containment. The regional groundwater flow and discrete fracture network model analyses considered alternate spacing of the vertical drain wells and alternate operating head conditions. The New York State Department of Environmental Conservation has recently selected the proposed TDCS as the groundwater remedy for the Site (NYSDEC, 2004).

INTRODUCTION

During the fabrication of electrical capacitors at an old manufacturing plant, there were releases of PCBs (primarily Aroclor 1242) to the environment. Although the use of PCBs was discontinued in 1977, PCBs have migrated as DNAPL into fractured bedrock and subsequently to the face of what is now usually a dry waterfall. Figure 1 shows the principal Site features.

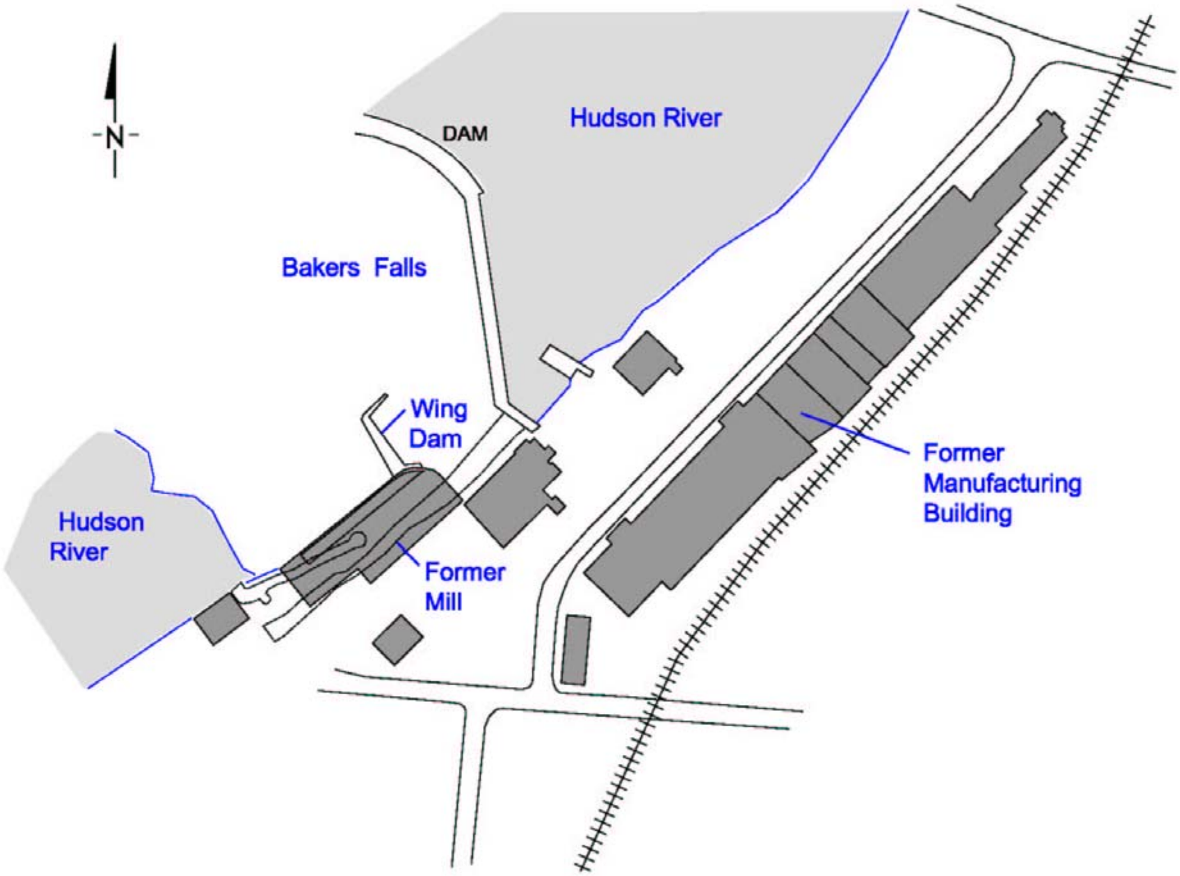

Figure 1. Site Features Map

Hydrogeologic Setting

Directly beneath the Site is a layer of unconsolidated deposits, up to 21 feet thick. The unconsolidated deposits are composed of glaciofluvial outwash, lacustrine clay, till, and artificial fill. Beneath the unconsolidated deposits is fractured shale, which ranges in thickness from 150 feet to 260 feet. The shale overlies two distinct limestone formations (Figure 2), which together are approximately 150 feet thick. A portion of the foundation of the main manufacturing building at the Site was excavated into the shale. Several drainage structures, tunnels, sewers, and air plenums were also excavated into the shale beneath the floor of this building. At the eastern edge of the river is a former mill. Historically, water from behind the dam was diverted through raceways and tunnels to drive the turbines in the mill. The primary pathways of DNAPL migration within the shale are the interconnected nearly vertical and approximately horizontal fractures. The fractured shale is exposed on cliffs and the dry waterfall immediately adjacent to the Site. In addition, two major parallel sub-horizontal thrust fault planes in the shale, locally referred to as the upper and the lower fault planes, are exposed on the dry waterfall and have provided major pathways for DNAPL migration.

A dam is located at the top of the waterfall. The dam diverts the flow of the Hudson River through a hydroelectric plant on the western side of the river. The total elevation drop from the top of the dam to the base of the falls is 67 feet. The waterfall itself drops approximately 40 feet. During much of the year, the total river flow (3,000 to 5,000 cubic feet per second [cfs]) is diverted through the hydroelectric plant and the waterfall is dry. Periodically, during routine maintenance at the hydroelectric plant and during high river flow (greater than 8,000 cfs), water spills over the dam onto the waterfall.

Nature and Extent of Contamination

PCB DNAPL is present in the bedrock beneath the former manufacturing facility as a result of the manufacture of electrical equipment from the 1950s to 1977. The use of PCBs was discontinued in 1977, but the dense PCB oil has migrated downward through the fractured shale, to the west toward the river, and to the east, stratigraphically down dip. Figure 3 shows the lateral extent of the DNAPL beneath the Site. Periodically, PCBs have been observed to flow from the fractured shale onto the dry face of the falls below the dam. Figure 2 is a schematic cross section showing the vertical distribution of DNAPL. Samples collected from angled monitoring wells beneath the river, and wells installed in the periodically dry portion of the waterfall indicate that there is DNAPL in the fractured shale beneath the river.

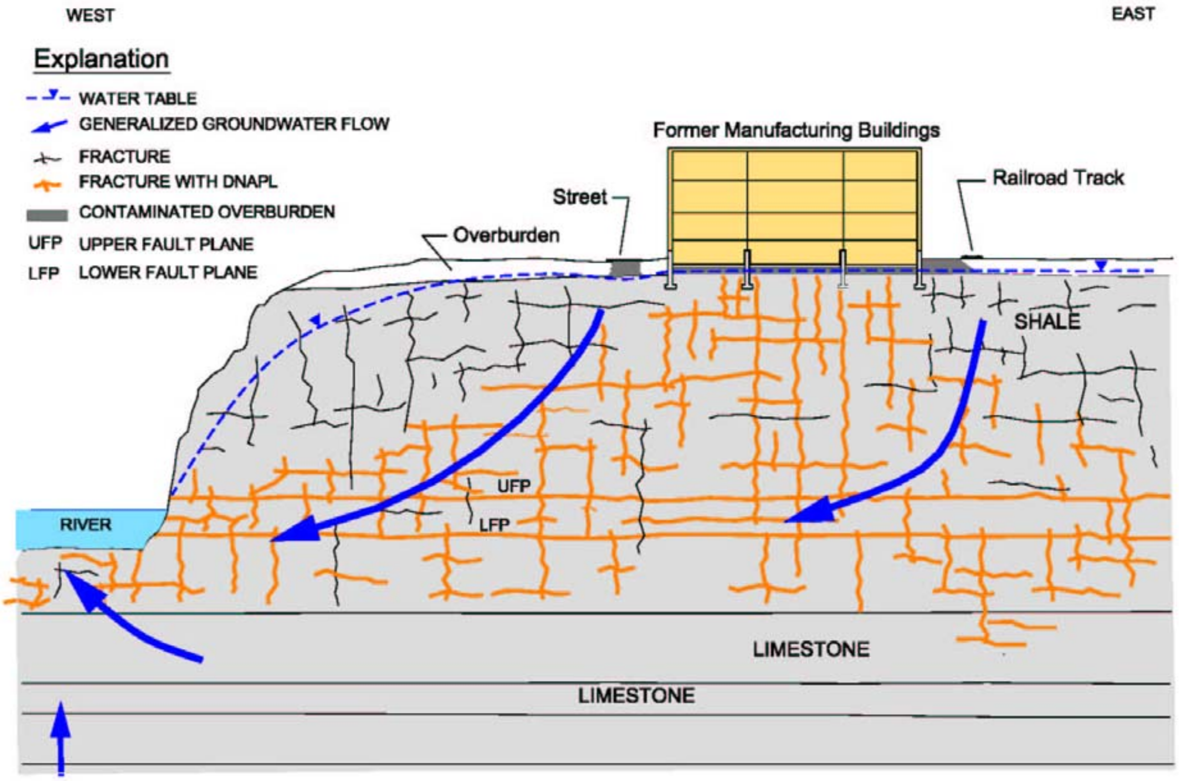

Figure 2. Schematic Contaminant Distribution Section

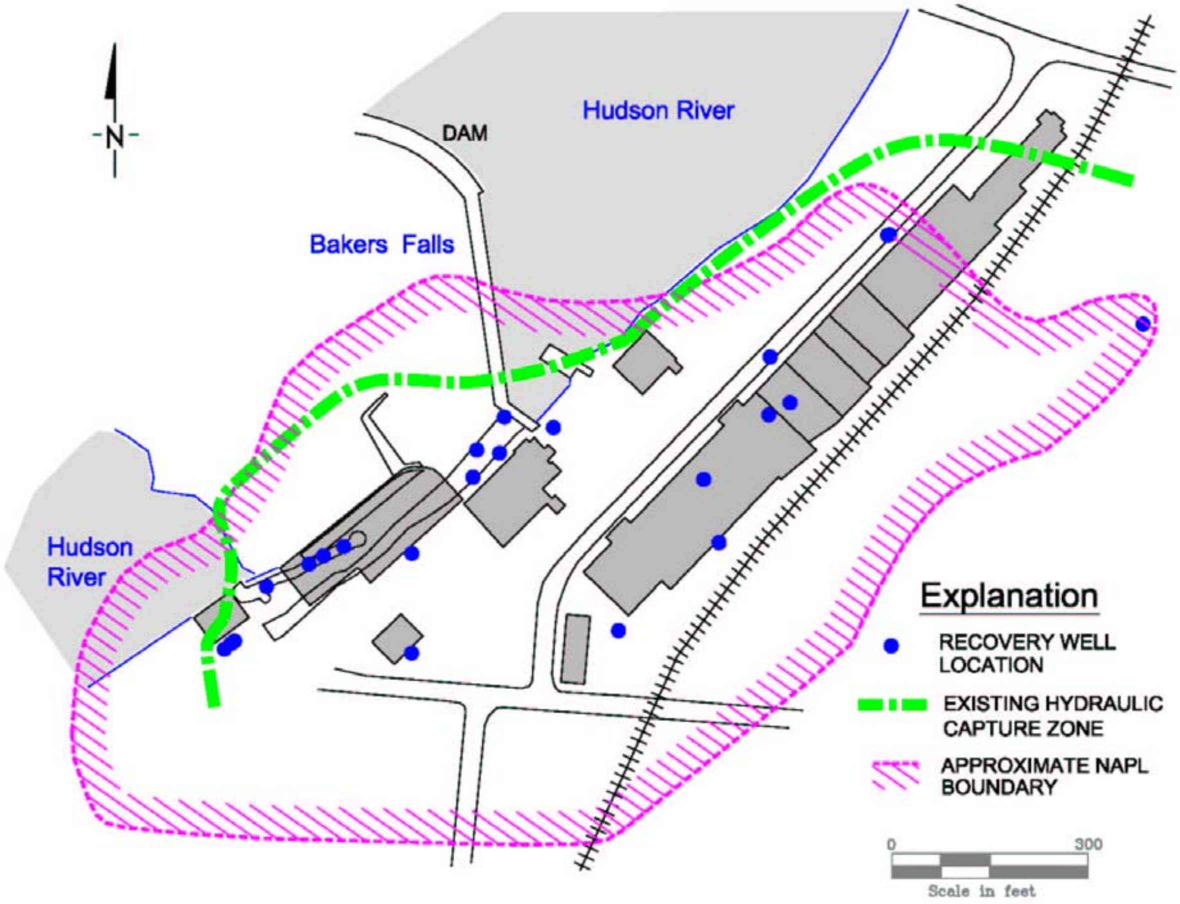

Figure 3. Site Contaminant Distribution Map

Existing Remedial System

The existing remedial system consists of 35 extraction wells and sumps. Sixteen of the extraction wells are dual-phase systems with groundwater and DNAPL pumps. Sumps are located in the tailrace tunnel, raceways, the plenum system, and utility tunnels at the Site. The locations of the extraction wells (recovery wells) are shown on Figure 3. Water pumped from the wells and sumps is conveyed to the on-site water treatment plant for treatment. DNAPL pumped from the dual-phase extraction wells is collected in a tank located at each wellhead. In addition, surface runoff from the Site is collected for treatment.

The treatment plant includes the following unit processes: equalization, polymer additions, clarification, multi-medial filtration, ultraviolet/chemical oxidation, air stripping, and granular activated carbon. Solids from the unit processes are pressed in a filter press. Accumulated solids and PCB oil are shipped off-site for disposal. Treated effluent from the plant is discharged to the river.

The existing remedial action creates a hydraulic capture zone that extends along the eastern edge of the Hudson River and beneath a portion of the dry waterfall. The downgradient boundary of the capture zone maintained by the existing remedial action is shown on Figure 3. The existing remedy does not completely capture or contain the DNAPL present at the Site. Therefore, enhancements to the remedy are necessary. In addition, due to the groundwater chemistry, the pumps and extraction wells require frequent cleaning and redevelopment, thereby resulting in high operating costs.

INVESTIGATIVE TECHNIQUES USED IN THE DEVELOPMENT OF THE SITE CONCEPTUAL MODEL

Installation of multi-level FLUTe™ monitoring systems to provide long-term groundwater level and quality monitoring in deep bedrock wells

Two multi-port bedrock monitoring wells were constructed east of the site using FLUTe™ monitoring devices. The FLUTe™ devices were installed in 378-ft. and 430-ft deep boreholes. The purposes of these wells were to characterize the geology east of the Site, determine the eastern extent of contamination, and provide long-term sentinel monitoring between the Site and some nearby bedrock residential supply wells. Several lines of evidence were used to select the depths of the ports. Fractures in the rock core were logged and described, straddle packer tests were conducted and bore hole geophysical logging was done. The borehole logs included natural gamma, spontaneous potential, single point resistivity, caliper, conductivity, temperature, acoustic televiewer and borehole flow. The criteria used to select the depths for the 10 monitoring ports in each well were that the ports should be located adjacent to a hydraulically active fracture and the ports should be distributed throughout the entire stratigraphic thickness penetrated by the bore hole. Water level and water quality data have been collected from these monitoring systems periodically since 2000.

Rock core and FLUTe™ swab sampling to identify DNAPL- bearing fractures

Four boreholes were drilled into the shale formation in the dry portion of the Bakers Falls. Rock core samples were collected during the drilling to gain a better understanding of the characteristics of the fractures where NAPL may have entered the borehole. Approximately one centimeter sections of the rock core were collected adjacent to open fractures to evaluate possible diffusion of PCBs into the rock matrix. The rock was crushed in the field and submitted to an analytical laboratory for PCB analysis.

Quality assurance/quality control (QA/QC) samples were also collected and analyzed for PCBs to evaluate the validity of the rock core sample results. Four types of QA/QC samples were collected: equipment blank wipe samples of the core barrel, equipment blank wipe samples of the rock crusher, wipe samples of the outside of the rock core, and rock core blank samples. Wipe samples were collected to determine if PCBs were being introduced into the rock samples during drilling or field processing. They were collected by wiping a tissue dampened with hexane over the internal surface of the core barrel or rock crusher or the outside of the rock core. Rock core blank samples were slices of core collected from portions of the core where there were no fractures.

Following drilling, a FLUTe™ swab was inserted in each borehole. Samples of the swab were collected and analyzed for PCBs. The swab is a white absorbent cloth attached to a water tight nylon tube, referred to as a liner. The swab was everted into the borehole, using water pressure, such that the absorbent cloth was pressed tightly against the wall of the borehole. The swab was left in place for two to six days to allow NAPL to be absorbed onto the cloth. The swab was then removed from the borehole and evaluated to identify stained areas that might indicate the possible presence of mobile NAPL. The swab was not capable of detecting residual NAPL present in fractures. Sections of the swab were sampled and submitted to an analytical laboratory for PCB analysis.

QA/QC samples of the swabs were collected and analyzed for PCBs. Swab blank samples were collected from unstained portions of the swab to determine if PCBs were introduced onto the swab from processes not directly related to NAPL migration into the borehole.

Evaluation of the analytical data from the rock core and swab sampling considered the following issues:

- Correlation of PCB Concentrations and NAPL – The magnitude of the mass of PCBs associated with rock core and swab samples that would be indicative of NAPL is uncertain. The concentrations of PCBs detected in these samples due to the presence of dissolved-phase PCBs, colloidal material containing PCBs or a PCB emulsion are also unknown. PCBs were detected in most of the QA/QC samples, suggesting that PCBs may have been introduced during drilling and field processing activities.

- Types of Aroclors Detected – The analytical laboratory reported the presence of Aroclor 1221, 1242, 1248 and 1260, with qualifiers; however they indicated that actual Aroclor 1221 was not present in any of the samples. The lab reported Aroclor 1221 to more accurately quantify that the PCBs present in certain samples had undergone environmental alteration. Review of the chromatograms for these samples indicated that all reported detections of Aroclor 1221 were actually the more water soluble congeners of Aroclor 1242. It was anticipated that the more water soluble congeners would be expected to diffuse into the rock matrix. Thus, the presence of Aroclor 1221-like PCBs suggests that DNAPL is or had been present at the locations and that the water soluble congeners of Aroclor 1242 diffused into the rock matrix.

  An environmentally altered Aroclor 1260 result was reported for one sample. Review of the chromatogram suggests that this sample contains extensively water-washed Aroclor 1242.

  All reported detections of Aroclor 1242 in the rock core and swab samples exhibited an altered PCB chromatographic pattern, characteristic of water-washed Aroclor 1242. Aroclor 1242 was detected in each of the equipment blank samples. In samples with only detections of Aroclor 1242, it was difficult to determine if the presence of PCBs was due to cross-contamination during drilling and/or sample processing.

  Aroclor 1242 and 1248 were reported in the swab sample results. Review of the chromatograms revealed that detections of Aroclor 1248 were actually the less soluble congeners of Aroclor 1242. The presence of Aroclor 1248 indicated that the swab was in contact with DNAPL containing Aroclor 1242 that had been in contact with water for a long period of time and become highly water-washed.

Aroclor 1242 was detected in rock core, swab, and QA/QC samples from each of the four boreholes, including wipe samples from the core barrel and rock crusher from each of the boreholes, wipe samples of the rock core from one borehole, one of the rock core blanks from one borehole, and one of the swab blanks samples from one borehole.

The presence of Aroclor 1221 in the rock core samples and Aroclor 1248 in the swab samples from the two boreholes closest to the Site indicate that DNAPL is likely present at these locations. The magnitude of the reported PCB concentrations was generally higher in these two boreholes, when compared with the concentrations detected in the samples from the two boreholes that are further from the Site. Aroclors 1221 and 1248 were not reported in samples from the remaining two boreholes, suggesting that DNAPL was not, and had not been present at these locations.

Borehole video logging to the spatial distribution of DNAPL and bedrock fractures

Video logging of three wells on the Site was completed to evaluate the spatial distribution of DNAPL and bedrock fracturing. Two of the wells have recovery systems installed in them and have open boreholes in the shale and the third is a monitoring well open to the underlying limestone. The borehole wall was not visible below the water table in one of the shale wells due to the turbidity of the water.

The limestone well is an eight-inch diameter borehole with an open interval from 254 to 274 feet below ground surface (bgs). The bottom of the steel casing was readily observed in the video log. The water level was visible in the video at a depth of approximately 273 feet bgs. Below the water table, the borehole wall was not easily observed in the video. A volcanic ash layer was observed in the video between depths of 255 and 256 feet bgs. Water and droplets that appeared to be DNAPL were observed dripping down the side of the borehole. It was not possible to determine from which fracture(s) the DNAPL and water were entering the borehole.

The remaining shale well was logged after it was rehabilitated using an acid treatment. The video from this well was very clear below the water table. Many calcite and pyrite layers were visible in the shale. DNAPL droplets were observed in the brecciated zone of the lower fault plane and a small pool of DNAPL was seen at the bottom of the borehole

Short-term water level monitoring in the dry portion of the Hudson Falls river bed using removable FLUTe™ systems

The four borings that were drilled in the dry portion of the Hudson River adjacent to the Site, and from which rock core and FLUTe™ swab samples were collectred for analysis, were also used to evaluate the areal and vertical distribution of potentiometric head and short-term water-level fluctuations resulting from changes in river stage and pumping of on-site recovery wells. Two six-port FLUTe™ monitoring devices equipped with pressure transducers and data loggers were used to monitor short–term water level fluctuations. The FLUTe™ devices were installed at different positions within each borehole for one-week periods. Observed short-term water level fluctuations were correlated with changes in river stage and on-site pumping. The data collected were used in the development of a regional groundwater flow model used during the conceptual design of the groundwater remedy.

*Cross-hole hydraulic monitoring to determine preferred orientations of hydraulically connected fractures***.**

A series of cross-hole hydraulic tests were done to evaluate the interconnections of hydraulically-active fractures and to estimate the bulk hydraulic conductivity of the bedrock in the Bakers Falls area. The testing consisted of short-term hydraulic stresses in which existing recovery wells located near the river were turned off for a short period of time and then restarted. Water levels were monitored with pressure transducers and data loggers prior to, during, and following the change in hydraulic stress. The water level response during the testing indicated that the fracture network beneath the Bakers Falls area is generally well connected (Figure 4).

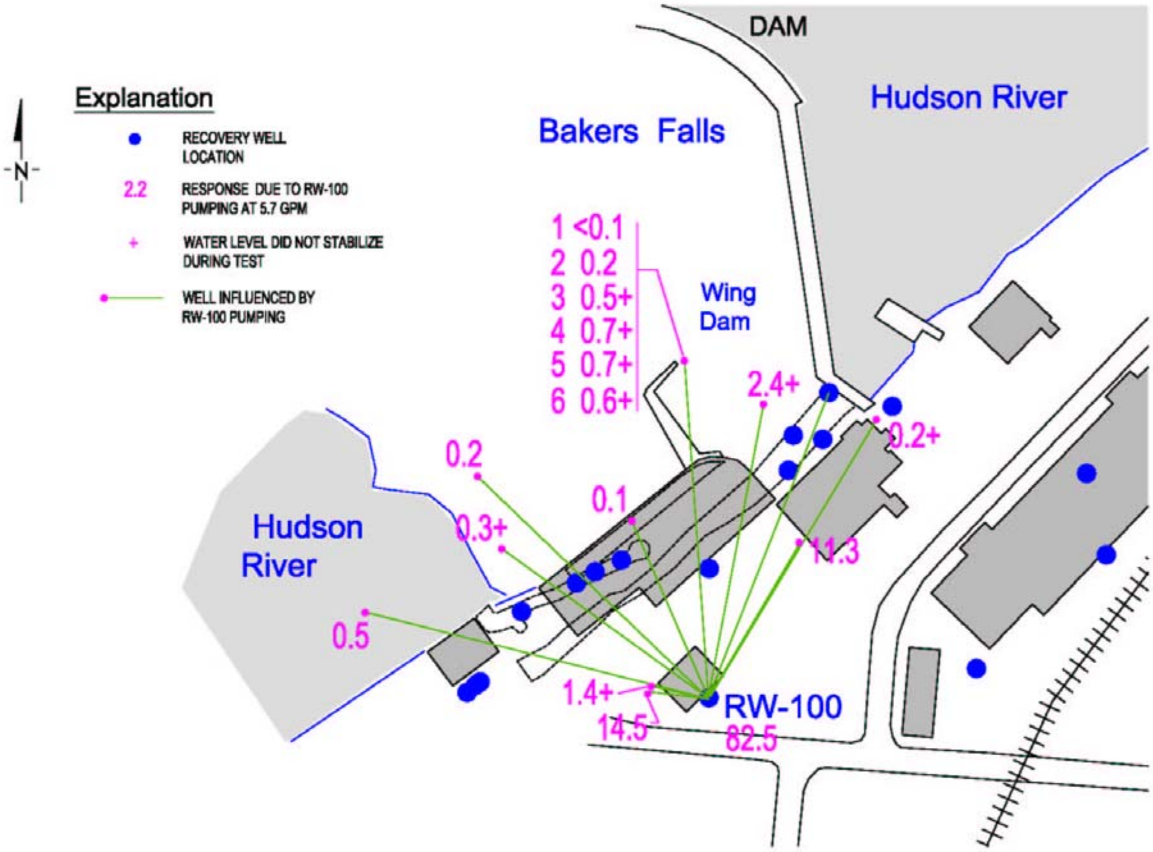

Figure 4. Water Level Change, in Feet, in Response to RW-100 Pumping Rate Change

Water level data from wells that showed a clear response to the pumping rate change were analyzed to estimate bulk hydraulic conductivity. The field conditions did not completely satisfy the simplifying assumptions of the analysis method, therefore the calculated values were considered to be approximate. The estimated bulk hydraulic conductivities ranged from $1x10^{-4}$ to 29 feet/day. Data from the four wells fitted with the FLUTe™ multi-level monitoring devices allowed the vertical distribution of hydraulic conductivity to be evaluated. Analyses of the data from these wells indicated that the bulk hydraulic conductivity decreased with depth**.**

DNAPL chemical fingerprint analyses

In addition to analyzing the chemical constituents of the DNAPL at the Site using standard U.S. EPA methods, DNAPL samples were also chemically fingerprinted using methods similar to those used in the oil industry to characterize crude oils. Chemically fingerprinting the DNAPL consisted of evaluating the relative proportion of the four primary components of the dielectric fluids used at the Site: Aroclor 1242 (PCBs), bis-(2-ethylhexyl)-phthalate (BEHP), phenyl xylyl ethane (PXE) and 1,2,4-trichlorobenzene (1,2,4-TCB). The relative proportion of these four components was calculated by measuring the area under the peaks corresponding to these four compounds on a gas chromatogram, adding these four areas together, and determining the relative contribution of each compound to the total area of the four compounds. Using this method, DNAPL samples from the Site have been found to contain up to 100 area percent PCBs, up to 83 area percent BEHP, up to 58 area percent PXE, and up to 17 area percent 1,2,4-TCB.

The relative proportion of PCBs, BEHP, PXE and 1,2,4 TCB in the DNAPL provided a descriptive fingerprint of DNAPL at the Site. As discussed previously, PCBs were used in manufacturing at the Site until 1977. They were then replaced with BEHP, TCB and PXE. Therefore, the components of the DNAPL provided an indication as to the relative time of release of DNAPL and the degree of mixing of the components of DNAPL. The fingerprints of the DNAPL were grouped into three categories: "old" DNAPL (greater than 90 area percent PCBs), "new" DNAPL (less than 10 area percent PCBs) and "mixed" DNAPL (between 10 and 90 area percent PCBs). These categories were interpreted to reflect the amount of mixing of different dielectric fluids.

The DNAPL composition at some locations was also observed to change over time. Such temporal changes in composition may reflect a typical variation in DNAPL composition at a given location, the migration of DNAPL containing a different composition, or mixing of different DNAPLs in the well.

DNAPL recovery from the 16 recovery wells equipped with automated DNAPL pumps, 69 monitoring wells from which DNAPL is recovered manually, and 62 seeps and shallow monitoring points located on the dry Bakers Falls, and where bedrock is exposed in the two raceways along the river bank is recorded on a regular basis. These data were used to evaluate the areal and vertical distribution of mobile DNAPL and locate potential localized reservoirs of recoverable DNAPL.

Pilot-scale water and polymer floods in shallow bedrock beneath the Wing Dam area

To evaluate the presence of DNAPL in the shallow fractured bedrock associated with the upper fault plane adjacent to a DNAPL seep in the wing dam containment system, a pilot-scale water flood and polymer flood were carried out. A controlled water flood was done first. Subsequently, the water flood was augmented with a viscous polymer (xanthan gum) to increase the viscosity of the fluid flowing through the fractured bedrock. Adding the polymer increased the sweep efficiency and reduced the adverse effect of hydrodynamic instabilities. During both the water flood and the polymer flood, the fluids were collected in a collection system immediately adjacent to the wing dam containment and collection system, where the upper fault plane was exposed on the face of the falls.

The purpose of the polymer flood was four fold:

- Accelerate and improve the recovery of DNAPL from fractures in the shallow bedrock in the localized area near the wing dam containment and collection system.
- Reduce the potential for future DNAPL seepage.

- Determine whether there was a localized recoverable DNAPL zone in the shallow bedrock.
- Evaluate whether a polymer flood could be used to recover DNAPL from other areas at or near the Site.

More than 95% of the fluids injected into the wells during the water flood and the polymer flood were recovered in the containment and collection system. During both the water flood and the polymer flood, only milliliter quantities of DNAPL were recovered. However, the polymer flood did recover 3.6 times more DNAPL than did the water flood.

The results from the polymer flood indicated that:

- The fractured shallow bedrock in the area of the test was sufficiently permeable so that water or a polymer could easily be pumped through the fractures.
- There was no large volume reservoir of DNAPL in the shallow fractured bedrock in the area of the test that could be recovered by either a water flood or a polymer flood.
- The polymer flood increased the recovery of DNAPL from the fractured shallow bedrock compared to the water flood.
- Chromatographic analysis of the PCBs in the DNAPL showed that the polymer flood accessed and recovered DNAPL that had not been previously influenced by the normal flow of groundwater.

TUNNEL/DRAIN SYSTEM PERFORMANCE CRITERIA

The principal performance criterion for the proposed TDCS is to establish and maintain hydraulic gradients that are sufficient to prevent discharge of dissolved-phase contamination and DNAPL from the fractured bedrock to the adjacent river. To achieve this goal, the TDCS must create an areally extensive region within which hydraulic gradients are directed toward the TDCS, including from the river toward the TDCS. The lateral extent of this region must be beyond the lateral extent of the DNAPL zone in the bedrock. In addition, the magnitude of the hydraulic gradient in the region of fractured bedrock that is above, and on the river side of, the TDCS must be sufficient to overcome gravitational forces that might cause DNAPL migration to the river along sloping bedrock fractures. A secondary performance criterion is that the water and DNAPL inflow to the TDCS cannot cause the influent flow rate to exceed the capacity of the on-site treatment plant.

Regional groundwater flow model analyses using the simulation code MODFLOW (McDonald and Harbaugh, 1988) and discrete fracture network (DFN) model analyses using the simulation codes FRACMAN (Golder, 1999) and MAFIC (Golder, 1999) were done to evaluate the expected performance of the TDCS. MODFLOW was used to evaluate the large-scale regional hydraulic gradients, zone of hydraulic capture, and increased water flow rates that would be created by the TDCS. The DFN analyses were done to evaluate smaller-scale hydraulic gradients that would likely be created in individual fractures and affect DNAPL migration within the fractures.

Regional Groundwater Flow Model Analyses

The regional groundwater flow model was constructed and calibrated as part of the Site Remedial Investigation (GeoTrans, 2001). The model, whose domain extended significantly beyond the Site boundaries (Figure 5), was constructed to assist with hydrogeologic characterization of the Site, and evaluation of the likely hydraulic effects of several remedial alternatives. The fractured bedrock beneath the Site was approximated as an equivalent porous medium for the specific applications of the regional groundwater flow model. The model was calibrated to several different stress periods prior to being used to evaluate the hydraulic effects of different remedial alternatives. Primary evaluation criteria for the various remedial alternatives were the areal extent and continuity of hydraulic capture and the increased water inflow rates. It is planned that, prior to construction of the proposed remedy, transient model simulations will be made to calculate expected changes in potentiometric levels and flow rates that would occur during TDCS construction. Comparison of observed potentiometric levels and flow rates during construction to model-calculated values will provide a basis for remedy design modifications.

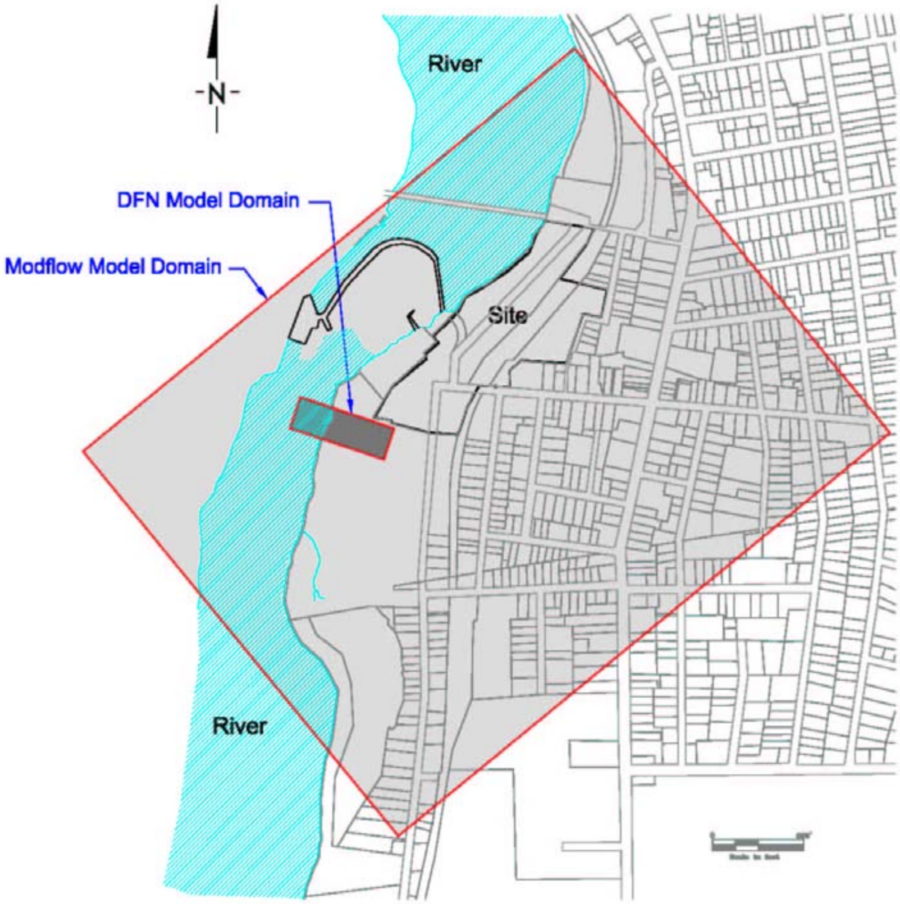

Figure 5. Regional and Small-Scale Model grids

Small-Scale Discrete Fracture Flow Analyses

The DFN model was developed to evaluate hydraulic gradients and their effects on DNAPL mobilization that would result from construction and operation of the TDCS. The DFN model domain used for these sensitivity analyses is also shown on Figure 5. Site-wide fracture statistical data were used to generate a discrete non-orthogonal fracture network using the code FRACMAN (Golder, 1999). A companion simulation routine, MAFIC (Golder, 1999) was used to simulate steady-state flow conditions for different operating conditions of the TDCS. The operating conditions that were varied were the hydraulic head in the tunnel and drain wells, as well as the lateral spacing of the vertical drain wells. Primary evaluation criteria for the various TDCS operating conditions were the distribution and magnitude of hydraulic gradients that would be created within the fracture network, and their effect on DNAPL mobilization and potential migration to the river. The results of the DFN model analyses were used to select the proposed spacing of the vertical drain wells that would be part of the TDCS.

TUNNEL/DRAIN SYSTEM CONCEPTUAL DESIGN

The concept of the TDCS was selected because of the need for a highly reliable recovery system that would prevent the migration of PCBs, in both dissolved and non-aqueous phases, to the river. The TDCS will be constructed from a shaft excavated to an elevation of about 40 feet, approximately 10 feet above the contact between the shale and limestone and approximately 80 feet below the deepest portion of the Hudson River at the base of Bakers Falls. It is anticipated that the tunnel will be excavated in three segments in the shale using a tunnel boring machine. Figure 6 shows the proposed layout of the TDCS. Following the excavation of each tunnel segment, vertical drain wells will be drilled from the tunnel to five to ten feet below the bedrock surface. Angled drain wells will also be drilled from the tunnel to beneath the riverbed. To determine if the drain spacing is sufficient to create the required hydraulic gradients throughout the containment area, a series of piezometers will be installed in the vicinity of the tunnel. These piezometers will be monitored during the construction of the TDCS. Based on data collected during construction, the drain spacing may be altered as construction proceeds.

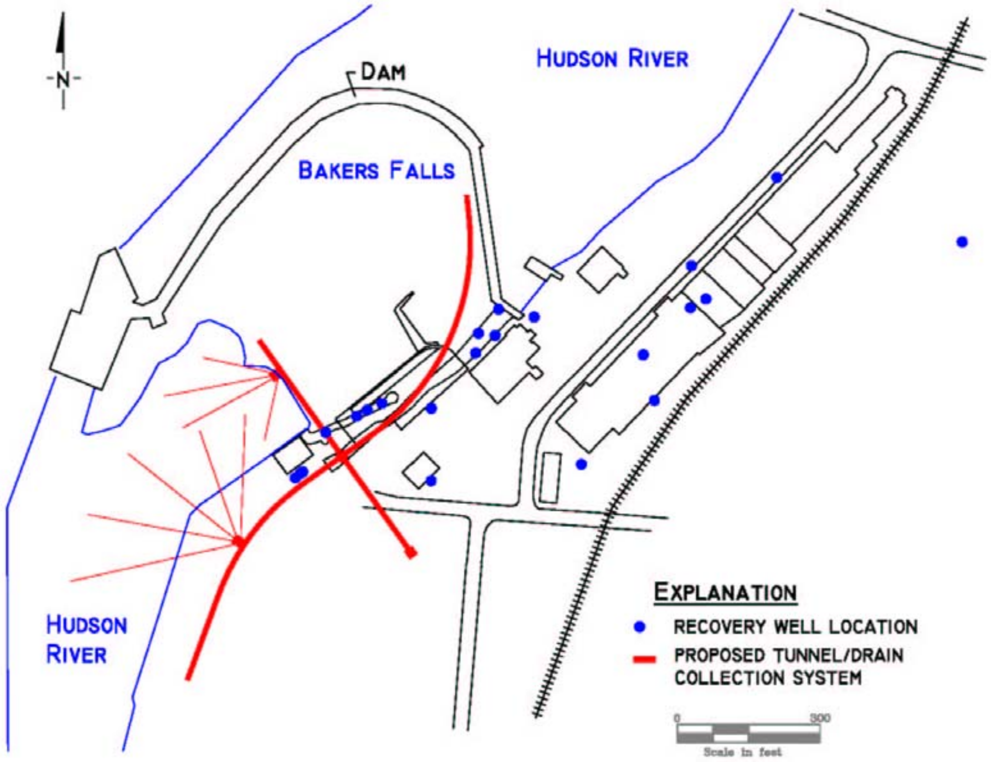

Figure 6. Tunnel/Drain Collection System Layout

The drain wells will be connected to a common manifold that will direct the collected water to an oil-water separator and pumping station located at the base of the shaft. The water will be pumped to an expanded treatment system at the surface for treatment. The drains will be equipped with valves to regulate the operating head. Based on the model analyses, an operating head of 100 feet NGVD with 50-foot drain spacing is expected to be sufficient to create the required hydraulic gradients for the TDCS to meet the goals of the remedy. Figure 7 is a block diagram schematic of the proposed TDCS. Provided that the water flow rate to the tunnel is not excessive, the TDCS may be maintained with an operating head of about 40 feet NGVD. This would allow the tunnel to be maintained as a dry tunnel. Figure 8 shows the model-calculated potentiometric surface and capture zone for the proposed TDCS. Subsequent to construction and operation of the TDCS, the necessity of an alcohol-polymer flood, or other localized supplemental remedial action to remove DNAPL from periodically exposed bedrock beneath the Bakers Falls will be evaluated.

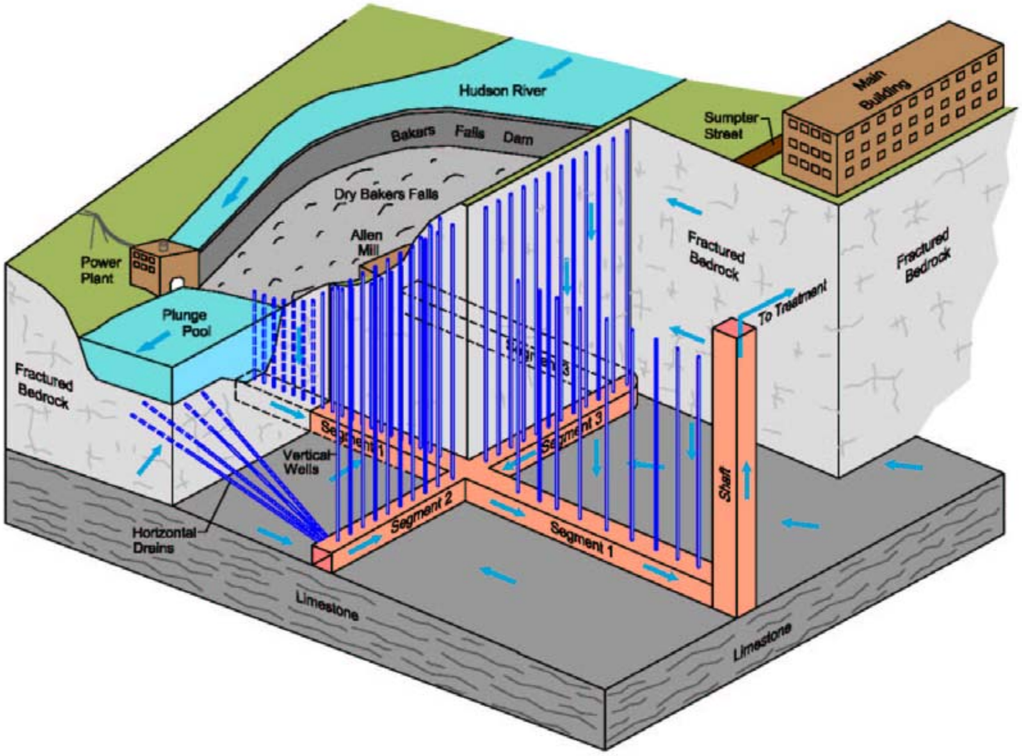

Figure 7. Block Diagram Schematic of the TDCS

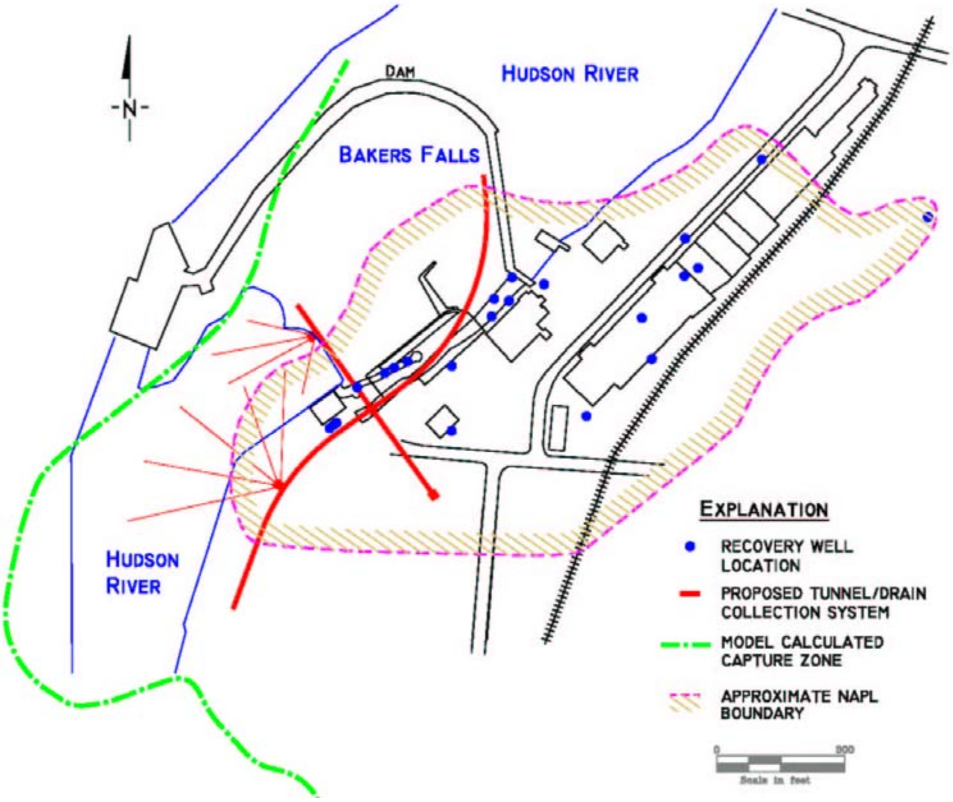

Figure 8. Model-Calculated Capture Zone with Operating TDCS

SUMMARY

A TDCS has been proposed as part of a comprehensive remedy for a site contaminated with PCBs and VOCs. Approximately 1,800 linear feet of 10- to 12-foot diameter tunnel is to be installed in fractured shale at a depth of about 160 feet below the Site. The primary objective of the TDCS is to prevent or minimize PCB releases to a nearby river. Large-scale regional groundwater flow model analyses and smaller-scale DFN model analyses indicate that the TDCS with vertical drain wells can effectively prevent PCB migration to the river in a dissolved phase, as an emulsion, and as a NAPL. In addition to meeting the primary objective, the TDCS will also be effective in meeting other remedial action objectives for the Site. The large-scale continuous hydraulic capture zone of the TDCS will prevent or minimize the migration of contaminated groundwater from the Site.

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Biographical Sketches

Dr. Guswa is a Principal of GeoTrans, Inc. He has more than 30 years of professional experience regarding the investigation and evaluation of groundwater flow and chemical transport. During the past 25 years much of his work has focused on the design, implementation and evaluation of remediation systems for contaminated soil and groundwater. [John H. Guswa, GeoTrans Inc, 6 Lancaster County Road, Harvard, MA 01451; jguswa@geotransinc.com; 978-772-7557 x 103 (ph); 978-772-6183 (fax)]

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