INTRUSIVE INVESTIGATIVE TECHNIQUES FOR THE IDENTIFICATION OF DNAPL

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Investigation of a sand and gravel aquifer contaminated with dense non-aqueous phase liquids (DNAPL) can potentially cause the unwanted movement of the DNAPL within the aquifer if appropriate steps are not taken. Intrusive investigative techniques such as soil borings and monitoring well installation must be conducted in a way that allows for continuous aquifer monitoring and minimal aquifer disturbance. As part of a hydrogeologic investigation performed in central Long Island, a deep monitoring well was required to determine the vertical extent of a tetrachloroethylene (PCE) plume. In order to prevent unwanted DNAPL migration; continuous screening of drill cuttings, split spoon samples, drilling fluid and aquifer pore water was performed.

Drilling Procedures

A drill rig equipped with a Tigre Tierra casing driver was used for the installation of the deep monitoring well. This method utilized a 7 7/8 inch diameter tri-cone roller bit with an open center to advance the boring. The roller bit was attached to four inch diameter drilling rods and run inside of an eight inch diameter steel casing. As the roller bit is advanced, the eight inch steel casing is driven via the casing driver directly behind the bit. Drill cuttings are removed from the casing by circulating potable water down through the drill rods, out of the roller bit and upward through the inside of the drill casing. Compared to mud rotary drilling techniques, the drive casing drilling method offered greater control during the collection of soil and groundwater samples and significantly reduced the risk of the borehole collapsing.

The potable water used for clearing the casing was obtained from a nearby hydrant with the permission of the local water district. Discharge from the casing was run through a settling tub to remove the sediments and recirculated through the drill rods. The drilling fluid was periodically changed to reduce the risk of advancing contaminated groundwater deeper in the aquifer. Wastewater generated during the drilling operation was contained on site in 21,000 gallon liquid storage tank pending characterization.

Initially, the eight inch steel outer casing was driven to a depth of 60 feet. The inside of the casing was then drilled out using the roller bit. In general, the boring was advanced by drilling 10 feet ahead of the eight inch outer casing. Prior to drilling further, the eight inch outer casing was driven to the drilled depth. During drilling, geologic identification was obtained by the collection of split spoon samples. Split spoon sampling commenced at 80 feet and continued in approximately 5 foot intervals. Figure 1 illustrates the geologic profile of the borehole.

Field Testing

Field testing techniques utilized during the installation of the deep monitoring well included headspace readings on drill cuttings, split spoon samples and drilling fluid. During the well installation, headspace and ambient air readings for volatile organic compounds were conducted using a Flame Ionization Detector. A Foxboro Organic Vapor Analyzer -128 was used for field screening for this project, when appropriate (i.e. screening for volatile organic compounds beneath the water table). The instrument was calibrated on site prior to sampling and at the end of each day. In order to provide direct readings, the instrument was calibrated specifically to PCE. Readings are expressed as calibration gas equivalents (cge) relative to PCE.

Additionally, hydrophobic dye testing for the presence of DNAPL was periodically performed on the used drilling fluid and selected split spoon samples. A Leak Tracer Dye Hydrocarbon Test Kit, manufactured by Arts. MFG & Supply, American Falls, Idaho was used to perform the dye testing. When screening liquid samples for the presence of DNAPL, a manufacturer prepared test tube was 1/2 filled with representative sample (i.e. drilling fluid). When screening representative soil material, a manufacturer prepared test tube was 1/3 filled with representative sample and 1/3 filled with distilled water. The test tubes were shaken vigorously for approximately 10 minutes and their contents allowed to settle. The presence of DNAPL would be indicated by the settling of a colored film on the bottom of the test tube. These techniques were used to detect the presence of free or retained DNAPL prior to the advancement of the drill string so that unwanted DNAPL movement could be prevented. No indication of DNAPL in either the soil or drilling fluid was observed during the well installation using this method. Table 1 contains the field testing results.

Groundwater Quality Screening

In order to delineate the vertical extent of PCE contamination in groundwater and determine the exact depth for the construction of the deep well, groundwater quality screening samples were collected.

Groundwater quality screening samples were collected through a temporary well installed inside the drill string. The temporary well was constructed of three feet of 1.25 inch diameter stainless steel well screen and 2.0 inch steel casing. The well screen was driven a minimum of five feet beyond the end of the drill string in order to obtain an undisturbed groundwater sample.

Prior to the collection of groundwater screening samples, the temporary well was pumped until approximately three 8.0 inch outer casing volumes and three times the estimated volume of drilling fluid lost to the formation was removed. The resulting wastewater also was stored in the on site 21,000 gallon storage tank pending characterization. The estimated volume of drilling fluid lost to the formation was based upon volume losses observed within the settling tub during drilling. Temperature, pH, and conductivity of the drilling fluid was compared to that of the pump discharge from the temporary well. This information was used to determine when the drilling fluid had been removed and that aquifer formation water was being evacuated. An alternative method of determining the amount of water to be pumped was also utilized as a contingency. Beginning at the 160 foot groundwater screening sample, the drop in water level within the 8.0 inch outer casing was monitored. The amount of water to be pumped was then calculated using three times the volume of water corresponding to the drop in the water level in the outer casing added to three times the estimated volume of lost drilling fluid.

Groundwater quality screening began at 90 feet below grade and continued in 10 foot intervals until 140 feet. Screening continued in 20 foot intervals from 140 feet to 184 feet. The samples were delivered to a local laboratory immediately after collection and analyzed for volatile organic compounds using EPA Method 601. Sample analysis was performed with an accelerated turnaround time of 24 hours or less in order to provide "field useable" data that would allow for rapid decision making in the field regarding completion depth of the well. Groundwater quality screening intervals and results are illustrated in Figure 1.

In general, PCE concentrations were found to decrease with depth from 90 feet to 130 feet below grade. The most significant decrease occurred at the Magothy Aquifer interface. This is most likely due to the large disparity between the vertical and horizontal hydraulic conductivities in this aquifer which causes groundwater to preferentially flow in the horizontal direction. As indicated in Figure 1, PCE concentrations increase at the 130 and 140 foot intervals before decreasing again. The differences in the PCE concentrations may be due to changes in the texture of the formation encountered in this interval. PCE concentrations further decreased at the 160 and 184 foot intervals. The tightness of the formation significantly increased from 180 feet to 198 feet, as dark brown, dry, hard plastic clay was encountered. The clay was observed to be interbedded with multicolored fine sand, fine sand in a silt matrix, and silty clay deposits. Due to the confining nature of these deposits, the relatively low concentration (110 ug/l) of PCE detected at the 184-186 interval, and the inability to draw a groundwater sample beneath 186 feet, the boring was terminated at 198 feet below grade.

A soil sample was collected from the split spoon taken at 196 - 198 feet below grade and submitted to the laboratory for analysis. The sample was analyzed for volatile organic compounds contained in EPA Method 8010. On the date of sampling, volatile organic compounds (including PCE) analyzed for were below detectable levels. Other volatile organic compounds detected in the groundwater quality screening samples, include trichloroethene (TCE) and 1,1,1-trichloroethane. Since TCE is a breakdown product of PCE, a portion of the TCE detected in the groundwater quality screening may be due to the breakdown of the plume or upgradient sources.

Deep Monitoring Well Construction and Development

Based on groundwater quality screening results and geologic information obtained through split spoon samples, the deep monitoring well was installed to a total depth of 175.11 feet. The well was constructed of 4 inch diameter, schedule 80 PVC flush joint risers and 10 feet of #10 slot size screen. The well was screened from 165.11 to 175.11 feet below grade. Figure 1 contains an illustration of the well construction details.

The borehole beneath the screened interval was backfilled with No. 2 grade uniform sand pack and covered with bentonite to seal the formation so that its confining nature was not compromised. The uniform sand pack was continued above the bentonite seal to approximately 2 feet above the top of the well screen. Two feet of fine sand was set on top of the No.2 sand pack prior to using a bentonite slurry to seal the annular space to the water table. A cement/bentonite slurry was used to seal the annular space from the water table to a few feet beneath land surface. The well was set flush to grade with a protective manhole and a water tight locking cap was placed on top of the PVC casing.

The deep monitoring well was developed immediately after its construction through a combination of pumping and surging with a submersible pump. The well was developed until a silt free discharge was obtained as determined through visual observation and turbidity readings obtained using a nephelometer. Specific conductivity, pH, and temperature measurements were also taken at routine intervals until these parameters stabilized to confirm that formation groundwater was being pumped.

Upon stabilization of the above parameters a groundwater sample was extracted from the well using a dedicated disposable polyethylene bailer. Final field parameters were taken on the bailed groundwater to ensure proper development. The sample yielded a turbidity of 42.8 nephelometric turbidity units (NTU) indicating satisfactory development.

Subsequent groundwater sampling events confirmed that the groundwater quality screening sample results used to determine the screen depth of the well were accurate. Groundwater samples collected from the deep monitoring well on two separate occasions reported PCE concentrations of 38 ug/l and 60 ug/l indicating that the deep monitoring well was screened at or near the base of the plume.

Disposal of Drilling Fluid and Cuttings

The construction of the deep monitoring well resulted in the generation of fifteen (15) drums of drill cuttings and approximately ten thousand (10,000) gallons of wastewater. The wastewater consisted of drilling fluid and purge waters from groundwater development and sampling.

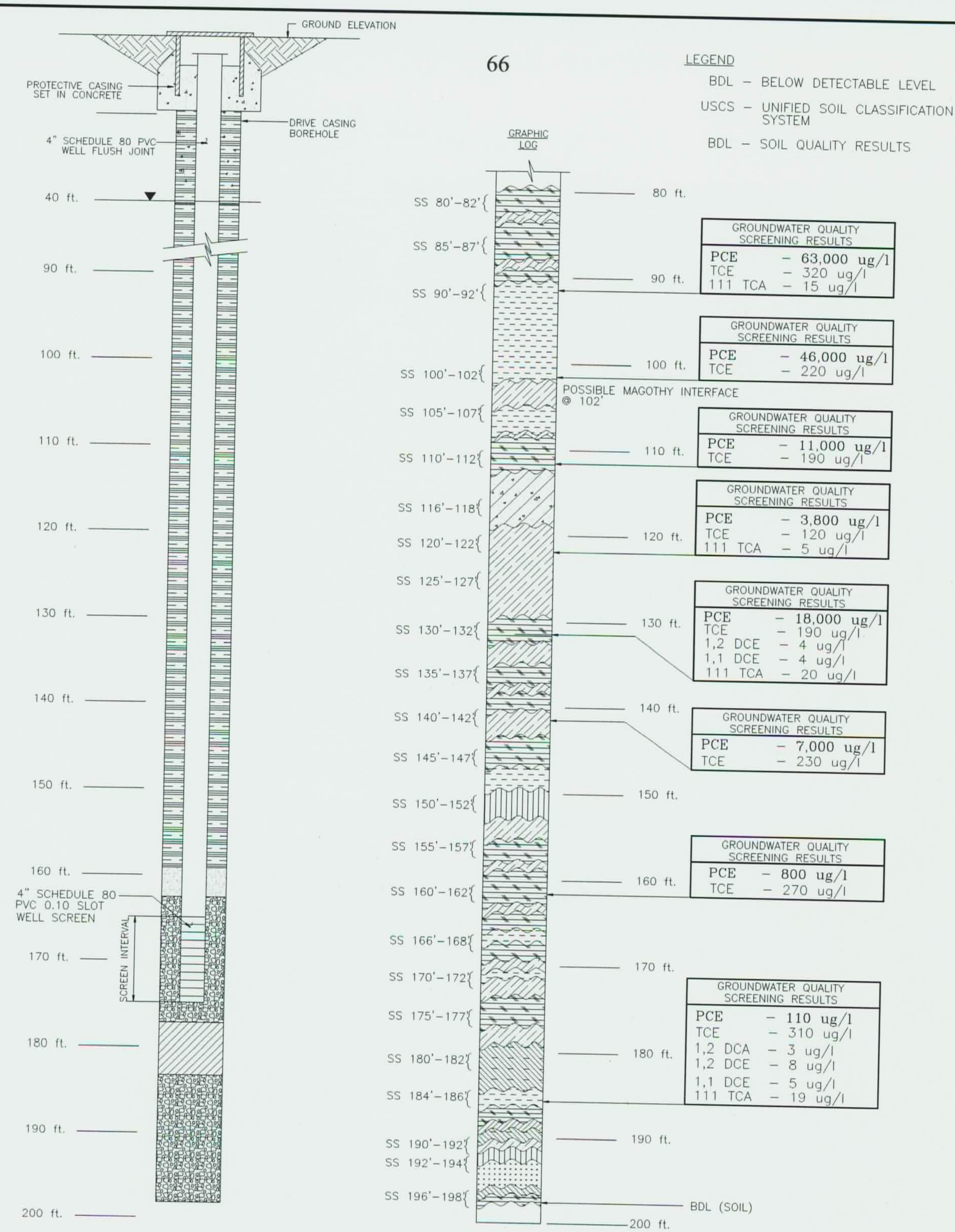
Drill cuttings were characterized for disposal through laboratory analysis. Composite samples collected from the drums were analyzed for the Resource Conservation and Recovery Act (RCRA) list of volatile organic compounds and the eight RCRA metals using the Toxic Characteristic Leaching Procedure along with pH, reactivity and ignitability. Based upon the results of these analyses, the drill cuttings were handled and disposed of as a non hazardous material.

Disposal of the 10,000 gallons of wastewater was coordinated with the local department of public works in an effort to have the material disposed of at a local sewage treatment plant. Under the oversight of a department of public works representative, the wastewater contained in the tank was aerated in an effort to reduce PCE concentrations. Aeration was performed using an air compressor and two inch slotted PVC pipe set in the bottom of the liquid storage tank for approximately 6 hours. During aeration, ambient air on top of the tank was monitored for volatile organic compounds using a Photoionization Detector (PID). The instrument, with readings expressed as cge, was calibrated on site to a known calibration gas prior to beginning the sampling activity and at the end of the day. No PID responses above background were recorded during the aeration project. Liquid samples collected from the storage tank after the aeration revealed significant reductions in PCE concentrations making the liquid acceptable for disposal at the local sewage treatment facility.

Conclusions

The drive casing method of drilling proved to be a useful technique for installing a deep monitoring well downgradient of a DNAPL source area. The control afforded by this drilling method allowed for periodic pauses during the operation to field test soil and water for the presence of DNAPL. Additionally, this technique permitted the collection of soil and groundwater samples ahead of the terminal end of the drill string providing the on site geologist an opportunity to inspect and analyze aquifer material for DNAPL prior to disturbing the aquifer. Accelerated turn around times on analytical samples further facilitated decision making in the field. Groundwater sampling results obtained after the well installation validated the accuracy of the field testing and confirmed that the base of the plume had been identified.

LEGEND
BDL – BELOW DETECTABLE LEVEL
USCS – UNIFIED SOIL CLASSIFICATION SYSTEM
BDL – SOIL QUALITY RESULTS



SYMBOL	USCS DESCRIPTION
	CLAYEY GRAVELS & GRAVEL SAND CLAY MIXTURE
	WELL GRADED SANDS, GRAVELLY SANDS & LITTLE OR NO FINES
	CLAYEY SANDS & SAND-CLAY MIXTURE
	SILTY SANDS & SAND-SILT MIXTURES
	INORGANIC CLAYS OF HIGH PLASTICITY & FAT CLAYS
	INORGANIC SILTS, VERY FINE SANDS, CLAYEY SILTS & SLIGHT PLASTICITY
	INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS & SILTY CLAYS

SYMBOL	DESCRIPTION
	CEMENT/BENTONITE SLURRY
	BENTONITE SEAL
	BENTONITE SLURRY
	FINE SAND
	GRAVEL PACK

(SCALE: 1" = 12'-0")

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DEEP MONITORING WELL
WELL CONSTRUCTION–GEOLOGIC/GEOCHEMICAL PROFILE

FIGURE NO: 1

TABLE 1
DEEP MONITORING WELL
FIELD TESTING RESULTS
APRIL/MAY 1995

SAMPLE INTERVAL	PID RESPONSE (HS)*		HYDROPHOBIC DYE TEST		DRILLING FLUID PARAMETERS	
	Split Spoon	Drilling Fluid	Split Spoon	Drilling Fluid	pH	CONDUCTIVITY
40' - 60'	16.0^	0.0	NA	NM	NM	NM
60' - 80'	NA	24.0	NA	NM	NM	NM
80' - 82' (SS)	30.0	8.0	NEGATIVE	NA	NA	NA
85' - 87' (SS)	100	NA	NEGATIVE	NA	NA	NA
85' - 90'	NA	8.0	NA	NEGATIVE	6.67	50
90' - 92' (SS)	100.0	NA	NEGATIVE	NA	NA	NA
95' - 97' (SS)	20.0	NA	NM	NA	NA	NA
95' - 100'	NA	NM	NA	NEGATIVE	6.98	71.1
100' - 102' (SS)	10.0	NA	NM	NA	NA	NA
100' - 105'	NA	10.0	NA	NM	NM	NM
105' - 107' (SS)	6.0	NA	NM	NA	NA	NA
105' - 110'	NA	NM	NA	NEGATIVE	5.55	72
110' - 112' (SS)	5.0	NA	NEGATIVE	NA	NA	NA
110' - 115'	NA	10	NA	NM	7.7	130
116' - 118' (SS)	0.0	NA	NM	NA	NA	NA
115' - 120'	NA	0.0	NA	NEGATIVE	7.5	113
125' - 127' (SS)	10.0	NA	NM	NA	NA	NA
125' - 130'	NA	1.0	NA	NEGATIVE	7.8	90
130' - 132' (SS)	25.0	NA	NEGATIVE	NA	NA	NA
135' - 137' (SS)	6.0	NA	NM	NA	NA	NA
135' - 140'	NA	0.0	NA	NEGATIVE	6.5	130
140' - 145'	NA	2.0	NA	NM	NM	NM
145' - 147' (SS)	1.0	NA	NM	NA	NA	NA
145' - 150'	NA	2.0	NA	NM	NM	NM
150' - 152' (SS)	8.0 - 2.0	NA	NM	NA	NA	NA
150' - 155'	NA	0.0	NA	NM	NM	NM
155' - 157' (SS)	0.0	NA	NM	NA	NA	NA
155' - 160'	NA	0.0	NA	NEGATIVE	8.2	92
160' - 162' (SS)	0.0	NA	NM	NA	NA	NA
160' - 165'	NA	0.0	NA	NM	NM	NM
166' - 168' (SS)	6.0	NA	NM	NA	NA	NA

TABLE 1
DEEP MONITORING WELL
FIELD TESTING RESULTS
APRIL/MAY 1995

SAMPLE INTERVAL	PID RESPONSE (HS)*		HYDROPHOBIC DYE TEST		DRILLING FLUID PARAMETERS	
	Split Spoon	Drilling Fluid	Split Spoon	Drilling Fluid	pH	CONDUCTIVITY
166' - 170'	NA	NM	NA	NM	NM	NM
170' - 172' (SS)	2.0	NA	NM	NA	NA	NA
170' - 175'	NA	2.0	NA	NM	NM	NM
175' - 177' (SS)	2.0	NA	NM	NA	NA	NA
175' - 180'	NA	0.0	NA	NEGATIVE	6.2	106
180' - 182' (SS)	0.0	NA	NM	NA	NA	NA
180' - 184'	NA	NM	NA	NM	NM	NM
184' - 186' (SS)	0.0	NA	NM	NA	NA	NA
180' - 186'	NA	0.0	NA	NM	6.9	109
186' - 190'	NA	0.0	NA	NM	NM	NM
190' - 192' (SS)	0.5	NA	NM	NA	NA	NA
186' - 192'	NA	0.0	NA	NM	NM	NM
192' - 194' (SS)	0.0	NA	NM	NA	NA	NA
192' - 196'	NA	0.0	NA	NM	7.2	84
196' - 198' (SS)	1.0	NA	NM	NA	NA	NA

NOTES:

PID responce given in calibration gas equivilants (cge)
HS = PID response in head space.
^ = headspace performed on drill cuttings.
(SS) = Split Spoon Sample
NM = Not Monitored at Sample Interval
NA = Not Applicable at Sample Interval
PID readings were taken of the ambient air within the breathing zone and above the settling tub at routine intervals to ensure health & safety of field personnel.