Abstract

Ground water investigations of dense non-aqueous phase liquid (DNAPL) or brine plumes that extend hundreds of feet deep into unconsolidated sediments present drilling and sampling challenges that can greatly increase investigation time and cost. Sonic drilling methodology is a preferred sampling method in these environments for its superior drilling speed, good recovery of undisturbed, large-diameter core samples, significant reduction of derived waste, uniform boreholes with a minimum of drift and the ability to seal off saturated zones from one another without setting permanent multiple outer-well casings. However, the required inducement of fluids during drill stem advancement can greatly increase time and expense where the collection of vertical aquifer profile (VAP) sampling is desired. PROSONIC Corporation (recently purchased by Boart Longyear Inc., hereafter Boart) has developed a new Push-Ahead™ sampling device that can collect representative ground water VAP samples while minimizing purge volumes and sampling time.

Introduction

Ground water investigations of DNAPL or brine plumes that extend hundreds deep feet into unconsolidated drinking water aquifers can be extremely costly and time consuming to adequately investigate as required by State and Federal regulations. The drilling and sampling challenges to investigating ground water quality at these depths are beyond the capabilities of most drilling methodologies.

Sonic drilling methodology is a preferred drilling and sampling technique for deep ground water investigations. Due to its superior drilling speed; good recovery of undisturbed, large diameter core samples; significant reduction of derived waste; uniform boreholes with a
minimum of drift; and the ability to seal off saturated zones from one another without setting multiple permanent outer well casings. Sonic drilling method can extend borings in unconsolidated sediments to depths in excess of 700 feet. However, the advancement of the drill stem (multiple outer casings and core barrel) into the unconsolidated sediments, particularly angular sands, typically requires the inducement of drilling fluids. The quantity of water required to advance the casing generally increases with depth due to increased friction against the casing. VAP sampling is generally conducted during drill stem advancement to assure proper selection of the monitoring well screened interval. The inducement of fluids during drill stem advancement can greatly increase the time and expense to collect representative VAP samples from the aquifer.

Traditional methods of VAP sampling with sonic drilling involve the installation of temporary wells within the drill stem and then retracting the drill stem to expose the screen. This leaves the temporary well casing filled with drill fluids and its screened interval in the zone of influence of the induced drilling fluids. Extensive purging of the temporary well is required to collect a representative formation sample. Other limited push ahead techniques have been developed (i.e. Simulprobe® or Hydropunch™), however, these limited push ahead techniques will generally not allow advancement more than a few feet beyond the drill stem and are still in the zone of influence of the induced drill fluids. Additionally these limited drive ahead techniques have minimal, if any, purge capabilities.

Boart has developed a new push ahead sampling device for use with the sonic drilling technique that can collect representative samples while eliminating purging requirements and minimizing sampling time. The Push-Ahead™ sampler is advanced without inducing additional drilling fluids and extends beyond the zone of influence of the drilling fluids that has been induced into the formation. Upon opening the sampling ports, an unadulterated representative VAP sample is collected directly from the zone of interest without purging requirements. If purging is desired, a sampling pump with or without a packer can be inserted into the drill rod to obtain the sample. The drill rod with the Push-Ahead™ sampler can then be removed and decontaminated for its next use.

To date, the Push-Ahead™ sampler has been approved and satisfactorily utilized at two MDEQ site investigations. The Wickes Manufacturing site investigation in Mancelona, Michigan conducted VAP sampling of a TCE plume with the sonic drilling Push-Ahead™ sampler to depths approaching 600 feet below ground surface (bgs). The Hoskins Manufacturing site in Mio, Michigan investigated a chlorinated solvent plume and hexavalent chromium release associated with a brine plume through multiple aquifers to depths over 400 bgs.

MDEQ has also approved use of the Push-Ahead™ sampler at the MDEQ Rexair site in Cadillac, Michigan to conduct VAP sampling of a chlorinated solvent plume through multiple aquifers to depths of approximately 330 bgs. At the Rexair project, the MDEQ contractor, the Mannik and Smith Group (MSG), will utilize the next generation (TNG) Push-Ahead™ sampler. The TNG Push-Ahead™ sampler has an improved sampling port seal, increase sampling port capacity, and a finer sampling port opening size to minimize sediment intake (See TNG Push-Ahead™ sampler Figure, next page).

This study examines the Push-Ahead™ sampler and its use, using the Wickes Manufacturing site as a case study where both the Push-Ahead™ sampler and standard temporary well technique were utilized to conduct VAP sampling. The case study is assessed for VAP sampling cost and time savings provided by use of the Push-Ahead™ sampler in comparison to traditional temporary monitor well methodology.
Push-Ahead™ Sampler Description and Methodology

The Push-Ahead™ sampler consists of a 2 7/8-inch ID drill rod threaded onto a carbide tipped drive point with flanges and sampling ports. The drive point sampling ports have a steel machined seal that remains closed until the tool is advanced to it desired sampling interval. Once the flanged drive tip is seated in the formation, the sampling ports are exposed by rotation of the drill rod. The sampling ports consist of four ¼-inch borings located at the base of the sampler drive head (See Original Push-Ahead™ sampler, previous page.)

The VAP sampling methodology utilizing the sonic drilling Push-Ahead™ sampler involves the advancement of core barrel and outer casing(s) to the water table or chosen depth interval using standard sonic drilling technologies. After the removal of the core barrel, a decontaminated and sealed Push-Ahead™ sampler is inserted through the outer casing(s) to the bottom of the boring. The Push-Ahead™ sampler is the sonically driven beyond the boring bottom into virgin material (approximately 5 to 15 feet in advance of the outer casing depending on lithology) beyond the zone of influence from any induced drill fluids (See Push-Ahead™ Sample Collection Illustration, left). A water level meter is then lowered within the drill rods to verify the seal and ensure no drill fluids has entered the drive point assembly. Once the seal is verified, the water level meter is removed and the Push-Ahead™ sampler is opened to allow formation water to enter the drill rods through the sampling ports. The water level meter is then re-lowered into the drill rods to verify formation water has entered the drill string. Since the ground water entering the drill rod through the sampling ports is representative of the formation (collected from beyond the zone of drill fluids influence), no purging is required but may be conducted if desired to reduce turbidly. Samples are collected directly from the drill rod using a bailer or submersible pump.

Draw backs to the use of the Push-Ahead™ sampler are 1) it is blindly advanced beyond the drill stem and may not obtain a sample if seated in a low permeability soil and 2) the sampler could potentially penetrate a confining layer. If a confining unit is breached, it can quickly be sealed off by advancement of the drill stem.

Case Study

The MDEQ retained Boart to conduct a Supplemental Investigation/ Monitoring Well Installation Project for the Wickes Manufacturing TCE Plume site in Mancelona, Michigan (Site). Boart retained the MSG as a subcontractor to aid them.

The former Wickes Manufacturing has operated as a manufacturing facility under various owners since the 1950’s. Scrap steel saturated with chlorinated paraffins was stockpiled outside the plant and untreated
wastewater was discharged to three seepage pits. TCE concentrations in ground water have been detected at levels exceeding 1,000 parts per billion. Prior investigations identified a TCE ground water plume extending approximately seven miles northwest from the former Wickes Manufacturing property.

The site lies on glacial outwash sand and gravel with post-glacial alluvium. Thickness of the unconsolidated sediments is reported to range from between 200 and 600 feet at the site. A regional aquifer exists within the unconsolidated soils and is present as inter-bedded aquifers, aquitards and aquicludes in the site vicinity. Regional ground water flow is to the northwest. Ground water is encountered at the site at depths ranging from less than 20 feet up to 260 feet below grade. From 2004 through 2006, Boart advanced 26 VAP borings and installed 32 monitoring wells. A total of 326 VAP samples were collected from the borings. Glacial alluvial sediments were explored to depths approaching 600 feet bgs.

Due to the extensive boring depths and angularity of the sands, large quantities of drilling fluids (treated city water) were required to advance the drill stem. Typically advancement of a 20 foot run of the override casing during sonic drilling requires inducing 50 to 100 gallons of drilling fluids into the formation, deeper runs requiring up to 1000 gallons.

In October 2004, the initial 15 VAP borings were completed and 188 VAP samples were collected using temporary monitoring wells to collect representative water samples. Based on the monitoring for the presences of products associated with the use of city water (trihalomethanes) and the stabilization of field monitoring parameters during purging (temperature, pH, conductivity, and turbidly), approximately 1.5 times the volume of induced drill fluids had to be purged to collect a representative sample. Approximately 120,000 gallons of purge water was generated and required off-site disposal as a result of the temporary well VAP sampling methodology.

In 2005, Boart developed the Push-Ahead™ sampler as a means to eliminate purging requirements and significantly reduce sampling time for the second phase of drilling. During the second phase of drilling, 13 VAP borings were completed and 138 VAP samples were collected, of which 129 samples were collected using the Push-Ahead™ sampler.

**Statistical Comparison of Sampling Data**

The data set consists of sample results from the VAP samples, sampling time, and purge water quantities during both phases, and the first following monitoring well sampling event. The VAP sample from the interval closest to the monitoring well screened interval was used for the comparisons. The VAP concentrations were plotted against the corresponding monitoring well concentrations from the monitoring well sampling event immediately after well installation (i.e., the July 2005 data from VAP borings installed in 2004 and the November 2006 data for VAP borings installed in 2005-2006). Linear regressions were then performed on the TCE concentration results from the traditional temporary monitoring well VAP sample collection data and the Push-Ahead™ sampler VAP data.

As part of the analysis, the Pearson’s coefficient (also known as the correlation coefficient) was calculated for each data set. The Pearson’s coefficient is a measure of the strength of the linear relationship between two variables. Pearson’s coefficient values range from +1 to -1, with +1 indicating a direct relationship and -1 indicating an inverse relationship. The Pearson’s coefficients were compared to $r_{0.05}$ (the critical value for statistical significance), which indicates the correlation is significant at the 99.5 percent level (or that there is a 0.5 percent chance that the correlation appears to be true but is not).
The temporary well VAP data shows a statistically significant linear relationship with the subsequent monitoring well sampling event (See VAP Temporary Wells – MW July 2005 Figure, below), with a Pearson’s coefficient of 0.846 and a \( r_{0.05} \) value of 0.590. Most temporary well VAP sample results were higher than the corresponding monitoring well’s results.

The Push-Ahead™ sampler VAP data shows a statistically significant linear relationship with the subsequent monitoring well sampling event (See VAP Push-Ahead – MW November 2006 Figure). However, the Pearson’s coefficient is 0.651, slightly above the \( r_{0.05} \) value of 0.641. The Push-Ahead™ sampler VAP results were quite variable compared to the corresponding monitoring well’s results. One major factor for the lower Pearson’s coefficient and the variability may be that the Push-Ahead™ VAP locations and monitoring wells were near the edge of the plume and thus lower overall chemical concentrations were obtained. Additionally, monitoring wells installed at the plumes edge may be more prone to temporal variation as the plume expands or due to minor seasonal variations in ground water flow direction. As a result, a difference of a few micrograms per liter would cause more scatter of the data and a much larger percentage change than the data from locations with higher concentrations, where a small absolute difference between the temporary well and monitoring well data would not influence the correlation as much.

Both the temporary wells and Push-Ahead™ sampler data show a statistically significant linear trend when compared to the monitoring well data. The different strengths of correlation is likely due to sample locations and not sampling methodology as additional data collected from future investigation are obtain with the Push-Ahead™ sampler, including VAP sampling through highly concentrated portions of the plumes. This data should be statistically evaluated to assess the technique correlation with traditional VAP sampling methods.

**Time and Purge Water Disposal Cost Savings**

During the 2004 VAP sampling, 188 VAP samples were collected using temporary wells in approximately 120 days of fieldwork (typically 10 hour work days).
The average boring length during this sampling event was 371 feet. The average collection rate was approximately 1.6 samples per day.

During the 2005-2006 VAP sampling, 128 samples were collected in 69 days of fieldwork. Temporary well VAP sampling was conducted in one boring to a depth of 457 feet. A total of 13 samples were collected in 9 days from this boring, for an average collection rate of 1.4 samples per day. Twelve VAP borings were sampled utilizing the Push-Ahead™ sampler device to an average depth of 419 feet. A total 129 Push-Ahead™ VAP samples were collected in 60 days, for an average collection rate of 2.2 samples per day.

Comparisons of the VAP sample collection rates from temporary wells and Push-Ahead™ technique indicates a field time saving of approximately 30 percent. Utilization of the Push Ahead™ technique during the 2004 VAP boring would likely have reduce the field duration by 40 out of the 120 days and cost savings at standard sonic drill crew rates in excess of $240,000. Purging of the temporary wells prior to sampling generated approximately 120,000-gallons (on average 638 gallons per sample) impacted water requiring off-site disposal. At $0.25 per gallon for non-hazardous disposal, this volume would cost $30,000 for disposal.

Conclusions

The Push-Ahead™ sampler was developed to overcome sampling difficulties associated with induced drilling fluids. Use of the Push-Ahead™ sampler resulted in the elimination of purge water and greatly reduced VAP sampling time and cost. Comparison of data and quality objectives using the new Push-Ahead™ sampler device to traditional sonic drilling VAP sampling techniques found both methods provide statistically correlated data to formation conditions (permanent monitoring well results). In the case study, the degree of correlation to permanent monitoring well results was slightly better with the traditional VAP sampling, however this may be due to the selected Push-Ahead™ sampler boring locations at the plume edges.

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