Assessment of a Low Purge Volume Technique For the Collection of Groundwater Samples At Brookhaven National Laboratory

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Abstract

The removal of three to five well casing volumes prior to sampling has been the industry and regulatory standard for many years. Recent research has indicated that high volume purging of monitoring wells prior to sample collection may not be necessary to provide data that are of sufficient quality for environmental surveillance and regulatory decision making. To evaluate contaminant concentrations as a function of purge volume, Brookhaven National Laboratory completed a groundwater sampling study in which samples were collected at multiple pre-determined purge volumes from twenty-one monitoring wells. Some wells were sampled twice to evaluate variations in contaminant concentrations as a function of time. A total of 219 samples were analyzed, resulting in 617 data points for the following major contaminants: 1,1,1-trichloroethane, trichloroethylene, 1,1-dichloroethane, 1,1-dichloroethylene, tetrachloroethylene, toluene, ethylbenzene, toluene, and tritium. In addition, the stabilization during purging of field water quality parameters such as pH, temperature, dissolved oxygen, conductivity and turbidity was also examined.

Most water quality parameters were found to stabilize following the removal of 0.05 to 0.25 well casing volume. In ten of fifteen (67 percent) well sampling events where one or more volatile organic compounds were detected at concentrations of >5 μg/L, and in all seven sampling events where tritium concentrations were $>1,000$ pCi/L, complete concentration stabilization (i.e., concentrations within ±20 percent for three consecutive samples) was achieved following the purging of 0.05 to 0.25 casing volume. In several cases however, initially stable VOC and tritium concentrations became less stable as more water was purged from the wells. Furthermore, significant differences in contaminant concentrations were observed in samples collected from the same well during different sample periods. These findings suggest that variations in plume concentrations and plume position relative to a monitoring well's location, screen position and pump position have a far greater effect on contaminant concentrations than the amount of water purged from a well prior to sampling. The water quality and contaminant concentration stabilization results indicate that representative groundwater samples can be collected by purging ≤ 0.25 casing volume. The use of low purge volume sampling will result in the collection of high quality groundwater samples while significantly reducing the time required for sample collection and costs associated with the handling, treatment and disposal of contaminated purge water.

Introduction

The routine collection of groundwater samples is an integral part of the Brookhaven National Laboratory's (BNL's) Facility Surveillance and Environmental Restoration Programs. BNL maintains an extensive groundwater monitoring well network that is designed to evaluate groundwater quality near active research and support facilities, and monitor groundwater contamination resulting from historical discharges and spills of chemicals and radionuclides. The groundwater monitoring well network currently consists of nearly 850 wells, and is likely to increase to over 900 wells by calendar year 2000. It is anticipated that as many as 600 of the wells will be sampled on a quarterly or semiannual basis.

In the 1980's, BNL's groundwater surveillance well network consisted of approximately 180 shallow wells located close to suspected contaminant source areas (usually less than 50 feet deep). However, detailed groundwater investigations conducted since 1990 have revealed volatile organic compound (VOC) and radionuclide contamination at greater depths within the shallowest aquifer system (Upper Glacial aquifer) in both on-site and off-site areas. The large increase in the number of deep wells at BNL has resulted in significant financial impacts to the groundwater monitoring programs due to higher sampling and wastewater management costs. With the prospect of continually reduced budgets, and stricter regulatory requirements for the treatment of contaminated monitoring well purge water, BNL evaluated a low purge volume alternative for obtaining representative groundwater samples. This study was designed to examine the extent to which the volume of water purged from a well prior to sampling affects the concentration of both VOCs and tritium.

Site Hydrogeology

BNL is located in Upton, Suffolk County, New York, near the geographic center of Long Island. The BNL is 5,265 acres in size, approximately 900 acres of which have been developed.

The hydrogeologic framework of the BNL site and surrounding region have been extensively studied over the past forty years (de Laguna, 1963; Smolensky *et al.*, 1989, Geraghty and Miller, 1996; Scorca *et al.*, 1997). The geology underlying the BNL site consists of approximately 1,500 feet of unconsolidated Cretaceous and Pleistocene-aged sediment overlying Precambrian bedrock. The unconsolidated deposits are subdivided from youngest to oldest as follows:

- Upper Pleistocene deposits (Upper Glacial aquifer)
- Pleistocene-aged Gardiners Clay (aquitard)
- Cretaceous deposits of the Matawan Group-Magothy formation (Magothy aquifer)
- Cretaceous deposits of the Raritan formation (Raritan confining unit and Lloyd aquifer)

The Upper Glacial, Magothy and Lloyd aquifers are designated as a Sole-Source Aquifer System by the US Environmental Protection Agency (USEPA). The Upper Glacial aquifer is widely used on Long Island for private water supply. Municipal water systems utilize both the Upper Glacial and Magothy aquifers. Drinking water and process water supplies at BNL are obtained exclusively from the Upper Glacial aquifer. Due to past waste management practices and accidental spills, the Upper Glacial aquifer has been impacted by VOC and radionuclide contamination. Although most of this contamination is found in the Upper Glacial aquifer, these contaminants have recently been observed in several Magothy aquifer wells.

The twenty-one wells used during this study are screened within the Upper Glacial aquifer. The Upper Glacial aquifer is composed of sediments that were deposited in a glacio-fluvial environment during multiple Wisconsinan glaciation events (de Laguna, 1963; Sirkin, 1986; Smolensky *et al.*, 1989). Pleistocene sediments at the BNL site range in thickness from 100 to 250 feet, and consist of outwash deposits from fluvial transport and some terminal moraine deposits. The glacial outwash deposits consist of weakly stratified silica-rich coarse to medium grained sand with variable amounts of fine to coarse gravel and trace amounts of silt and clay. Samples from deep Upper Glacial aquifer wells indicate that in some areas of the site, the basal 50 feet of the aquifer is characterized by fine to medium sand with 5 to 10 percent interstitial clay. Furthermore, the near surface geology in the vicinity of the Peconic River consists of variable sequences of sands, silts and clays. These low permeability deposits have considerable influence on shallow groundwater flow patterns in the Peconic River area. Across most of the BNL site, the Upper Glacial aquifer and Magothy aquifer are hydraulically separated by either the Gardiners Clay (Pleistocene) or discontinuous clay units which characterize the uppermost portions of the Magothy formation. Most upper Magothy aquifer monitoring wells at BNL are installed in more permeable zones consisting of fine to medium grained silica sand which are found immediately below these clay units. In several areas of the site, the Gardiners Clay and Magothy clays are absent. Consequently, there is a more direct hydraulic connection between the two aquifers in those areas.

Groundwater in the Upper Glacial aquifer beneath the BNL site generally exists under unconfined conditions. However, in areas along the Peconic River where low permeability near surface silt and clay deposits exist, semi-confined conditions may occur. Across the BNL site, depth to groundwater varies from a few feet below land surface within the lowlands near the Peconic River, to as much as 75 feet in higher elevation areas in the central and western portions of the site. The water transmitting properties of the Upper Glacial aquifer have been evaluated during four aquifer pumping tests (Warren *et al.*, 1968; CDM Federal Programs Corporation, 1995; and IT Corporation/Geraghty and Miller, Inc., 1997). Hydraulic conductivity values for outwash sections of the Upper Glacial aquifer range between 160 to 175 feet per day. The weak stratification of the glacial deposits has a pronounced effect on vertical hydraulic conductivities, resulting in an approximate anisotrophy ratio of 10:1. The specific yield (effective porosity) of the Upper Glacial aquifer is 0.24. The horizontal hydraulic gradient at BNL is typically 0.001

feet per foot (ft/ft). However, in active recharge and pumping areas, the hydraulic gradient can steepen to 0.0024 or greater. In most areas of the site, the natural groundwater flow velocity is calculated to be approximately 0.75 feet per day (ft/d). However, flow velocities in recharge areas may be as high as 1.45 ft/d, whereas velocities up to 28 ft/d have been calculated for areas immediately adjacent to potable and process supply wells (Woodward-Clyde Consultants, 1993). The vertical component of groundwater flow in the BNL area is downward. Water level measurements taken from paired water table and deep Upper Glacial wells located along BNL's northern boundary (near a regional groundwater divide) indicate downward gradients up to 0.006 ft/ft. Head differences become negligible within paired Upper Glacial wells located in the central to southern portions of BNL. Downward flow gradients are observed in paired water table and upper Magothy aquifer wells across the entire BNL site, indicating significant deep-flow recharge conditions, with downward vertical gradients of up to 0.027 ft/ft.

Data on the hydraulic characteristics of the Magothy aquifer are limited. Based upon a single pumping test at BNL, the US Geological Survey has estimated that hydraulic conductivity values for sand-rich zones within the Magothy range between 14 and 57 ft/d (Warren *et al.*, 1968). The hydraulic gradient within the Magothy is approximately 0.0006 ft/ft, and assuming a porosity value of 0.25, the groundwater flow velocity would range between 0.03 to 0.14 ft/d (see Warren *et al.*, 1968).

Review of Monitoring Well Sampling Methods

The removal of three to five well casing volumes prior to sampling has been the industry and regulatory standard for many years. A well casing volume is defined as the volume of water from the top of the water column (before pumping begins) to the bottom of the well casing, including the well's screened section and sediment trap. This method was developed during a period when monitoring wells were routinely purged using non-dedicated, high flow-rate electrical submersible pumps. Once the wells are purged using this method, Teflon or stainless steel bailers are used to collect groundwater samples from the uppermost portion of the water column. The method reflects concerns over the sampling of "stagnant" water in wells that have significant columns of water present in the casing above the screened interval. Studies have shown that geochemical changes can occur if water is allowed to stand in a well for an extended period of time (see Robin and Gillham, 1987; Gibs and Imbrigiotta, 1990). These geochemical changes could result from the interaction with well casing materials as well as the potential loss of VOCs due to volatilization at the air-water interface within the well. Therefore, it was assumed that to collect samples that were representative of groundwater chemistries in the aquifer, it was imperative to remove all standing water in the well prior to sample collection.

BNL Sampling Method

Dedicated bladder pumps have been installed in all BNL wells that are monitored on a routine basis. The pumps are positioned within the screened zones of the wells. Although initial capital costs are high (approximately $1,000 per well, and associated pump controllers), the installation of dedicated pumps is highly cost effective over the course of a multi-year sampling program. Dedicated pumps eliminate the need to decontaminate pumps between each well, cost for disposable discharge tubing, and the analytical costs associated with verifying the efficiency of decontamination procedures. The routine method of sampling groundwater surveillance wells at the BNL site consists of purging three well casing volumes of water prior to sample collection. The maximum rate of purge using the bladder pump system ranges from one to three gallons per minute depending upon pump depth. Purge water is monitored in the field to verify that the pH, temperature, specific conductance and turbidity have stabilized before samples are collected.

The time required to evacuate three casing volumes of water is approximately 0.5 to 1 hour for wells screened at or close to the water table (to approximately 70 feet deep). Figure 1 provides a comparison of well depth to purge water volumes required for the removal of 0.25 through 3 casing volumes of water. Because excessive purge times are required to remove three casing volumes from deep wells using bladder pumps alone (2 to 7 hours), non-dedicated electrical submersible pumps are occasionally used to remove approximately 95 percent of the required purge volume (at a rate of 5 to 10 gpm). Several deep wells have dedicated air displacement pumps that allow for faster purge rates. The electrical submersible pumps (or air displacement pumps) are positioned within the screened zone immediately above the bladder pumps. The bladder pumps are used to purge the remainder of the required purge volume and for sample collection. The time required to evacuate three casing volumes using this dual pump method is approximately 40 minutes for wells screened in the middle Upper Glacial aquifer (approximately 70 to 130 feet deep), one hour for deep Glacial wells (130 to 180 feet deep), and 1.5 hours for very deep Glacial and Magothy aquifer wells (180 to 280 feet deep). The non-dedicated electrical pumps are decontaminated between each well, an effort that requires approximately 20 minutes to accomplish. Data presented below indicate that consistent, stabilized VOC concentrations can be obtained using either a single bladder pump to purge the well, or one of the dual pumping systems (e.g., compare data for wells 105-06, 130-02 and 130-03).

Review of New Sampling Methods

Over the past ten years, a number of groundwater sampling studies have been conducted to evaluate the potential effects that purging methods, purge water volume, purge rates, and sampling device location have on sample quality (or representativeness with formational waters). Results of most of these studies indicate that representative groundwater samples can be collected using low-flow rate, low purge volume sampling techniques. The practice of performing low-rate/low-volume purging is also referred to as "micro-purging." Studies

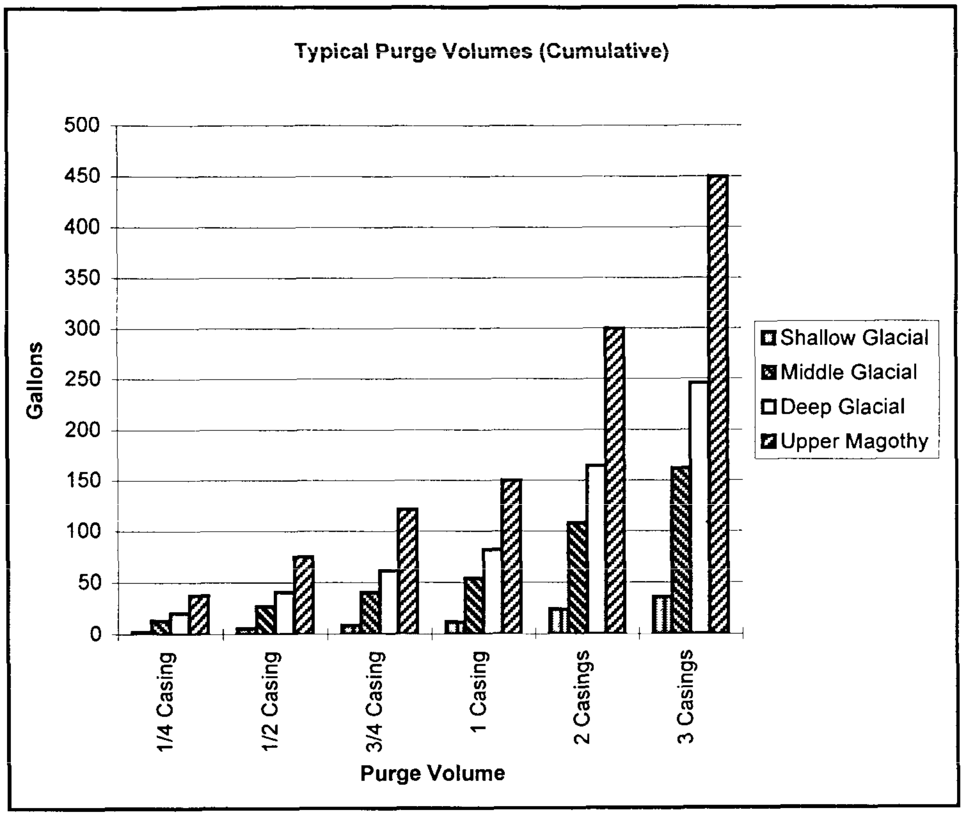

Figure 1: Comparision of typical purge water volume vs. sampling method.

conducted by Robin and Gilham (1987) have demonstrated that water within a screened interval of a well will be purged by the natural flow of water through the screen. Robin and Gillham conclude that this natural purging "presents the possibility of obtaining a sample without (or with very little) purging of the well." Most BNL wells are screened in the Upper Glacial aquifer, where a relatively high hydraulic conductivity results in a groundwater flow rate of approximately 0.75 feet per day. Therefore, the residence time for water in the screened zone of a typical four-inch diameter well should be on the order of one day or less. BNL wells that are routinely monitored are equipped with dedicated sample pumps that are positioned close to the mid-point of the screened interval. In deep wells where large volumes of water must be purged before sampling, there is significant separation between the intake of the sample pump and the air/water interface at the top of the water column. Because the sample pump intake is located within the screen zone of a well, water drawn into the pump is not stagnant, and the groundwater chemistry should be representative of formation pore waters located directly out side the well. Several studies have shown that contaminant concentrations stabilize after very small purge volumes (Barcelona *et al.*, 1994; Puls and Paul, 1995). Additionally, an extensive study conducted by the Western States Petroleum Association at over 100 sites in California found little systematic difference between contaminant concentrations in samples collected prior to purging and those collected after being fully purged (SECOR International, 1996).

US EPA Region II Procedure: The USEPA Region 2 has recently approved a low purge volume procedure for EPA sampling personnel (USEPA, 1998). The EPA Region II sampling protocol can be used for the collection of all (dissolved phase) contaminants typically detected in groundwater at contaminated sites being evaluated by the EPA, which includes BNL. The key criterion for the low purge volume method is minimizing the intake velocity of the sample pump to a flow rate that limits drawdown inside the well. It is recommended that the sample pump be placed within the most permeable zone in the screened interval. Following the guidelines established by Puls and Barcelona (1995), the EPA recommends collecting groundwater samples following the stabilization of dissolved oxygen, pH, redox potential, and turbidity. However, the protocol allows for the collection of samples if these parameters cannot be stabilized. Predetermined, minimum purge volumes are not required. The EPA protocol notes that the key indicator parameter for samples to be analyzed for VOCs is dissolved oxygen, whereas the key parameter for all other constituents is turbidity. Furthermore, depending upon site conditions, EPA suggests that stabilization of these water chemistry parameters generally occurs quickly, resulting in the need for very small purge volumes.

DOE Fernald and Princeton Plasma Physics Laboratory Procedures: Monitoring well sampling studies conducted at the DOE's Fernald site located in Ohio have successfully demonstrated to the DOE, USEPA and the State of Ohio that representative groundwater samples can be collected after purging very small volumes of water. The representativeness of the samples has been demonstrated by comparing contaminant concentration data (e.g., metals and Uranium) from samples collected following the purging of two times the volume of the pump and discharge tubing to those in samples collected after the typical three well casing volumes were purged (FEMP, 1993). The Fernald site is situated in a hydrogeologic setting (i.e., a glacial sand and gravel aquifer) that is similar to BNL, and groundwater samples are collected using dedicated sample bladder pumps that are positioned within the screened zones of the wells. A similar low-flow purge method is also being used at the DOE's Princeton Plasma Physics Laboratory in New Jersey (DOE, 1995).

BNL Low Purge Volume Study

Well Selection

From 1995 through 1997, twenty-one Upper Glacial aquifer wells were sampled. Six of the wells were sampled twice. The wells were chosen based upon historical levels of VOC and tritium contamination, position of the wells relative to contaminant source areas, and depth below the water table (Tables 1, 2 and 3). Wells used in this study are used to monitor contaminant plumes originating from: the Hazardous Waste Management Facility; Current Landfill; Sewage Treatment Plant; Central Steam Facility; Building 650; Supply and Materiel area; Alternating Gradient Synchrotron (AGS) area; Brookhaven Medical Research Reactor (BMRR); and the High Flux Beam Reactor (HFBR). The groundwater study was conducted in two phases.

Phase I: From October 1995 through January 1996, eight Upper Glacial aquifer wells were sampled over varying purge volumes for VOCs. One well was also sampled for tritium (Table 2). Seven of the wells were shallow Upper Glacial wells, and two were middle Upper Glacial aquifer wells. Each well had historical records of VOC contamination, with concentrations ranging from near the typical New York State Ambient Water Standard (NYS AWQS) of 5 µg/L (i.e., 5 µg/L to 30 µg/L) to higher concentrations in the range of 100 µg/L to 1,500 µg/L. One well also had historically low-level tritium contamination in the range of 2,000 pCi/L. The NYS AWQS for tritium is 20,000 pCi/L.

Phase II: From July 1997 through September 1997, nine Upper Glacial aquifer wells were sampled over varying purge volumes for VOCs only, two wells were sampled for both VOCs and tritium, and six wells were sampled for tritium only (Table 3). Of the eighteen wells; thirteen were shallow Upper Glacial wells, three were middle Upper Glacial wells, and two of the wells were situated in deep Upper Glacial aquifer. Twelve wells had historical VOC concentrations ranging from near the typical NYS AWQS of 5 µg/L (i.e., 5 µg/L to 30 µg/L) to significantly higher concentrations ranging between 100 µg/L to 1,500 µg/L. Nine wells had historical tritium concentrations ranging from just below the NYS Drinking Water Standard (NYS DWS) of 20,000 pCi/L to significantly higher concentrations of over 1,000,000 pCi/L. Six of the wells

Brookhaven National Laboratory
Low Purge Volume Groundwater Sampling Study
Monitoring Well Locations
Table 1

Wells	Monitoring Area and Contaminant(s) of Concern	CERCLA Operable Unit
88-109 98-57 98-59 115-13	Hazardous Waste Management Facility and Current Landfill Areas - Volatile organic compounds and radionuclides associated with historical spills and waste disposal practices.	OU I
64-03 65-02	Alternating Gradient Synchrotron Facility - Volatile organic compounds associated with historical solvent discharges to cesspools (primarily TCA). Tritium from activated soils at accelerator beam stops.	OU III
96-06 96-07	Supply and Materiel Area - Volatile organic compounds associated with Building 208 solvent spill site (primarily TCA).	OU III
75-12 75-43 75-48	High Flux Beam Reactor - Tritium release from spent fuel pool.	OU III
84-12 84-13	Brookhaven Medical Research Reactor – Tritium releases from floor drain piping.	OU III
130-02 130-03	Southern Boundary - Volatile organic compounds released from central areas of site.	OU III
76-04 76-08 76-21 105-06	Central Steam Facility - 1977 fuel oil/solvent spill.	OU IV
76-23	Building 650 – Solvent spills (TCA)	OU IV
39-05	Sewage Treatment Plant - Tritium released at filter bed and STP outfall areas.	OU V

Brookhaven National Laboratory
Low Purge Volume Groundwater Sampling Study
1995/1996 Sampling Schedule
Table 2

October 1995

Well Number	Sampled for VOCs	Sampled for Tritium	Screen Zone (BGS)	Depth to Water (BGS)	Position in Glacial Aquifer	Pump Type
76-04	✓		30'-50'	38'	Shallow Glacial	Geoguard
98-57	✓		40'-50'	18'	Shallow Glacial	Geoguard

November 1995

Well Number	Sampled for VOCs	Sampled for Tritium	Screen Zone (BGS)	Depth to Water (BGS)	Position in Glacial Aquifer	Pump Type
96-06	✓		35'-45'	33'	Shallow Glacial	Geoguard
98-59		✓	120'-130'	19'	Middle Glacial	Geoguard

January 1996

Well Number	Sampled for VOCs	Sampled for Tritium	Screen Zone (BGS)	Depth to Water (BGS)	Position in Glacial Aquifer	Pump Type
64-03	✓		38-58'	41'	Shallow Glacial	Geoguard
76-08	✓		30'-50'	39'	Shallow Glacial	Geoguard
88-109	✓		6'-21'	13'	Shallow Glacial	Geoguard
96-07	✓		30'-40'	30'	Shallow Glacial	Geoguard
130-02	✓		105'-125'	49'	Middle Glacial	Geoguard (a)

Note 1: VOC analyses performed by BNL Analytical Services Lab using EPA Method 624.
Note 2: Tritium analyses performed by BNL Analytical Services Lab using EPA Method 906.
a: Dual pumping system consisting of Geoguard gas displacement (purge) pump and bladder (sample) pump

Brookhaven National Laboratory
Low Purge Volume Groundwater Sampling Study
1997 Sampling Schedule
Table 3

July 1997

Well Number	Sampled for VOCs	Sampled for Tritium	Screen Zone (BGS)	Depth to Water (BGS)	Position in Glacial Aquifer	Pump Type
76-04	✓		30'-50'	32'	Shallow Glacial	Geoguard
76-08	✓		30'-50'	34'	Shallow Glacial	Geoguard
76-21	✓		25'-45'	35'	Shallow Glacial	Geoguard
76-23	✓		28'-48'	29'	Shallow Glacial	Geoguard
96-06	✓		35'-45'	28'	Shallow Glacial	Geoguard
96-07	✓		30'-40'	25'	Shallow Glacial	Geoguard
105-06	✓		70'-80'	19'	Middle Glacial	Geoguard

August 1997

Well Number	Sampled for VOCs	Sampled for Tritium	Screen Zone (BGS)	Depth to Water (BGS)	Position in Glacial Aquifer	Pump Type
64-03	✓		38'-58'	35'	Shallow Glacial	Geoguard
84-12		✓	55'-70'	58'	Shallow Glacial	Grundfos (a)
84-13		✓	53'-68'	58'	Shallow Glacial	Grundfos (a)
115-13	✓		140'-150'	26'	Deep Glacial	Geoguard
130-02	✓		105'-125'	44'	Middle Glacial	Geoguard (b)
130-03	✓	✓	160'-165'	44'	Deep Glacial	Geoguard (c)

September 1997

Well Number	Sampled for VOCs	Sampled for Tritium	Screen Zone (BGS)	Depth to Water (BGS)	Position in Glacial Aquifer	Pump Type
39-05		✓	4'-24'	7'	Shallow Glacial	Geoguard
65-02	✓	✓	55'-65'	39'	Shallow Glacial	Geoguard
75-12		✓	59'-69'	51'	Shallow Glacial	Geoguard
75-43		✓	47'-57'	52'	Shallow Glacial	Grundfos (a)
75-48		✓	63'-73'	36'	Middle Glacial	Grundfos

Note 1: VOC analyses performed by H2M Labs using EPA Method 524.2.
Note 2: Tritium analyses performed by BNL ASL using EPA Method 906.
a: Pump intake positioned within 3 feet of water table.
b: Dual pumping system consisting of Geoguard gas displacement (purge) pump and bladder (sample) pump.
c: Dual pumping system consisting of Grundfos (purge) pump and Geoguard bladder (sample) pump.

initially sampled during Phase I of the study were re-sampled to evaluate the consistency of contaminant concentrations following changes in water table position and minor changes in groundwater flow directions.

Monitoring Wells and Sampling Pumps

The twenty-one Upper Glacial aquifer monitoring wells used for this study are constructed of four-inch diameter PVC well casings and screens. The shallow to middle Upper Glacial aquifer wells are typically constructed with 0.02 inch slotted screens, whereas deep Glacial wells typically have of 0.01 inch slotted screens. The wells were installed using hollow-stem auger drilling techniques. During well construction, filter packs (using Number 1 or Number 2 Morie silica sand) were installed to two feet above the screened interval. The remainder of the annual space was sealed first with a two foot layer of bentonite, followed by either a cement-bentonite or bentonite grout extending to the surface. The wells were installed from 1990 through May 1997, and were fully developed following installation. In most cases, the wells had been sampled many times prior to their use in this study.

As noted above, the wells used for this study monitor the shallow (including water table), middle and deep portions of the Upper Glacial aquifer, and have screen lengths that vary between 10 to 20 feet (Tables 2 and 3). The wells ranged in depth from 21 to 165 feet below land surface. Seventeen of the wells have dedicated Geoguard® bladder sample pumps with either 0.5-inch or 0.6-inch diameter Teflon®-lined polyethylene discharge tube. One well (130-02) is also equipped with a dedicated Geoguard air displacement pump that is used to purge the well. The Geoguard pumps are generally located within the lower third to middle portions of the screened zone of each well. Four of the wells sampled for tritium did not have dedicated pumping systems at the time of sampling. These wells were sampled using variable-speed electrical submersible (Grundfos® Redi-Flo2™) pumps with disposable polyethylene discharge tubing. Following sampling, the electrical submersible pumps were thoroughly decontaminated using non-phosphate soap and distilled water rinses. Equipment blanks were collected and analyzed to verify the effectiveness of the decontamination procedure.

Purging and Sampling

Prior to the start of purging, the water level in each well was determined by using a Slope Indicator Company Inc. electrical water level indicator calibrated to 0.01 ft. Using the water level measurements and well construction data, the amount of standing water (i.e., well volume) in each well was calculated. The Geoguard pumps were maintained in their fixed positions, and pump flow rates were typically maintained to <1 gallon per minute (gpm). However, for some shallow wells, Geoguard pump rates occasionally ranged between 1.5 to 2 gpm. To evaluate the current method of sampling deep wells at BNL (described above), two of the deep wells (Wells 130-02 and 130-03) were purged and sampled using dual pumping systems. These dual-pumping systems consisted of a dedicated low flow rate (<1 gpm) sample bladder pump coupled with a dedicated higher flow rate (2-4 gpm) air displacement purge pump (Well 130-02) or a non-dedicated Redi-Flo2 electrical submersible pump (Well 130-03). Both pumps were situated in the mid-screen zone, with the pump intakes separated by approximately four feet. The air displacement pump or electrical submersible pump was used to remove approximately 95 percent of the required purge volume, with the remaining five percent being removed with the sample bladder pump. Three of the middle to deep Upper Glacial wells used in this study (98-59, 105-06, and 115-13) were purged and sampled using bladder pumps only. Electrical submersible pumps were used to sample newly installed wells located downgradient of the HFBR and BMRR facilities. Due to significant stratification of tritium concentrations within these wells (see discussion below), the pumps were positioned within two feet of the water table, where the highest tritium concentrations are typically found. As the result of the relatively high transmissivity characteristics of the Upper Glacial aquifer, flow rates of even 2 gpm result in little to no measurable draw down (<0.05 ft).

Purge water was directed into plastic graduated cylinders (for purge volumes of <1 gallon), or calibrated 10-gallon plastic buckets. At each sample interval, a 500-ml sample of purge water was collected and immediately measured for temperature (°C), pH, conductivity (µS/cm), dissolved oxygen (mg/L), and turbidity (NTU). Temperature, pH, conductivity, and dissolved oxygen were measured using a calibrated YSI® Multi-Parameter Water Quality Meter (Model YSI 610-DM/600XL). Turbidity was measured separately using a calibrated Hach/HR™ turbidimeter. At each designated sample collection interval, pump rates were reduced to between 100 and 500 ml/min to prevent turbulence as the water is directed into sample containers.

Samples for VOC analysis were collected directly into new, certified clean 40-ml glass vials with Teflon-lined septums. The samples were immediately acidified to a pH of <2 using hydrochloric acid and cooled to four degrees Centigrade. Samples collected for tritium analysis were collected into new 250-ml glass containers. No preservation steps are required for tritium samples. All samples were transported to the appropriate analytical laboratory under chain-of-custody.

During Phase I, eight groundwater samples per well were collected at pre-determined purge volumes. Samples were collected at a frequency of: 1) two discharge tubing volumes; 2) four discharge tubing volumes; 3) 0.25 casing volume; 4) 0.5 casing volume; 5) 0.75 casing volume; 6) one casing volume; 7) two casing volumes; and 8) the standard three casing volumes. A discharge tubing volume is defined as the volume of water contained in the tubing from the pump to the top of the well casing (39 or 60 ml/ft.). Because the bladder pumps are equipped with check-valves, the removal of two discharge tubing volumes is required to fully evacuate the any residual water that may be in the pump (a maximum volume of 550 ml) or discharge line from an earlier sampling event. In shallow wells, two discharge tubing volumes is often equivalent to 0.05 to 0.1 casing volume, and four discharge tubing volumes is equivalent to 0.25 casing volume. Duplicate samples and field trip blanks were routinely collected for quality assurance purposes. Because dedicated sampling equipment was utilized at each well, equipment blank samples were not required.

During Phase II, six groundwater samples per well were collected at pre-determined purge volumes. Samples were collected at a frequency of: 1) 0.25 casing volume; 2) 0.5 casing volume; 3) 0.75 casing volume; 4) one casing volume; 5) two casing volumes; and 6) the standard three casing volumes. Duplicate samples and field trip blanks were routinely collected for quality assurance purposes. When non-dedicated Grundfos pumps were used, equipment blank samples were collected to verify the effectiveness of decontamination procedures.

Laboratory Analysis

Samples collected in the winter of 1995/1996 were analyzed for VOCs and tritium by BNL's Analytical Services Laboratory (ASL). Samples were analyzed for VOCs using USEPA Method 624 and for tritium using USEPA Method 906. Samples collected in the summer/fall of 1997 were analyzed for VOCs by H2M Labs, Inc., Melville, New York, using USEPA Method 524.2, and for tritium by the BNL ASL using USEPA Method 906. Analytical results are presented in Appendix A.

The ASL is certified by the New York State Department of Health (NYS DOH) for each of the analyses performed. The ASL also participates in the DOE Environmental Measurements Laboratory (EML) QA Program and the EPA National Exposure Research Laboratory Performance Evaluation Study. H2M Labs, Inc. is a NYSDOH certified analytical laboratory for Method 524.2 analysis. The BNL ASL and H2M Labs, Inc. have established standard operating procedures to calibrate instruments, analyze samples, and check quality control. Depending upon the analytical method, quality control checks include the analysis of blanks or background concentrations, use of Amersham or National Institute for Standards and Technology (NIST) traceable standards, and analysis of reference standards, spiked samples, and duplicate samples. The VOC analytical data were evaluated for completeness and accuracy according to the protocols and QC requirements of the analytical method, USEPA Region II CLP Organics Data Review (CLP/SOW OLM 03.2) SOP No. HW-6 Revision #11 (May 1996), and USEPA Contract Laboratory Program National Functional Guidelines for Organic Data Review (February 1994). Tritium data were validated using USDOE Guidance for Radiochemical Data Collection and Review (EM-76, dated March 17, 1997).

Results and Discussion

Well purge volume calculations, pump rates, water quality data, and contaminant concentration data for each well examined during this study are presented in Appendix A. All trend plots showing water quality and contaminant concentration data are presented in Appendix B. Results of the study are summarized below.

Water Quality Parameter Stabilization

For this study, field water quality parameters were evaluated over successive purge volumes. These parameters were considered stabilized when three successive temperature or dissolved oxygen (DO) values were within ±10 percent, ±3 percent for conductivity, or ±0.1 units for pH (following the guidelines of Puls and Barcelona, 1995). Turbidity was considered stabilized when three successive values were < 10 NTU, or within ±10 percent for values >10 NTU. The amount of water removed from a well casing to achieve stable values for field water quality parameters and contaminant concentrations is shown in Tables 4 and 5. In all cases, temperature stabilized either before or following the removal of 0.25 casing volume (Table 6). Most of the remaining parameters (pH, conductivity, dissolved oxygen and turbidity) stabilized prior to or following the removal of 0.25 casing volume. Although 70 percent of the DO readings appeared to stabilize following the removal of 0.25 to 0.5 casing volume, instrumentation problems or exposure of the purge water samples to ambient air while taking the measurements appear to have resulted in inaccurate DO measurements on as many as ten occasions. In these cases, DO readings were recorded which exceed published solubility limits based upon atmospheric pressure and temperature of the groundwater. Since this study, more reliable DO results have been obtained by using a flow-through cell specifically designed for the YSI Water Quality Meter. Figures 3 and 4 show comparisons of field water quality parameters and VOC concentrations.

Contaminant Concentration Stabilization

Volatile Organic Compounds: Nineteen of twenty well sampling events had detectable levels of VOCs. In samples from ten of fifteen (67 percent) events where one or more of the VOCs were detected at concentrations >5 μg/L (the typical NYS AWQS), VOC concentrations stabilized within ±20 percent (in three consecutive samples) following the purging of 0.05 to 0.25 casing volume (Table 4).[1] Three of these were Phase I sampling events, where stabilization was achieved with the purging of only 0.05 to 0.19 casing volume. In two sampling events complete stabilization of all compounds did not occur until 0.75-casing volume was purged, and in one case the removal of one casing volume was required for complete stabilization. During two events (for Wells 76-04 and 88-109), some VOC concentrations did not stabilize at all. In four out of nineteen sampling events, VOC concentrations were < 5 μg/L. In three of these events, complete stabilization appears not to occur until the removal of 0.05 casing volume. However, in these cases very small variations in concentrations of ±0.1 to 1 µg/L were observed between samples collected at 0.25 casing volume and those at 0.5 casing volume. When evaluating concentration stabilization on a compound-by-compound basis for all nineteen wells (using a total of 57 sets of VOC concentration data), 70 percent of the VOC concentrations stabilized

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[1] Twenty percent was chosen as the indicator for contaminant concentration stabilization because it is the typical USEPA Environmental Monitoring System Laboratory (Cincinnati) performance criteria for VOC analyses, and the USDOE Environmental Measurements Laboratory performance criteria for tritium analyses.

Brookhaven National Laboratory
Low Purge Groundwater Sampling Study
Well Casing Purge Volumes Required to Reach Field Water Quality Parameter and VOC Stabilization (±20%)[(c)]
Table 4

Well	Temp. (±10 %)	pH (±0.1)	Cond. (±3 %)	DO (±10 %)	Turb. (±10 %)	TCA	TCE	PCE	DCA	DCE	Cis 1,2-DCE	Chloro-form	Ethyl-benzene	Xylene	Toluene
64-03a	0.09	NS	0.09	0.19 (e)	0.09(d)	0.19	0.19	--	0.19	0.19	--	--	--	--	--
64-03b	0.25	0.5	0.25	NM	0.25(d)	0.25	0.25 (f)	--	0.25 (f)	0.25 (f)	--	--	--	--	--
65-02b	0.25	0.5	0.25	0.5	0.25 (d)	0.5 (f)	0.5 (f)	--	0.5 (f)	--	--	0.25 (f)	--	--	--
76-04a	0.15	0.15	0.15	0.15	0.07 (d)	--	--	--	--	--	--	--	0.25	0.03	NS
76-04b	0.25	0.25	0.5	1.0	NS	--	--	1.0	--	--	1.0	--	1.0	1.0	0.5
76-08a	0.25	0.25	0.75	0.5	0.25 (d)	0.25 (f)	0.25 (f)	0.75	--	--	--	--	0.75 (f)	--	--
76-08b	0.25	0.25	0.5	0.25	0.25 (d)	--	--	0.25 (f)	--	--	0.5 (f)	--	--	--	--
76-21b	0.25	0.25	0.25	0.25	0.25 (d)	--	--	0.25	--	--	0.25	--	--	--	--
76-23b	0.25	0.5	0.5	0.25 (e)	0.25 (d)	--	--	0.25	--	--	--	--	--	--	--
88-109a	0.05	0.75	NS	0.75	0.05 (d)	--	--	--	NS	--	--	0.05 (f)	--	--	--
96-06a	0.12	0.12	0.12	0.12	0.75 (d)	0.12	--	--	--	--	--	--	--	--	--
96-06b	0.25	0.25	0.25	0.5	0.5 (d)	0.5 (f)	--	--	--	--	--	--	--	--	--
96-07a	0.12	0.25	0.5	0.5 (e)	0.12 (d)	0.25	0.12 (f)	--	--	--	--	--	--	--	--
96-07b	0.25	0.75	0.5	0.25	0.25 (d)	0.5	--	--	--	0.75	--	--	--	--	--
105-06b	0.25	0.5	0.5	0.25	0.25 (d)	0.25 (f)	0.25	0.25	--	--	0.25	0.25 (f)	--	--	--
115-13b	0.25	0.25	0.25	0.5 (e)	0.25 (d)	--	--	--	--	--	--	0.25 (f)	--	--	--
130-02a	0.05	0.25	0.05	NS (e)	0.05 (d)	0.05	0.05	0.05	--	--	--	0.05 (f)	--	--	--
130-02b	0.25	0.25	0.25	0.75	0.25 (d)	0.25	0.25 (f)	0.5 (f)	0.25 (f)	0.25	--	--	--	--	--
130-03b	0.25	0.5	0.25	0.75	0.25 (d)	0.25	0.25	--	0.25 (f)	0.25 (f)	--	0.25 (f)	--	--	--

a: Phase I Sample.
b: Phase II Sample.
c: Stabilization over three consecutive samples.
d: Turbidity was considered stabilized after three consecutive readings of <10 NTU.
e: Some DO values were outside acceptable solubility ranges.
f: VOC concentrations were ≤5 µg/L.
NS: Indicates that water quality parameter or VOC concentration did not stabilize.
---: Indicates that constituent was not detected.
NM: Parameter not measured
Note: VOC Data from well 98-57 was inconclusive due to non-detectable values.

Brookhaven National Laboratory
Low Purge Groundwater Sampling Study
Well Casing Purge Volumes Required to Reach Field Water Quality Parameter and Tritium Stabilization (±20%)(c)
Table 5

Well	Temp. (±10 %)	pH (±0.1)	Cond. (±3 %)	DO (±10 %)	Turb. (±10 %)	Tritium (±20 %)
39-05b	0.25	0.5	1.0	NM	0.25 (d)	0.25
65-02b	0.25	0.5	0.25	0.5	0.25 (d)	(f)
75-12b	0.25	0.5	0.25	0.25 (e)	0.25 (d)	0.25
75-43b	0.25	1.0	0.25	0.5 (e)	NS	0.25
75-48b	0.25	0.25	0.25	0.25 (e)	0.25 (d)	0.25
84-12b	0.25	0.25	0.25	0.5 (e)	0.25 (d)	0.25
84-13b	0.25	0.25	1.0	0.75 (e)	0.25 (d)	0.25
98-59a	0.04	0.07	0.25	0.04	0.04 (d)	0.04
130-03b	0.25	0.5	0.25	0.75	0.25 (d)	(f)

a: Phase I Sample.
b: Phase II Sample
c: Stabilization over three consecutive samples.
d: Turbidity was considered stabilized after three consecutive readings of <10 NTU.
e: Some DO values were outside acceptable solubility ranges.
f: Tritium data were inconclusive because some values were either marginally above or were below minimum detection limits.
NS: Indicates that water quality parameter or Tritium concentration did not stabilize.
NM: Parameter not measured.

Brookhaven National Laboratory
Low Purge Groundwater Sampling Study
Summary of Water Quality Parameter and Contaminant Concentration Stabilization
Table 6

Water Quality Parameter	Percent Stabilization Relative to Volumes Purged			
	≤0.25 Casing	0.5 Casing	0.75 Casing	1.0 Casing
Temperature (±10 %)	100%	--	--	--
PH (±0.1 SU)	58%	27%	8%	4%
Conductivity (±3 %)	62%	23%	4%	8%
Dissolved Oxygen (±10 %)	42%	27%	15%	4%
Turbidity (±10 %)	81%	8%	4%	--

Contaminant	# Detections	Percent Stabilization Relative to Volumes Purged (a)			
		≤0.25 Casing	0.5 Casing	0.75 Casing	1.0 Casing
1,1,1-Trichloroethane (TCA)	12	75%	25%	--	--
Trichloroethylene (TCE)	9	89%	11%	--	--
Tetrachloroethylene (PCE)	8	63%	12%	12%	12%
1,1-Dichloroethane (DCA)	6	67%	17%	--	--
1,1-Dichloroethylene (DCE)	5	80%	--	20%	--
Cis-1,2-Dichloroethylene (Cis 1,2-DCE)	4	50%	25%	--	25%
Chloroform	6	100 %	--	--	--
Ethylbenzene	6	33%	--	33%	33%
Xylene (total)	2	50%	--	--	50%
Toluene	2	--	50%	--	--
Tritium	7	100 %	--	--	--
All Volatile Organic Compounds (b, c)	57	70%	14%	5%	7%
All Tritium (d)	7	100%	--	--	--

a: VOCs and tritium concentrations are considered stabilized when values are within ±20 % for three consecutive samples.

b: Other less common compounds detected in wells 76-04 and 88-109 not included in this summary. See Appendix A for complete data set.

c: 4% of VOCs did not stabilize.

d: Tritium data from Wells 65-02 and 130-03 not included because tritium concentrations were either marginally above or were below the MDL.

before or following the removal of 0.25 casing volume (Table 6). Figure 2 provides VOC concentration trend plots for three wells in which VOC concentrations stabilize before or following the removal of 0.25 casing volume. Data presented in Figure 2A shows the stabilization of TCA concentrations in shallow Upper Glacial Well 96-06 following the removal of only 0.12 casing volume (or 2 discharge tubing volumes). Figures 2B and 2C show stabilization of VOCs in Wells 105-06 and 130-03, screened in the middle and deep Upper Glacial aquifer, respectively. Well 105-06 was sampled using a dedicated sample bladder pump, whereas Well 130-03 was sampled using a dedicated dual pumping system consisting of an air displacement purge pump and a bladder pump. Additional examples of concentration stabilization following the removal of 0.25 casing volume are presented in Appendix A and Appendix B.

Achieving concentration stabilization or maintaining stabilization was not possible for some of the compounds detected in two wells (76-04 and 88-109). Both wells are located directly downgradient of source areas, where significant variations in contaminant concentrations within the plumes are likely to occur. Most VOC concentrations either increased or decreased with purging of successive well volumes during the two sampling events at Well 76-04 (Figure 3, Table 4). Figure 3A shows VOC concentrations stabilizing early in the purging process during the first sampling event, only to become less stable as more water was removed. During the second sampling event, VOC concentrations became stable only after the removal of one casing volume (Figure 3B). In Well 88-109, chloroform concentrations stabilized early, whereas 1,1-dichloroethane and chloroethane did not achieve stabilization during the entire purging process (see Well 88-109 data in Appendix A). Furthermore, continuous stabilization could not be achieved during the January 1996 sampling of Well 64-03, where two separate periods of TCA concentration stabilization were observed (Figure 5A). These stabilization periods are separated by a 25 percent increase in TCA concentrations following the removal of 0.5 casing volume.

The lack of continuous VOC concentration stabilization during purging is likely to be the result of variations in contaminant concentrations within a plume, and the position of the plume relative to the well screen interval and sample pump position rather than an indication of "non-representative" samples. If a contaminant plume is narrow or thin, excessive pumping could cause mixing with cleaner portions of the aquifer. Therefore, concentrations may decrease as more water is pumped. Conversely, mixing with higher concentration portions of a plume could cause concentrations to increase. Detailed VOC and radionuclide plume characterization studies have been conducted at BNL using closely spaced, drilled and driven (hollow stem auger and Geoprobe™) temporary wells. During these studies, groundwater samples were collected at multiple vertical intervals as the temporary wells were extracted (i.e., pulled). These studies have demonstrated that there can be significant variability in contaminant concentrations within a plume over small vertical and horizontal distances (within 3 to 5 feet).

Plume position relative to the well screen can also be influenced by periodic changes in groundwater flow directions and water table fluctuations. In the case of Well 76-04, there was six-foot increase in the position of the water table between the two sampling events. Significant changes in VOC concentrations between sample periods were also observed in Wells 64-03 and

96-06 (Figures 4 and 5). Figure 6 provides a one-to-one comparison of VOC concentrations in samples collected after purging 0.25 casing volume to those collected after purging three volumes. The VOC concentration "outliers" depicted in Figure 6A result from ethylbenzene, toluene, and xylene concentration data from Well 76-04. As discussed above, continuous stabilization of these compounds was difficult to achieve. Figure 6B shows a comparison of VOC concentrations excluding the Well 76-04 data, which are presented separately in Figure 6C.

Tritium: Tritium was detected at concentrations >1,000 pCi/L in seven of the nine well sampled (the minimum detection limit is typically 250 to 300 pCi/L; results of > 1,000 pCi/L are generally considered reliable).[2] In these seven wells, tritium concentrations stabilized to within ±20 percent before or following the removal of 0.25 casing volume (Tables 5 and 6). Figure 7 shows tritium concentrations as a function of purge volume for three permanent wells used to monitor the HFBR tritium plume, and one monitoring the BMRR tritium plume. In several cases tritium concentrations decreased as more water was removed (Figures 7B and 7C). In the case of BMRR Well 84-13, initially stable tritium concentrations became unstable following the removal of 0.75 casing volume (Figure 7C). Similar to the variations observed in VOC concentrations describe above, decreases in tritium concentrations over successive purge volumes suggest that over pumping resulted in the pulling water from less concentrated portions of the tritium plumes. Conversely, the increase in tritium concentrations during the purging of Well 84-13 is likely to be the result of obtaining water from a more concentrated portion of the plume (Figure 7D). Figure 8 provides a one-to-one comparison of tritium concentrations in samples collected after purging 0.25 casing volumes to those collected after purging three volumes.

Detailed characterization of the HFBR tritium plume in 1997 using closely spaced Geoprobe wells revealed concentrations exceeding 200,000 pCi/L in samples collected within two feet of the water table in an area directly downgradient of the reactor building. Concentrations dropped off markedly with depth, decreasing to <5,000 pCi/L six to eight feet below the water table. Similar patterns of tritium stratification (probably due to being immediately downgradient of the source and the lack of significant density differences between tritiated and non-tritiated water) was observed in Geoprobe wells installed directly downgradient of the BMRR. HFBR Well 75-43 and BMRR Wells 84-12 and 84-13 are screened across the water table to allow for fluctuations in water table position. Therefore, in order to obtain meaningful tritium data between sampling events, consistent placement of sample pump intakes within three feet of the water table is required for these wells.

Revised BNL Sampling Procedure

BNL has revised its groundwater sampling procedure based upon the results of this study and the recently published USEPA-Region II groundwater sampling procedure (USEPA, 1998). The USEPA sampling procedure is presented in Appendix C.

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[2] Data from two of the wells (65-02 and 130-03) were inconclusive because tritium concentrations for a number of the samples were either just marginally above or were below the minimum detection limit (see Appendix A).

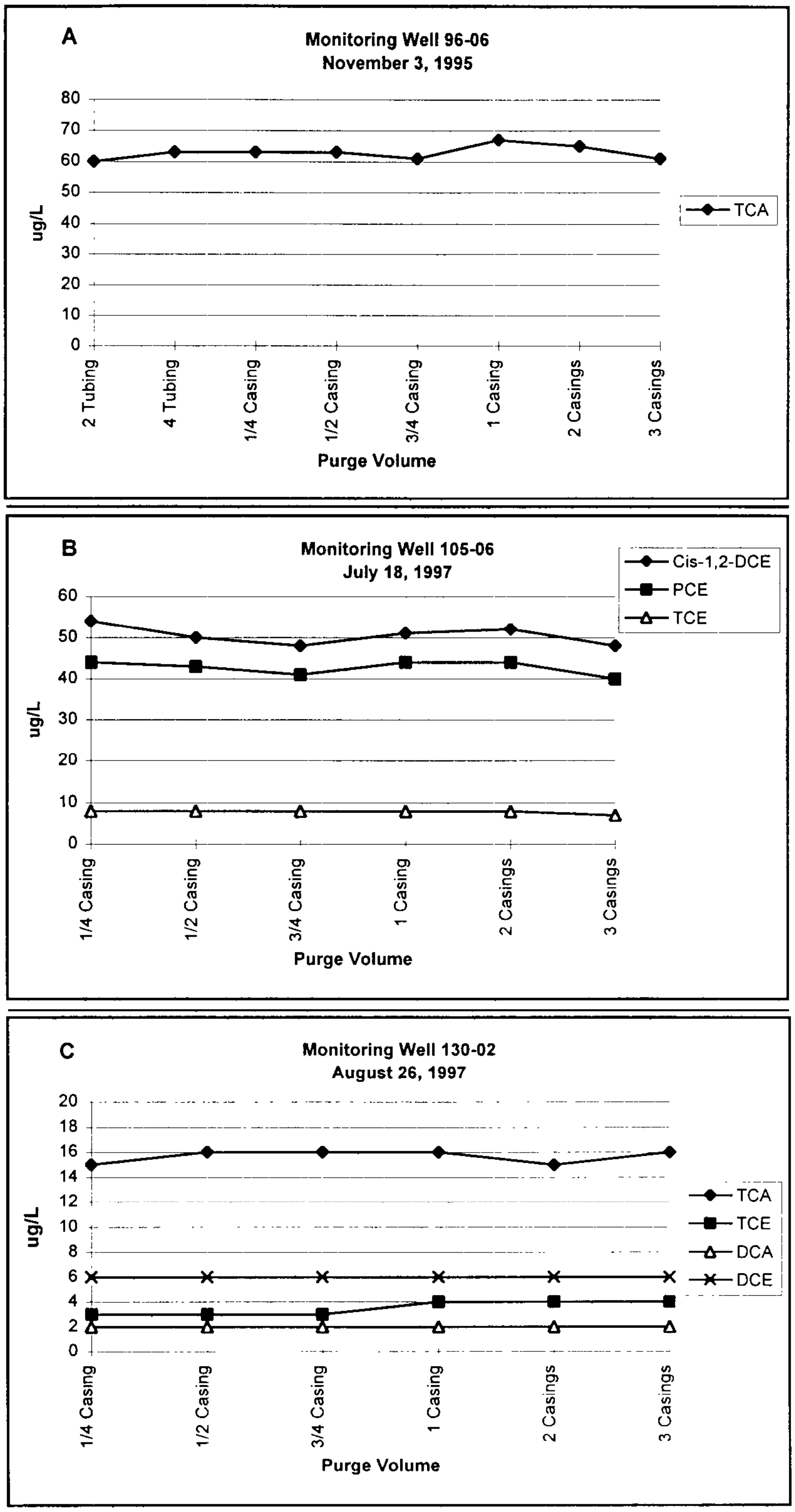

Figure 2. Stabilization of VOC concentrations in three monitoring wells: A) VOC concentrations stabilize following the removal of two discharge tubing (or 0.12 casing) volumes; B and C) VOC concentrations stabilize following the removal of 0.25 casing volumes.

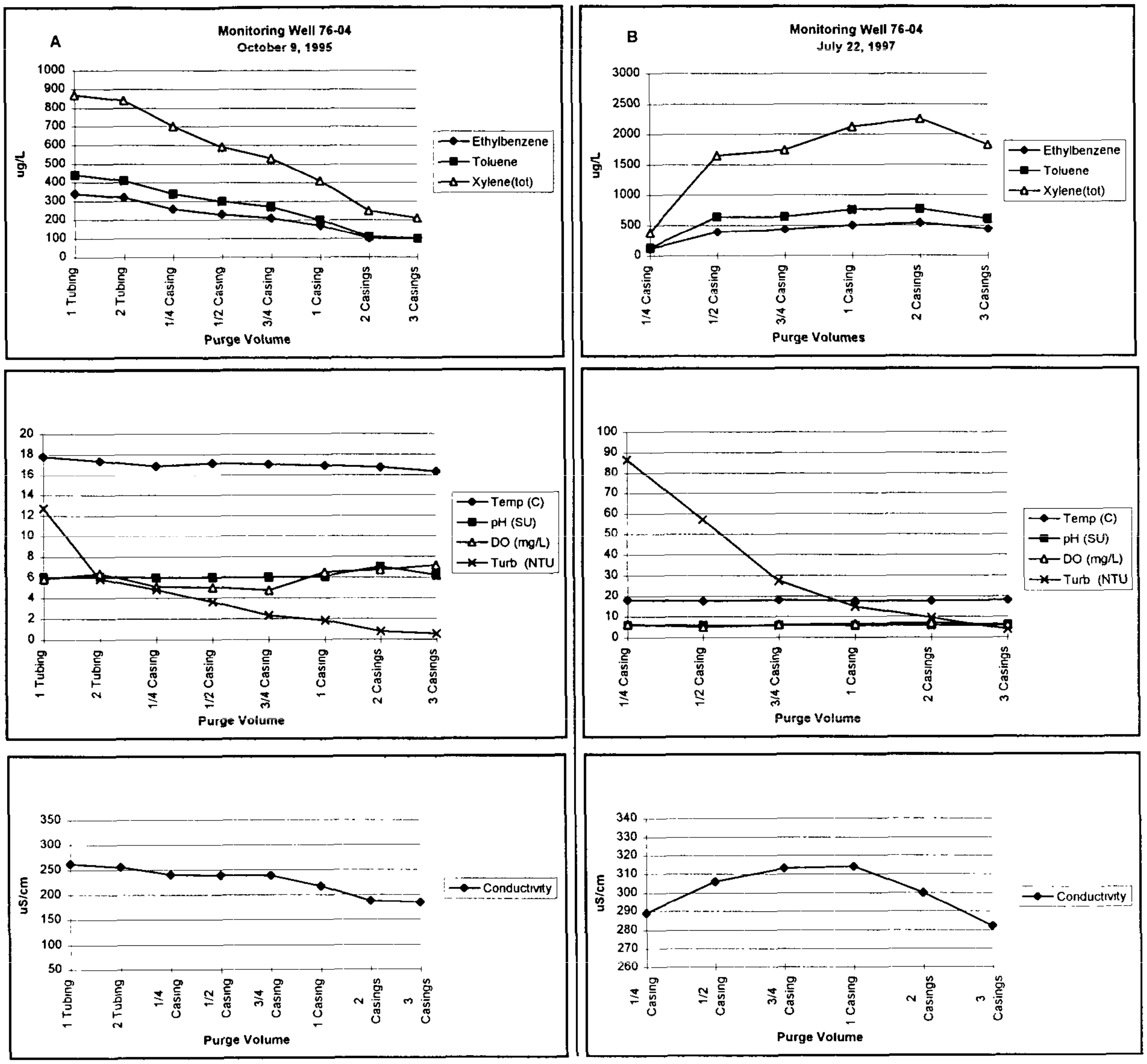

Figure 3. Comparison of water quality parameters and VOC concentrations in Well 76-04 during two separate sample periods: A) Samples collected October 9, 1995; B) Samples collected July 22, 1997. Water table position increased by approximately six feet between the two sample periods.

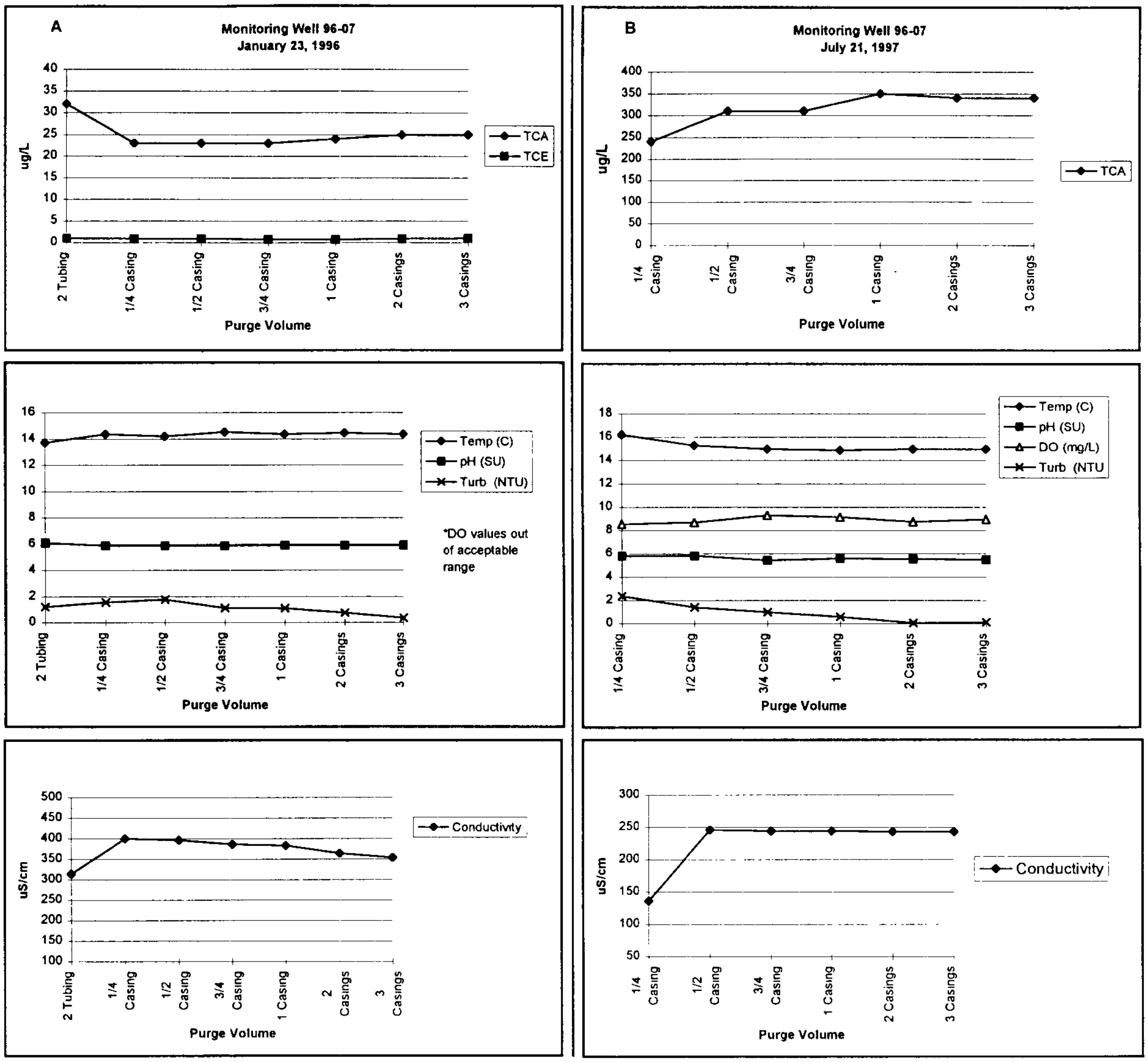

Figure 4. Comparison of water quality parameters and VOC concentrations in Well 96-07 during two separate sample periods: A) Samples collected October 9, 1995; B) Samples collected July 21, 1997. Water Table position increased by approximately five feet between the two sample periods.

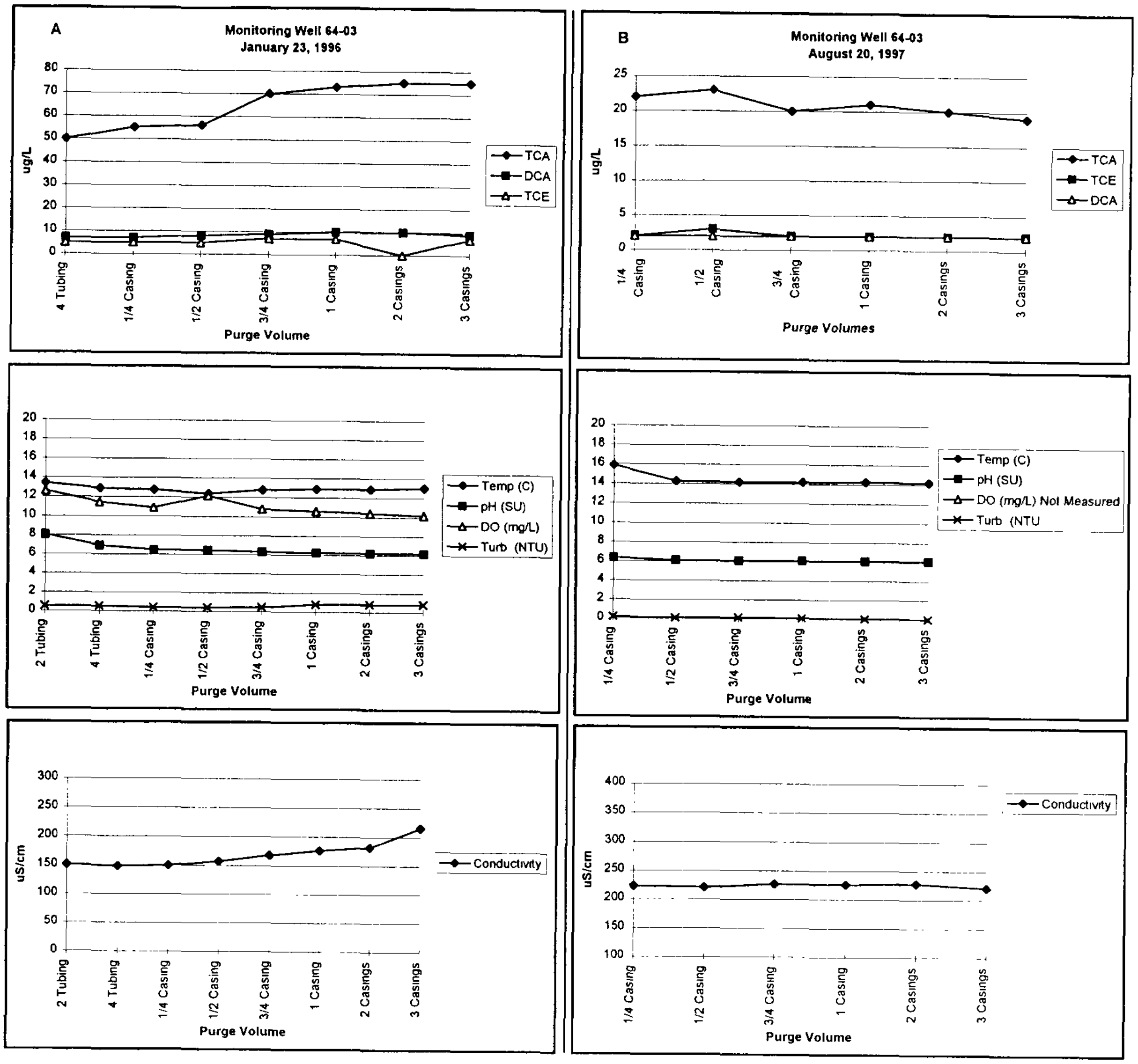

Figure 5. Comparison of water quality parameter and VOC concentrations in Well 64-03 during two separate sample periods: A) Samples collected January 23, 1996; *B) Samples collected August 20, 1997. Water Table position increased by six feet between the two sample peiods.*

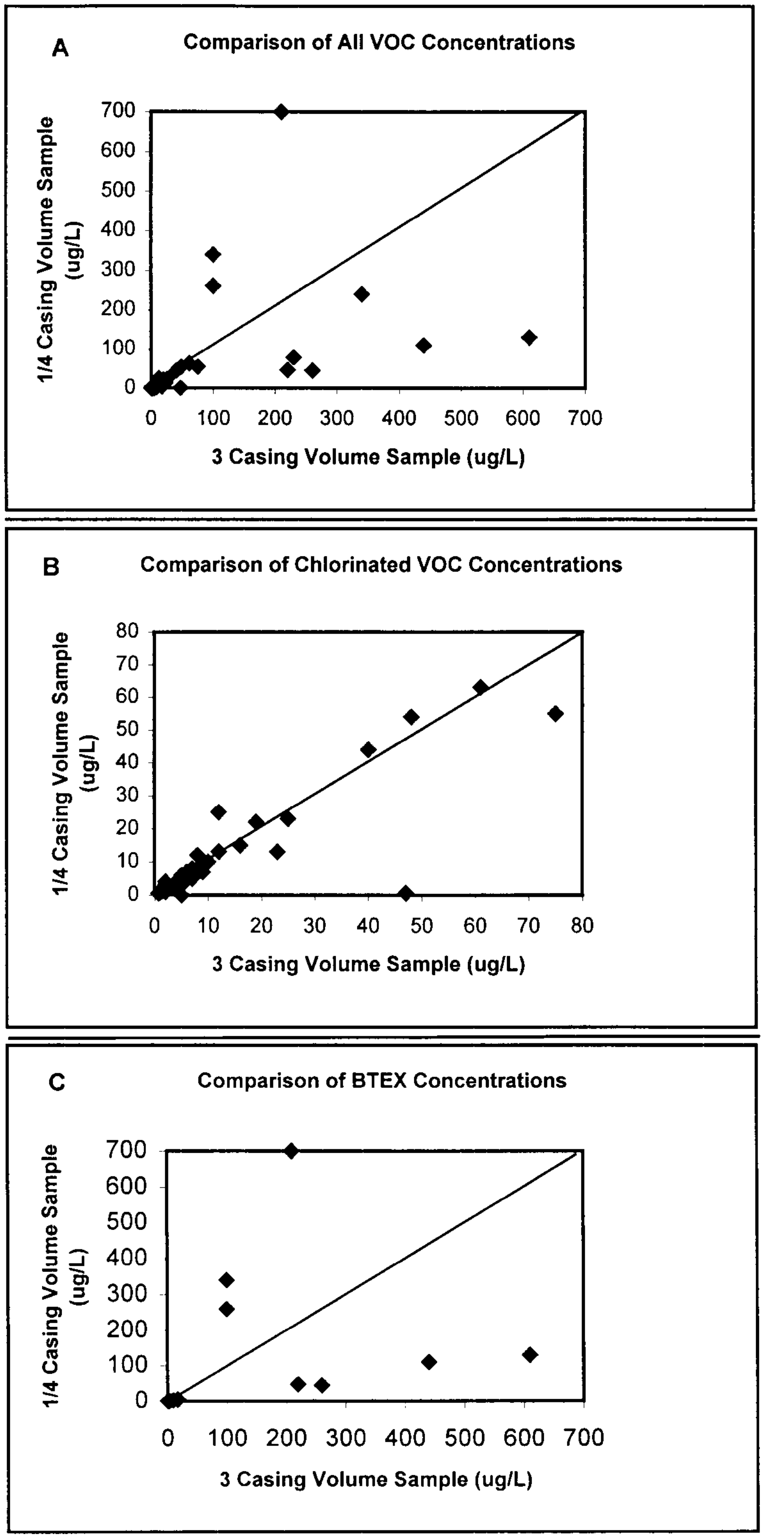

Figure 6: Comparison of VOC concentrations in samples collected after the purging of 0.25 casing volume to those collected after 3 casing volumes.

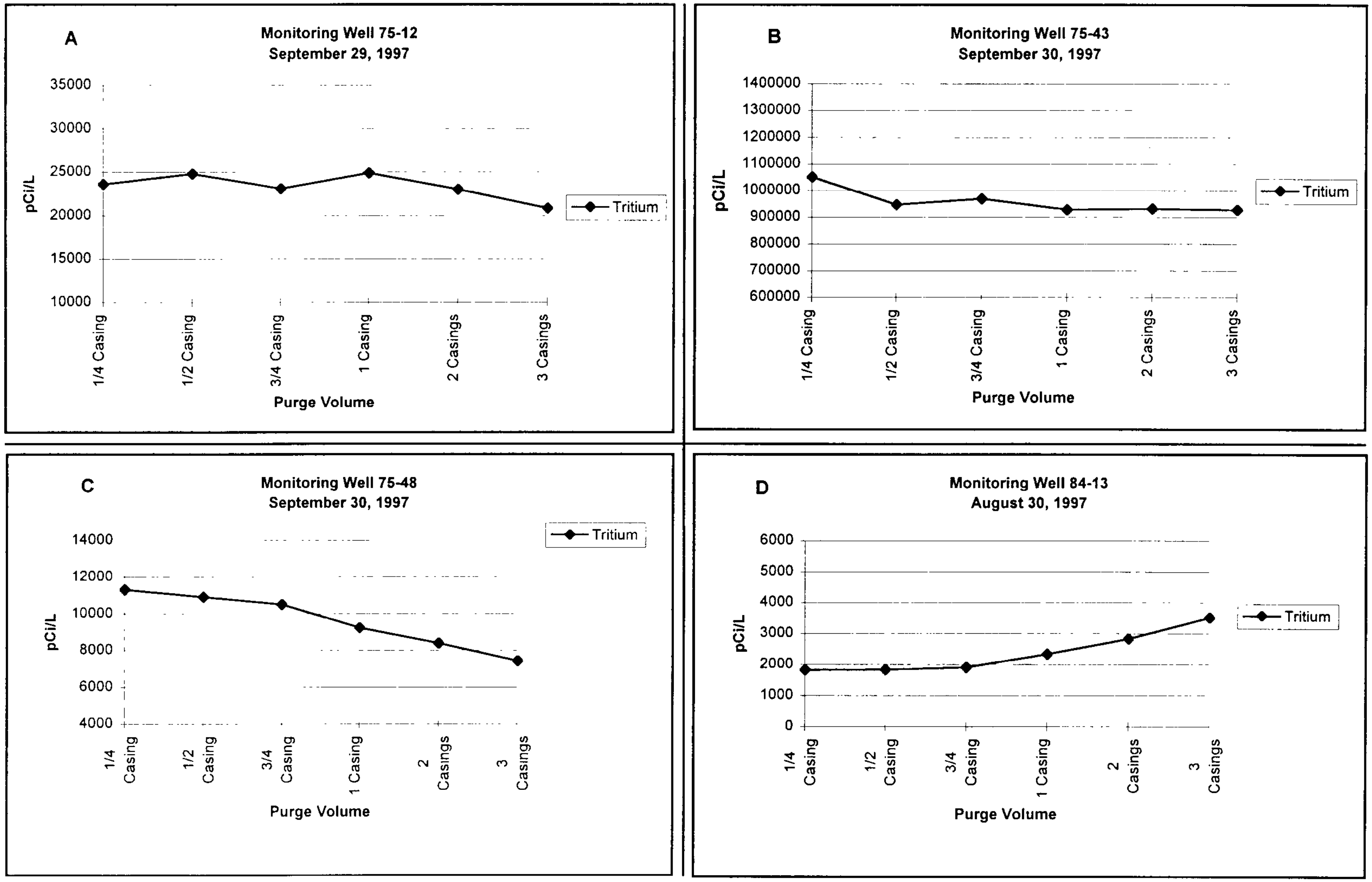

Figure 7. Comparison of tritium concentrations in four monitoring wells: A, B, and C) Wells located downgradient of the HFBR facility; and D) Well 84-13 located downgradient of the BMRR. All wells sampled using electrical submersible pump positioned within three feet of the water table.

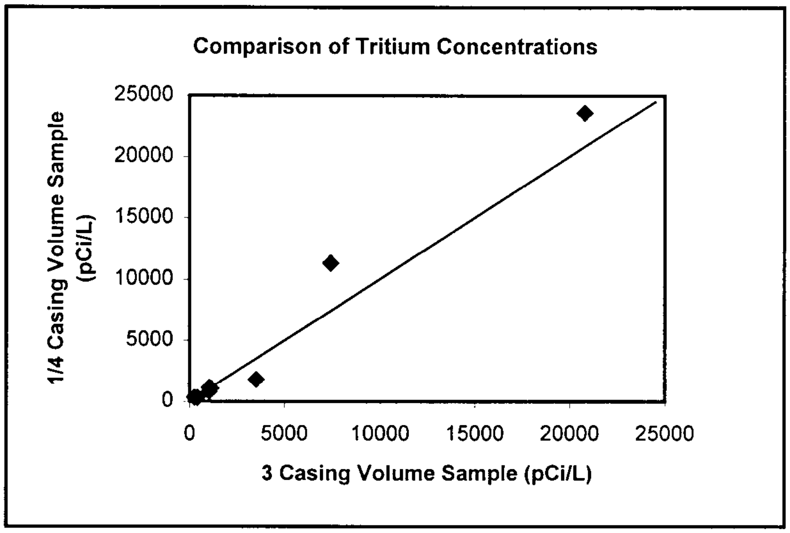

Figure 8: Comparison of tritium concentrations in samples collected after puring 0.25 casing volume to those collected after purging 3 casing volumes.

After an initial pilot program to field-test the new low-purge volume sampling technique, the procedure was fully adopted by BNL in April 1999. The revised BNL Monitoring Well Sampling Procedure is presented in Appendix D. The new sampling protocol is based upon the following conditions:

- Dedicated bladder pumps are installed in all wells that are routinely monitored. Dedicated pumps eliminate disturbing the water column above the screen zone during pump installation, and the need to decontaminate sampling equipment. Dual pumping systems (i.e., gas displacement pump/bladder pump or electrical submersible pump/bladder pump combinations) will no longer be used to purge and sample wells.

- Low purge rates and purge volumes, combined with the high water transmitting properties of the Upper Glacial aquifer, are likely to result in very small zones of influence (or capture) for the bladder pumps. Therefore, for wells screened below the water table, screens should be no more than ten feet in length and sample pumps should be positioned at the screen's mid-point. For wells with longer screened sections (e.g., potable well field sentinel wells with 20 foot screens), the installation of two dedicated pumps (an upper and lower screen zone pump) should be considered. If sampling water close to the water table is desired (i.e., for collecting groundwater samples in water table wells positioned close to tritium source areas such as the HFBR and BMRR), the sample pump intake must be carefully repositioned within two to three feet of the water table before purging begins.

- To ensure that concentration data from different sample times are comparable, the sample pump should remain either in a fixed position within the screened zone or carefully repositioned to the same relative position each time that a well is sampled.

- Purge rates will be maintained at approximately 0.25 gpm (~1 liter per minute).

- Sampling can take place following the removal of a (minimum) purge volume that is equivalent to two-times the calculated volume of the pump and discharge tubing, and the stabilization of water quality parameters over three consecutive readings taken approximately two minutes apart.

- One-quarter casing volume will be the maximum purge volume for most wells. To achieve water quality stabilization, final purge volumes may be slightly higher in some shallow wells where the minimum purge volume of two-times the calculated volume of the pump and discharge tubing is close to 0.25 casing volume (typically 0.15 to 0.2 casing volume).

- Field water quality parameters (e.g., pH, specific conductance, redox, dissolved oxygen and turbidity) will be monitored using a single multi-channel water quality meter and flow-though cell. If one or more of these parameters do not stabilize by the time 0.25 casing volume has been removed, purging will be discontinued, samples will be collected, and attempts to reach stabilization will be documented.

Estimated Cost Savings

Advantages of low purge volume sampling include significant long-term cost savings by improving sampling program efficiency and minimizing the amount of purge water that needs to be handled, containerized, managed, and treated or otherwise properly disposed of. Compared to the current three casing volume purge method, a >92 percent reduction in purge water volume will be realized. During 1999, it is estimated that groundwater sampling activities associated with the Environmental Restoration Program will generate 144,000 gallons of contaminated purge water (with concentrations > NYS AWQS) that will have to be managed and treated (Table 7). It is estimated that the Facility Groundwater Surveillance Program will generate an additional 5,700 gallons of contaminated purge water. The costs associated with the management and treatment of this purge water could be as much as $557,000 depending upon whether on-site or off-site water treatment options are utilized. Implementation of the proposed sampling protocol will result in the purging of approximately 12,000 gallons of water for the year, and result in savings of up to $512,000 in waste management and treatment costs.

Preliminary estimates on savings in labor costs associated with well sampling indicate that the proposed maximum one-quarter casing volume purge method will result in saving approximately 40 minutes for shallow to middle Upper Glacial aquifer wells, and sixty to ninety minutes for deep Glacial and Magothy aquifer wells (Table 8). For 1999, it is estimated that approximately $160,000. in labor costs can be saved by using the low purge volume method.

Conclusions

The comparison of analytical data from samples collected at multiple purge water intervals indicates that representative groundwater samples can be collected without purging large amounts of water. Results of this study indicate that most water quality parameters stabilized prior to or following the removal of 0.25 well casing volume. In ten of fifteen (67 percent) of well sampling events where one or more VOCs were > 5 μg/L, and all seven wells with tritium concentrations >1,000 pCi/L, contaminant concentrations stabilized within ±20 percent (over three consecutive samples) following the removal of 0.05 to 0.25 well casing volume. In several cases, initially stable VOC and tritium concentrations became less stable as more water was purged from the wells. Additionally, significant differences in contaminant concentrations were observed in samples collected from the same well during different sample periods.

The results of this study indicate that variations in plume concentrations and plume position relative to a monitoring well's location, screen position and pump position have a far greater affect on contaminant concentrations than the amount of water purged from the well prior to sampling. If the screened section of a well intercepts a contaminant plume that is narrow or thin, excessive pumping could cause mixing with either cleaner or more contaminated portions of the aquifer, resulting in concentrations which fail to stabilize or that become less stable as more water is purged. Furthermore, pump placement and pumping rates must be standardized to ensure that concentration data from different sample periods are comparable.

Brookhaven National Laboratory
Low Purge Volume Groundwater Sampling Study
Estimated Waste Management Cost Savings for CY 1999 Using Low Purge Volume Method(a)
Table 7

Environmental Restoration Program

Waste	3 Casing Volume	Low Purge Volume	On-site Treatment Option(c)		Off-Site Treatment Option		Est. Cost Savings Low Purge Volume Method
			3 Casing Vol.	Low Purge	3 Casing Vol.	Low Purge	
Strontium-90	27,000 gal.	2,200 gal.	$81,000	$6,500	$460,000	$37,400	$74,500 - $422,600
Tritium	2,000 gal.	160 gal.	$16,000	$1,300	$24,000	$2,000	$14,700 - $22,000
VOCs	115,000 gal.	9,200 gal.	$29,000	$2,300	-----	-----	$26,700
Total	144,000 gal.	11,560 gal.	$126,000	$10,100	$484,000	$39,400	$115,900 - $471,300

Environmental Monitoring Program

Waste	3 Casing Volume	Low Purge Volume	On-site Treatment Option		Off-Site Treatment Option		Est. Cost Savings Low Purge Volume Method
			3 Casing Vol.	Low Purge	3 Casing Vol.	Low Purge	
Tritium	3,600 gal.(b)	290 gal.	$28,000	$2,300	$43,000	$3,500	$25,700 - $39,500
VOCs	5,700 gal.	450 gal.	$1,500	$100	-----	-----	$1,400
Total	5,700 gal.	450 gal.	$29,500	$2,400	$43,000	$3,500	$27,100 - $40,900

Totals for Both Programs

Total	149,700 gal.	12,010 gal.	$155,500	$12,500	$527,000	$42,900	$143,000 - $512,200

(a): Assumes that all water containing VOCs or radionuclides above NYS Drinking Water Standards is to be treated/disposed of. Estimate includes most waste management (i.e., containerization, transport, and storage), analyses, treatment and labor costs.

(b): This water would also have to be treated for VOC contamination, and is part of the estimated 5,700 gallons for VOC treatment.

(c): On-site treatment option for strontium-90 is currently under evaluation

Brookhaven National Laboratory
Low Purge Volume Groundwater Sampling Study
Estimated Sampling Personnel Cost Savings for CY 1999 Using Low Purge Volume Method
Table 8

Environmental Restoration Program

Aquifer	Number of Wells	Sampling Events	Low Purge Method Average Time Saved	Total Hours Saved	Estimated Cost Savings Low Purge Method (c)
Shallow Glacial	172	688	40 min. (a)	460 hrs.	$36,800
Middle Glacial	106	424	40 min. (b)	283 hrs.	$22,600
Deep Glacial	173	692	55 min. (b)	634 hrs.	$50,750
Very Deep Glacial/ Magothy	28	112	80 min. (b)	149 hrs.	$11,950
Total	479	1,916	-----	1,526 hrs.	$122,100

Environmental Monitoring Program

Aquifer	Number of Wells	Sampling Events	Low Purge Method Average Time Saved	Total Hours Saved	Estimated Cost Savings Low Purge Method (c)
Shallow Glacial	131	493	40 min. (a)	330 hrs.	$39,600
Total	131	493	-----	330 hrs.	$39,600

Totals for Both Programs

Total	610	2,409	-----	4,480 hrs.	$161,700

(a): Assumes purging using dedicated bladder pumps with typical 1 to 2 gpm purge rate.

(b): Based upon a comparison of using a dedicated bladder pump alone to the former method of purging deeper wells using an electrical submersible pump at a rate of 5 gpm followed by collecting samples with a bladder pump, and time required for decontamination of the electrical submersible pump.

(c): Labor cost estimate assumes sampling team of two persons, with hourly sampling team rates of $80 for ER Program and $120 for EM Program.

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