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Surfactant-Enhanced Aquifer Remediation at the Portsmouth Gaseous Diffusion Plant

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DISCLAIMER

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Introduction and Objectives

Many DOE facilities are situated in areas of sand and gravel which have become polluted with dense, non-aqueous phase liquids or DNAPLs, such as chlorinated solvents, from the various industrial operations at these facilities. The presence of such DNAPLs in sand and gravel aquifers is now recognized as the principal factor in the failure of standard groundwater remediation methods, i.e., "pump-and-treat" operations, to decontaminate such systems (Mackay and Cherry, 1989).

The principal objective of this study, as stated in the Statement of Work of the contract (DE-AC21-92MC29111), is to demonstrate that multi-component DNAPLs can be readily solubilized in sand and gravel aquifers by dilute surfactant solutions. The specific objectives of the contract are:

1. to identify dilute surfactants or blends of surfactants in the laboratory that will efficiently extract multi-component DNAPLs from sand and gravel aquifers by micellar solubilization (Phase 1);
2. to test the efficacy of the identified surfactants or blends of surfactants to solubilize *in situ* perchloroethylene (PCE) and trichloroethylene (TCE) DNAPLs by the injection and the subsequent extraction through an existing well or wells at a government-owned contaminated site (Phase 1); and
3. to demonstrate the full-scale operation of this remedial technology at a government-owned contaminated site (Phase 2).

Specific objective number 1 has been completed and reported to DOE (INTERA, 1995). However, the results of the test referred to in specific objective number 2, conducted at Paducah Gaseous Diffusion Plant in 1994, were inconclusive. Following this first test, it was decided by DOE and INTERA to move the test site elsewhere due to difficulties with obtaining core samples of the sand and gravel aquifer containing the DNAPL and with ascertaining the location of the DNAPL relative to the injection well. The solubilization test at the Portsmouth Gaseous Diffusion Plant (PORTS) will constitute the second test of Phase 1 of this contract.

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The goal of the interwell DNAPL solubilization test ("surfactant flood") is to test the efficacy of a micellar-surfactant solution to solubilize the DNAPL *in situ.* The test should also demonstrate the ability of Surfactant-Enhanced Aquifer Remediation (SEAR) to enhance the efficiency of conventional pump-and-treat systems in the remediation of DNAPL contamination. SEAR technology uses non-toxic biodegradable surfactants to enhance the solubility of DNAPLs in the subsurface. It is anticipated that the concentrations of trichloroethylene (TCE) and other chlorinated solvents removed during the surfactant flood will be at least an order of magnitude higher than those achieved by simple pump-and-treat operations.

The Field Test Site

The surfactant flood is be undertaken at the X701B site at Portsmouth Uranium Enrichment Plant (PORTS) using 62G as the injection well and BW2G as the extraction well (see Figure 1). The X701B area at PORTS originally contained a holding pond which received liquid wastes, including chlorinated solvents, from industrial operations elsewhere on site.

The X701B area is underlain by lacustrine silts and clays and by deeper alluvium. These Quaternary units lie unconformably on the Sunbury shale which, in turn, overlies the Berea sandstone. The geologic and hydrologic properties of the X701B area are shown in the table below and the hydrostratigraphy of the test site is shown in Figure 2 of this proposal.

Formation	Lithology	Hydraulic Conductivity [cm/s]	Approximate Average Thickness [m]
Minford	Clay	8.1 E-08	4.6
Minford	Silty clay	1.5 E-06	3.0
Gallia	Sand	E-02 to E-03	1.5
Sunbury	Shale	K_v =E-08	3.0
Berea	Sandstone	5.6 E-05	9.1
Bedford	Shale	2.1 E-05	30

The Gallia alluvium was deposited by the ancient Portsmouth river which left abandoned alluvial and fluvio-lacustrine deposits across the PORTS site. Hydraulic conductivities in the Gallia are of the order of 10^{-2} to 10^{-3} cm/s. The Gallia is underlain by the Sunbury shale which is estimated to have a vertical hydraulic conductivity of the order of 10^{-8} cm/s. It is proposed using X701-62G as the injection well and X701-BW2G as the extraction well during the DNAPL solubilization test. Both wells are screened in the Gallia sand and gravel aquifer and are only 5 meters apart. They are shown in Figure 1.

Well BW2G has been producing free-phase DNAPL since at least 1988. The specific gravity of the DNAPL is approximately 1.4 and the viscosity is measured as 4 centipoise. The DNAPL is a multicomponent liquid composed of trichloroethene [TCE], tetrachloroethene [PCE] and a number of minor components including PCBs and 1,1-dichloroethene. The approximate composition of DNAPL from Pumping Well 1 at the X701B area is given in the table below:

Compounds Identified in DNAPL Sample	Quantity [g/L]	Notes
Trichloroethene	12	
Tetrachloroethene	3.6	exceeds initial calibration range
Perchloromethane	0.22	"carbon tetrachloride"
1,1-dichloroethene	0.034	
1,1,2-trichloro-1,2,2-trifluoroethane	1.6	[CFC-113], tentatively identified
1,1,1-trichloroethane	2.3	tentatively identified
1,1,2-trichloroethane	0.12	tentatively identified
toluene	0.028	tentatively identified
xylenes	0.060	tentatively identified
1,2,4-trimethylbenzene	0.080	tentatively identified
polychlorinated biphenyls	820 ug/g [0.08%]	identified as PCB-1254

It should be noted that the chemical analysis only identifies a small fraction of the DNAPL components since the DNAPL weighs about 1400 g. Thus, the listed quantities are probably significantly underestimated, in particular TCE.

The dissolution of this DNAPL by ground waters flowing through the Gallia has led to the development of a long plume of TCE and other components of the DNAPL. The extent of the TCE contamination during 1993 is shown in Figure 3. Recent measurements of TCE indicate that TCE concentrations at the perimeter fence have reached 800 mg/L.

Approach

Future work includes:

- ❑ PORTS site-specific training for INTERA's five-person field staff;

- collaboration with PORTS personnel in the field to collect soil cores from the Gallia aquifer for analysis at the State University of New York at Buffalo (SUNY);
- surfactant screening and other laboratory experiments at SUNY;
- tracer screening and selection at the University of Texas at Austin [UT];
- a pumping test to determine injection/extraction rates during the Fall of 1995;
- test design and permitting during the Winter of 1995-6;
- a partitioning interwell tracer test (PITT; see Jin et al., 1995) prior to the solubilization test to measure the interwell volume of DNAPL;
- an interwell DNAPL solubilization test (see Butler et al., 1995) to solubilize and recover DNAPL from the Gallia aquifer during the Spring of 1996;
- a second PITT, this one following the solubilization test, to measure the quantity of DNAPL remaining in the Gallia;
- analysis and interpretation of the test data; and
- a final report presenting the test results.

Benefits of Applying SEAR

The benefits of SEAR arise from the very high effective solubilities which can be obtained by using dilute surfactant solutions to "solubilize" NAPLs. Because of this enhanced solubilization, it is possible to accelerate the rate of NAPL removal from the subsurface, which in turn reduces overall operations and maintenance costs for any particular pump-and-treat facility. A further advantage of SEAR is that the technology can be superimposed on an existing pump-and-treat systems so that the infrastructure which is invested in the site can be used more efficiently in the future.

Acknowledgments

We appreciate the assistance of Keith Westhusing of DOE Laramie, our COR, in defining the scope of work for this phase of the project and the collaboration of our subcontractors: Dr. John C. Fountain of the State University of New York at Buffalo and Dr. Gary Pope of the University of Texas at Austin. The period of performance of this part of the contract is from August 1, 1995 to December 31, 1996.

References

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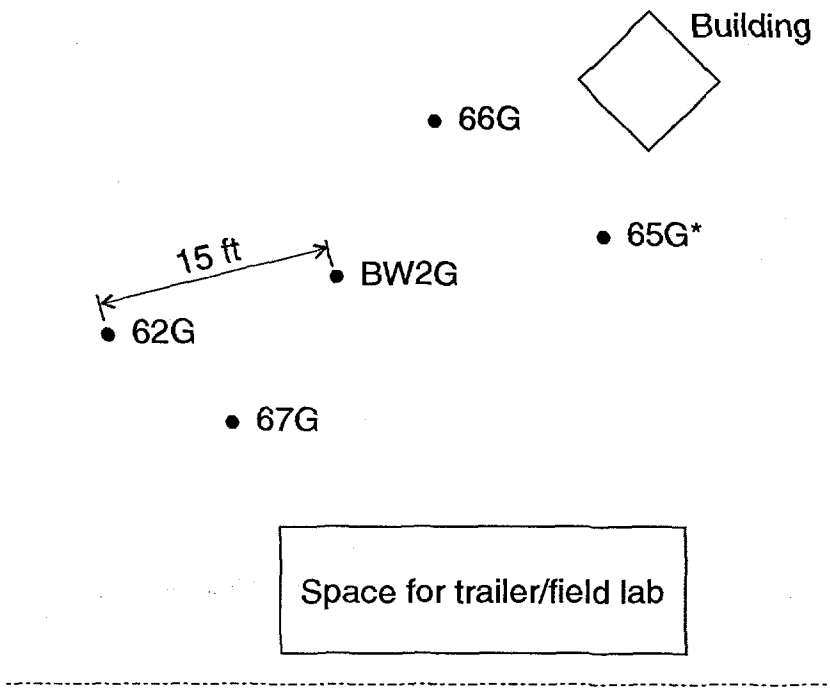


Figure 1 Site Map for the X701B Area, DOE Portsmouth

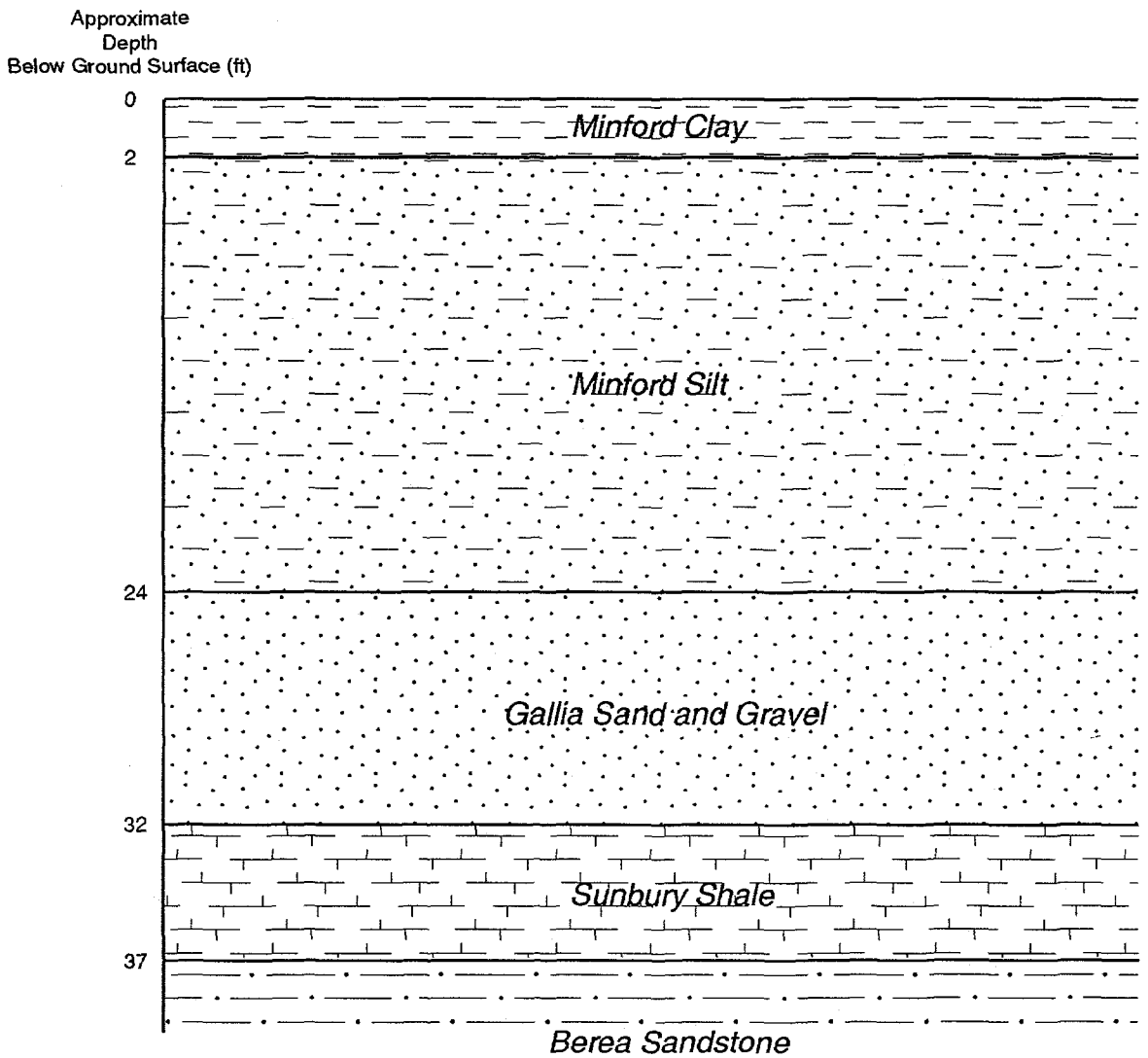
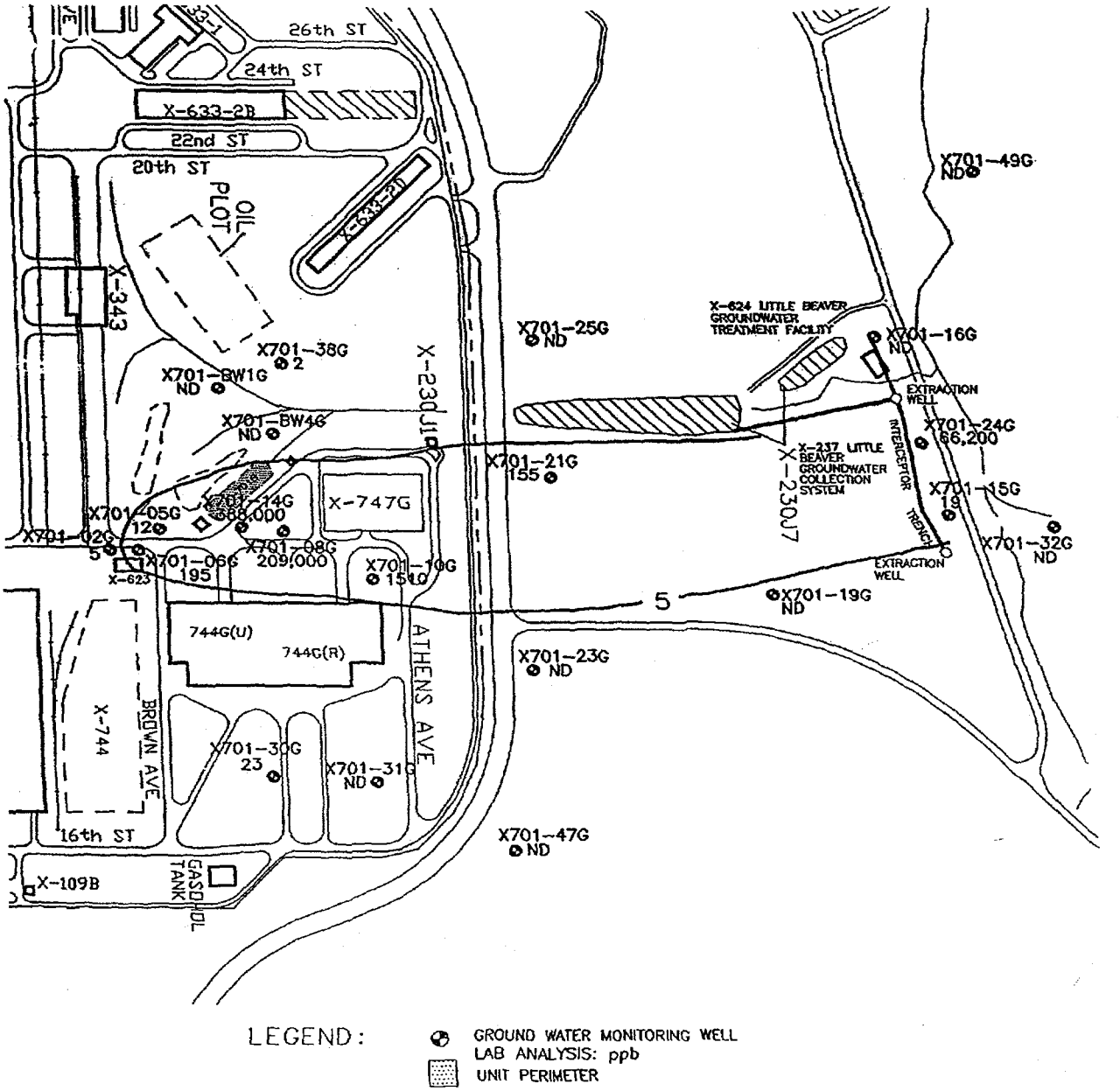


Figure 2 Hydrostratigraphy of the Proposed Test Site, X701B Area.



LEGEND: GROUND WATER MONITORING WELL
LAB ANALYSIS: ppb
UNIT PERIMETER

Figure 3 Extent of Trichloroethene Concentration 2nd Quarter 1993