EVALUATION OF PLUME CAPTURE ALTERNATIVES FOR A HETEROGENEOUS FLUVIAL AQUIFER AT PORTSMOUTH, OHIO

B. T. Hurst[1], S. C. Young, N.J. Williams, D. H. Barton, and D. J. Benton

INTRODUCTION

A three-dimensional groundwater model was developed for predicting the migration of the X-120 and X-749 TCE plumes at the Portsmouth Gaseous Diffusion Plant (PORTS). The model consisted of FRAC3DVS to predict groundwater flow and PTRAX, which couples to FRAC3DVS output, to predict groundwater solute transport. Model calibration and verification were based on hydraulic heads, base flow in Big Run Creek (the major local stream), and trichloroethylene (TCE) concentration data. The model was used to simulate the capture of TCE-contaminated groundwater by the X-120 horizontal well for six possible scenarios. The simulations suggest that the horizontal well will deliver a steady flow of approximately 3 gal/min, with an initial TCE concentration between 140 and 200 ppb. After approximately one and three years, the TCE concentration is predicted to decrease to less than 50 ppb and 10 ppb, respectively.

GROUND WATER SOLUTE TRANSPORT MODEL

To simulate contaminant transport at PORTS, a numerical ground water flow model was constructed using FRAC3DVS (Williams *et al.*, 1996) using K-zonations based on a sedimentological model. Solute transport was simulated using the particle tracking code PTRAX with the velocity field generated by the 3-D flow model to accurately model dispersivities in the range of 0.01 - 6.0 ft. There are two main purposes for performing solute transport at the X-120 and X-749 sites. First, the solute transport model is useful to predict the migration of the TCE plume through the ground water system and to determine when the plume will enter an environmental media that will facilitate public exposure to TCE. Second, this model will assist in selecting an effective remediation alternative for the site.

There are two major geologic features in the X-120/X-749 area that greatly effect the ground water flow, and thus the migration of the TCE plume. Construction activities have removed a significant amount of overburden material and used it to fill a drainage channel that was produced by a western stream and its tributaries in the X-120 area. Presumably, because the topography was leveled as part of preparations for future construction, the fill material was compacted during its installation. This produced the first major geologic feature of a low hydraulic conductivity channel in this portion of the model domain. The second geologic feature is a relatively high hydraulic conductivity zone in the central portion of the model domain, which is the resultant of a sand unit and a gravelly sand unit. The sand unit represents the sands and silts primarily associated with overbank deposits/levees and upper point bar deposits. The gravelly sand unit covers the largest area and likely represents a mixture of channel lag lower point bar deposits.

The ground water flow was calibrated with the April, 1995 water table survey composed of 95 water table measurements. The root-mean-square for the differences between the observed and predicted heads is 1.39 ft. The estimated base flow contributions to Big Run Creek, which runs along the eastern boundary of the model domain, was also used for model calibration. Weir data measured base flow contributions to equal

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[1] Environmental Consulting Engineers, Knoxville, TN , USA Phone: 615-691-3668; Fax: 615-691-0661; E-mail address for Mr. Hurst is "bhurst@ece.com".

7.2 gal/min which corresponds with the model predicted value of 5.1 gal/min. Results from both data sets suggest that the ground water flow model is properly calibrated.

PTRAX is a fast, three-dimensional particle tracking code capable of two- and three-dimensional simulations for grids based on an assortment of element types. After reading in a velocity file, PTRAX can delineate flow paths and/or simulate groundwater transport. Because its mathematics are based on triangles and tetrahedra, PTRAX can couple with virtually any velocity field. This capability is particularly valuable where a non-layered finite-element grid has been used to simulate flow through complex stratigraphy. In addition, because it uses distance as the variable of integration, PTRAX can simulate particle movements significantly faster than conventional particle tracking codes.

To ensure that PTRAX could accurately predict the migration of the TCE plume, it was necessary to perform history matching. Because of the limitations of the site characterization data and the TCE data base, history matching will focus on the general trends associated with the bulk movement of the TCE plumes during the last 39 years and on the TCE breakthrough curves from 1988 to 1995 for selected wells.

Because the distribution and the amount of spilled TCE is unknown and the plume sampling did not begin until 1988, there is insufficient data to realistically evaluate a numerical simulation of the evolution of the TCE plumes. Although the TCE data is insufficient to accurately characterize the three-dimensional structure of the X-120 and X-749 plumes, the data is sufficient to characterize the general configuration of the plumes. To evaluate the solute transport model, the assumption is made that the current plume configurations were caused by TCE spills that began 39 years ago at the Goodyear Training Center (X-120 area) and at the X-749 Landfill.

Appropriate FRAC3DVS and PTRAX runs were performed to simulate the evolution of the X-120 and X-749 plumes from January 1988 until September 1994. Simulations of the breakthrough curves began and ended with the plume as shown in Figure 1. These plumes are similar to the ones used for the Corrective Measures Study (CMS) study. The simulations included two flow fields in order to account for the installation of the low-K barriers and cap at the X-749 landfill in September 1991. As shown in Figures 2, the simulated and measured breakthrough curves for X-749-13G have consistent trends and have similar magnitudes. Overall, the results suggest that PTRAX provides a realistic and credible simulation of the transport processes at PORTS.

TCE PLUME CAPTURE ALTERNATIVES

Several remediation alternatives were studied to determine which one would remove the TCE plume, as shown in Figure 1a, from the X-120 and X-749 sites. Currently, a passive ground water collection system utilizing a horizontal well, placed in a natural ravine, that intercepts the X-120 branch of the TCE plume is being recommended for removal for this portion of the contamination. The collected contaminated ground water will be passed through a reactive media that will facilitate the breakdown of the TCE by reductive dehalogenation. If this media proves to effectively treat the ground water, then this media will in a large-scale in-situ funnel and gate system to remediate the X-749 plume. Two major geologic features in this area greatly effect the ground water flow, and thus the TCE migration.. These features are important in the decision making process because they, as well as the current position of the TCE plume, are major factors in selecting the location and type of remediation alternative to be implemented.

REMEDIATION OF X-120 TCE PLUME

A horizontal well, which is a passive ground water collection system, has been recommended for removal of TCE contaminated ground water in the X-120 area (ECE, 1995b). It is passive because the ground water flows into the well only due to the hydraulic gradients produced in the surrounding ground water system. Key design criteria for the horizontal well are its location, length, and head losses. Head losses need to be minimized to maximize the available hydraulic head to drive the ground water flow through the treatment facility. The length of the horizontal well affects the amount of ground water flow, which determine the amount of plume capture and the volume of contaminated ground water available for passing through the treatment media. The location of the horizontal well is important because it greatly impacts the ground water flow and TCE concentrations delivered to the testing facility.

Among the two most important variables required to properly design the well is delineation of the X-120 TCE plume and the hydraulic conductivity, K, field of the Gallia deposits near the TCE plume. Prior to the evaluation of the horizontal well's performance, the selection of the X-120 looked promising based on the high K values presented in Geraghty & Miller, 1989 and the plume configuration. Geraghty & Miller reported K values from 45 to 62 ft/day and previously depicted X-120 plumes like that in Figure 4 suggest a rather large and Gaussian-shaped plume with a midsection of about 1000 ppb.

As discussed in Williams *et al.*, 1996, the high-K values within the X-120 area are significantly lower than indicated by previous three-dimensional models. A crucial issue to the horizontal well performance is its location relative to the low-K channel. Given the relatively low Gallia K values, the horizontal well was designed to be as long as possible (1200 ft) without extending far into regions where TCE concentrations were less than 100 ppb. For maximum flow withdrawal, the well performance was simulated with a hydraulic head of 645 ft MSL (mean sea level). The 645 ft elevation represents the lowest head that could be maintained without desaturating the Gallia deposits.

Three TCE plume configurations were utilized for plume migrations simulations. The TCE plume utilized in the CMS study is the maximum possible plume based on the current TCE data summaries for the X-120/X-749 area. The ECE plume was developed based on a review of all TCE monitoring data (ECE, 1995a), a consideration for the low-K channel in the Gallia, and numerous TCE measurements from mini-piezometers installed via cone-penetrometers in April 1995. The Conservative ECE plume is a modification of the ECE plume based on the possibility that the X-120 TCE plume is not contiguous but a piecewise accumulation of several smaller TCE plumes caused by the spreading of contaminated soils by cut-and-fill activities at PORTS. All three plumes were assumed to reside uniformly throughout the Gallia layer. No DNAPL source terms were associated with any of the plumes.

The predicted performance of the horizontal well for the case of 645 ft hydraulic head and three points in time (0, 10, 30 years) is illustrated in Figure 3. The three scenarios have similar values for the removal of TCE plume's mass. After five years, all scenarios show a TCE removal percentage between 40 - 55%. After 30 years, all scenarios show a TCE removal percentage between 60% and 80 %. However, because of the almost 10 fold difference in the TCE mass among the plume configurations, the three scenarios have considerable differences in the predicted TCE concentrations for the X-120 treatment facility. As predicted, the majority of the residual TCE after 30 years resides in the low-K channel.

REMEDIATION OF X-749 TCE PLUME

One objective of the CMS was to evaluate various remediation technologies to determine which one would be best to remove the TCE plume from the X-749 area. Five alternatives were modeled using the 3-D groundwater solute transport model. Each alternative supplemented the current remediation efforts with use of a variety of containment and removal systems. The alternative chosen to implement at the X-749 site had to have a high removal efficiency of the TCE plume and be cost effective.

The alternative currently being pursued for implementation at the X-749 area is a funnel and gate collection system. This system is similar to the horizontal well being recommended for the X-120 in that it passively diverts the ground water. The funnel and gate terminology describes a system of barriers that will be used to alter the current flow of the ground water and direct it into treatment media. This treatment media, placed at several locations along the system, is designed to absorb the TCE. The media can be removed and disposed once it has reached its saturation limit or the plume has been remediated to acceptable limits.

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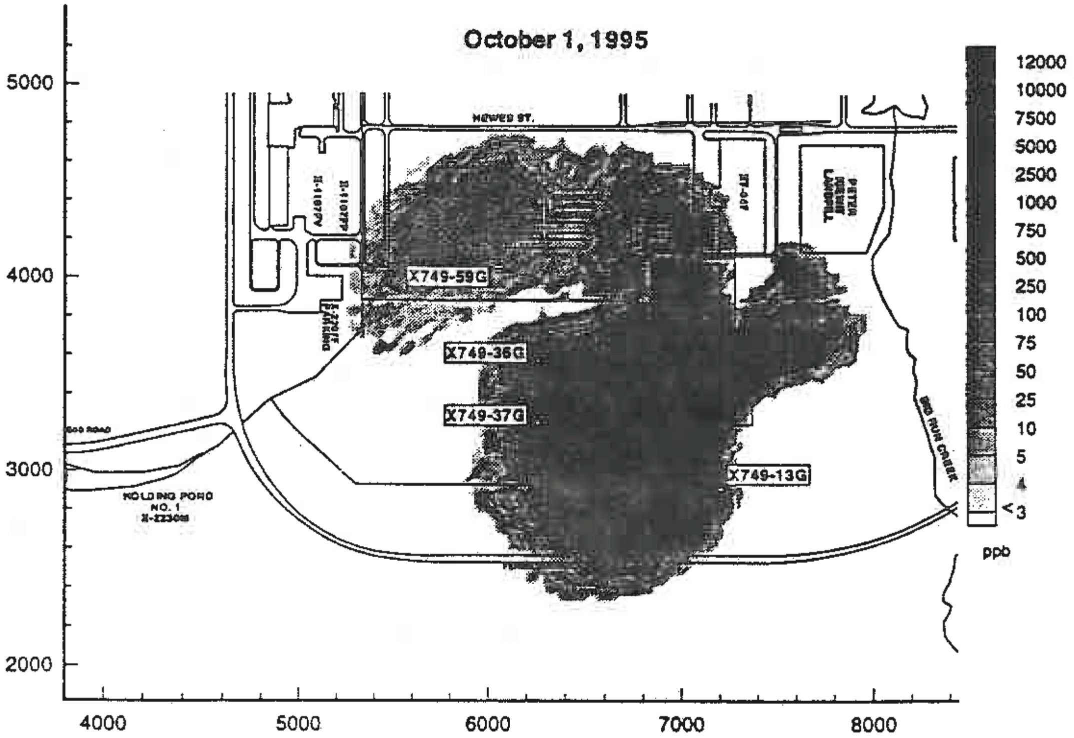


Figure 1. Final plume configuration for the simulated period of 1988 to 1994.

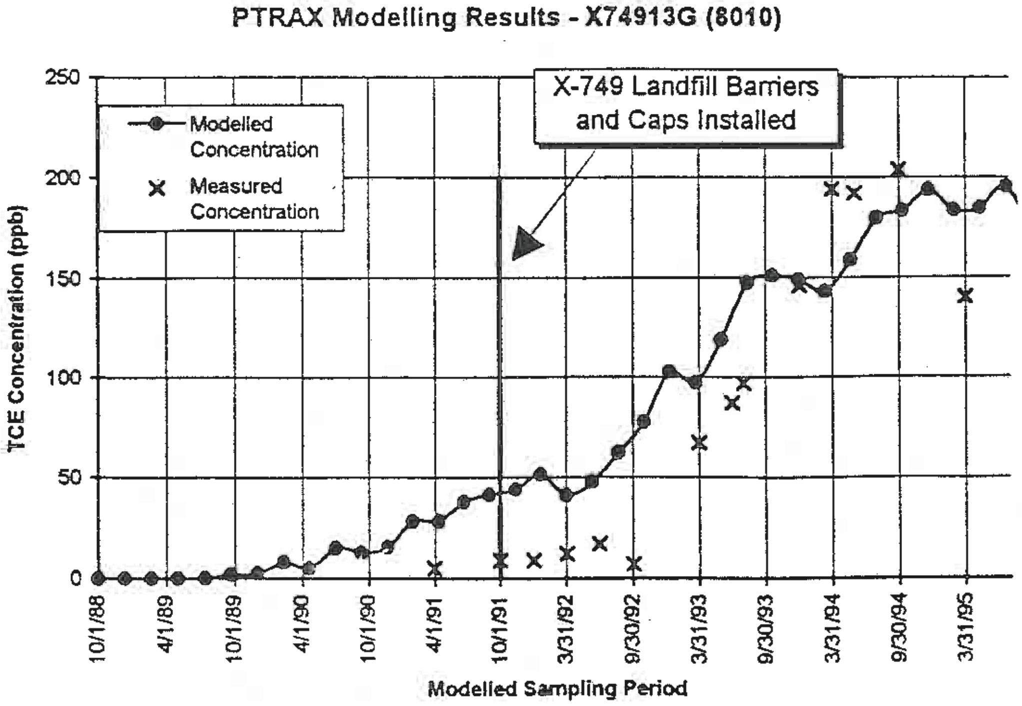
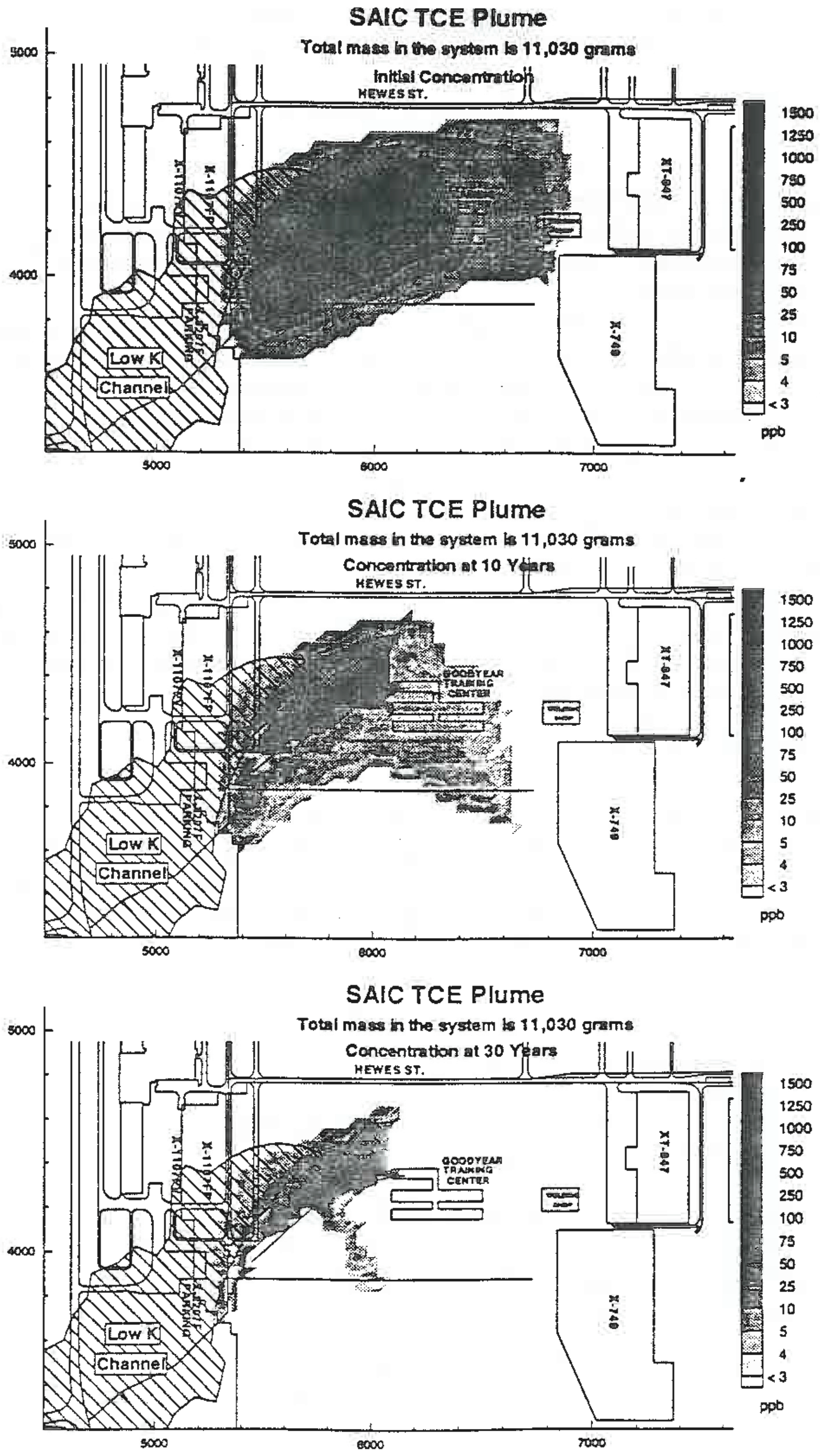


Figure 2. Simulated and observed breakthrough curve for X-749-13G.



SAIC TCE Plume
Total mass in the system is 11,030 grams
Initial Concentration

SAIC TCE Plume
Total mass in the system is 11,030 grams
Concentration at 10 Years

SAIC TCE Plume
Total mass in the system is 11,030 grams
Concentration at 30 Years

Figure 3. X-120 plume configurations for time periods 0, 10, and 30 years after installation of horizontal well.