Hydrogeologic Modeling at the Sylvania Corning FUSRAP Site – 13419

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ABSTRACT

A comparative groundwater hydrogeologic modeling analysis is presented herein to simulate potential contaminant migration pathways in a sole source aquifer in Nassau County, Long Island, New York. The source of contamination is related to historical operations at the Sylvania Corning Plant ("Site"), a 9.49-acre facility located at 70, 100 and 140 Cantiague Rock Road, Town of Oyster Bay in the westernmost portion of Hicksville, Long Island. The Site had historically been utilized as a nuclear materials manufacturing facility (e.g., cores, slug, and fuel elements) for reactors used in both research and electric power generation in early 1950s until late 1960s. The Site is contaminated with various volatile organic and inorganic compounds, as well as radionuclides. The major contaminants of concern at the Site are tetrachloroethene (PCE), trichloroethene (TCE), nickel, uranium, and thorium. These compounds are present in soil and groundwater underlying the Site and have migrated off-site. The Site is currently being investigated as part of the Formerly Utilized Sites Remedial Action Program (FUSRAP).

The main objective of the current study is to simulate the complex hydrogeologic features in the region, such as numerous current and historic production well fields; large, localized recharge basins; and, multiple aquifers, and to assess potential contaminant migration pathways originating from the Site. For this purpose, the focus of attention was given to the underlying Magothy formation, which has been impacted by the contaminants of concern. This aquifer provides more than 90% of potable water supply in the region.

Nassau and Suffolk Counties jointly developed a three-dimensional regional groundwater flow model to help understand the factors affecting groundwater flow regime in the region, to determine adequate water supply for public consumption, to investigate salt water intrusion in localized areas, to evaluate the impacts of regional pumping activity, and to better understand the contaminant transport and fate mechanisms through the underlying aquifers. This regional model, developed for the N.Y. State Department of Environmental Conservation (NYSDEC) by Camp Dresser & McKee (CDM), uses the finite element model DYNFLOW developed by CDM, Cambridge, Massachusetts. The coarseness of the regional model, however, could not adequately capture the hydrogeologic heterogeneity of the aquifer. Specifically, the regional model did not adequately capture the interbedded nature of the Magothy aquifer and, as such, simulated particles tended to track downgradient from the Site in relatively straight lines while the movement of groundwater in such a heterogeneous aquifer is expected to proceed along a more tortuous path.

This paper presents a qualitative comparison of site-specific groundwater flow modeling results with results obtained from the regional model. In order to assess the potential contaminant migration pathways, a particle tracking method was employed. Available site-specific and regional hydraulic conductivity data measured in-situ with respect to depth and location were incorporated into the T-PROG

module in GMS model to define statistical variation to better represent the actual stratigraphy and layer-heterogeneity. The groundwater flow characteristics in the Magothy aquifer were simulated with the stochastic hydraulic conductivity variation as opposed to constant values as employed in the regional model.

Contaminant sources and their exact locations have been fully delineated at the Site during the Remedial Investigation (RI) phase of the project. Contaminant migration pathways originating from these source locations at the Site are qualitatively traced within the sole source aquifer utilizing particles introduced at source locations. Contaminant transport mechanism modeled in the current study is based on pure advection (i.e., plug flow) and mechanical dispersion while molecular diffusion effects are neglected due to relatively high groundwater velocities encountered in the aquifer. In addition, fate of contaminants is ignored hereby to simulate the worst-case scenario, which considers the contaminants of concern as tracer-like compounds for modeling purposes. The results of the modeling analysis are qualitatively compared with the County's regional model, and patterns of contaminant migration in the region are presented.

INTRODUCTION

The lithology and associated hydrogeologic characteristics of heterogeneous aquifer systems are often lumped into a single hydrogeologic unit to simplify evaluation of fate and transport through the aquifer. This simplification is generally regarded as a necessary step in systems that are identified by interbedded materials that have no obvious lateral continuity. A numerical model can then be created using one or more, large scale hydrogeologic units to define the aquifer as lithologic material types, which are aggregated into laterally and vertically extensive aquifers with uniform characteristics. The simplified aquifer is then simulated and generally calibrated by adjusting input parameters until measured and predicted water levels are in close agreement. Another comparison that can be made during model calibration is to simulate particle pathlines and compare them to the longitudinal distribution of a contaminant plume, providing that a plume exists and that its distribution is understood well enough to be useful in this regard. The problem with this approach is that particle pathline tracking in a simulated aquifer will generally result in particle paths that move in a quasi-straight line from their point or origin to a downgradient sink (i.e., well, drain, river or general head boundary). This means that while the particle pathline(s) may give an indication of the centerline of transport it provides no indication of the deflection of particles as they migrate through the heterogeneous aquifer. This phenomenon was recognized as a potential deficiency in the development of a groundwater flow model for the Magothy Aquifer in Long Island, NY. In particular, when trying to use the regional flow model to identify sites for the placement of future monitoring wells.

DESCRIPTION

The TPROGS geostatistical program (Carle, 1999) was utilized to evaluate the reliability of particle pathlines predicted using a uniform aquifer simulation and to compare them to pathlines predicted using each of several T-PROGS developed aquifer "realizations". The evaluation was undertaken to provide more realistic locations for monitoring wells in the absence of a calibrated fate and transport model. The evaluation was conducted using the following steps:

1. Apply a simplistic groundwater flow model
2. Simulated particle pathlines from source areas downgradient to groundwater sinks
3. Applied T-PROGS program to develop statistically based aquifer “realizations”
4. Simulated particle pathlines using each of 10 realizations

The following subsections provide a description of each task and a brief summary of results.

Apply a Simplistic Groundwater Flow Model

The geology of western Long Island is widely known and is comprised of a basal Lloyd Aquifer overlain by the Raritan Clay aquitard. This aquitard effectively separates the deep Lloyd Aquifer from the overlying Magothy Aquifer, which gradually fines from deep to shallow, and ultimately the upper and lower glacial units at the surface. The aquifer of interest in this investigation is the Magothy Aquifer, which is a sole source aquifer for Long Island that has been thoroughly investigated. Both large scale regional models and more site-specific groundwater models including the Magothy Aquifer are known to exist and the Magothy Aquifer, in the vicinity of the Site, is generally simulated as a single hydrogeologic unit, albeit one with multiple model layers, with consistent hydrogeologic properties throughout. The steady-state model developed for this investigation is a site-specific MODFLOW (Harbaugh, et al, 2000) model developed using a similar but refined finite-difference grid and boundary conditions predicted using an existing regional groundwater model (NYSDEC, 2003). Hydrogeologic properties applied to the regional model in the area of the Site are summarized in Table I and an oblique view of the regional aquifer system is represented in Figure 1.

Table I: Hydraulic properties used to describe regional model aquifer.

Material Type	K_h (ft/day)	K_v (ft/day)
Upper Glacial	200	20
Lower Glacial	35	0.6
Upper Magothy	40	0.7
Lower Magothy	125	1.25

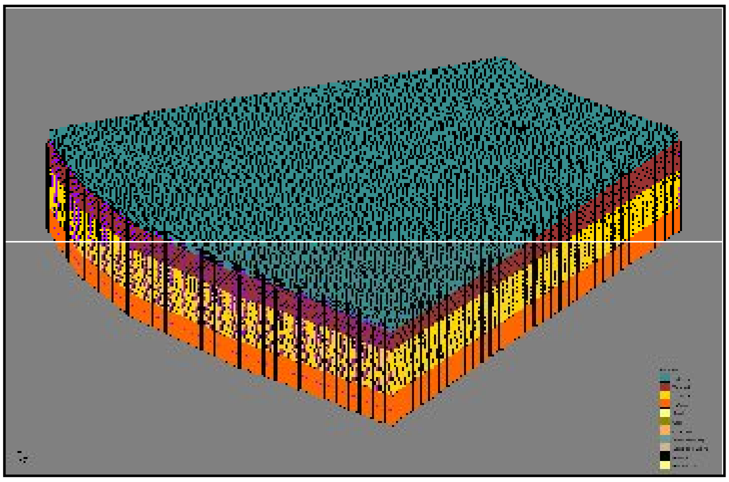

Figure 1: Oblique view of aquifer material types applied to regional model.

Simulate Particle Pathlines in Homogeneous Magothy Aquifer

The screening level model developed using the existing regional model (NYSDEC, 2003) was not calibrated during this phase of the investigation but was used to predict water levels throughout the site-specific model domain. While the lateral and vertical distribution of predicted water levels has not been calibrated the flow model is largely controlled by the boundary conditions predicted by the regional model and predictions are not expected to be dramatically different and similarly reliable. Calibration will be conducted as part of model refine in a later phase of model development. The MODPATH model (Pollock, et al, 1994) was used to simulate the migration of particles from upgradient Site to identify locations suitable for monitoring well placement. MODPATH simulations indicate that particles would migrate in a quasi-straight line from the point of initiation to the extraction wells without any lateral deviation from a direct course (Figure 2 and Figure 3). Without a transport simulation, the predicted particle paths offer little insight into the effect of the heterogeneous aquifer on contaminant migration.

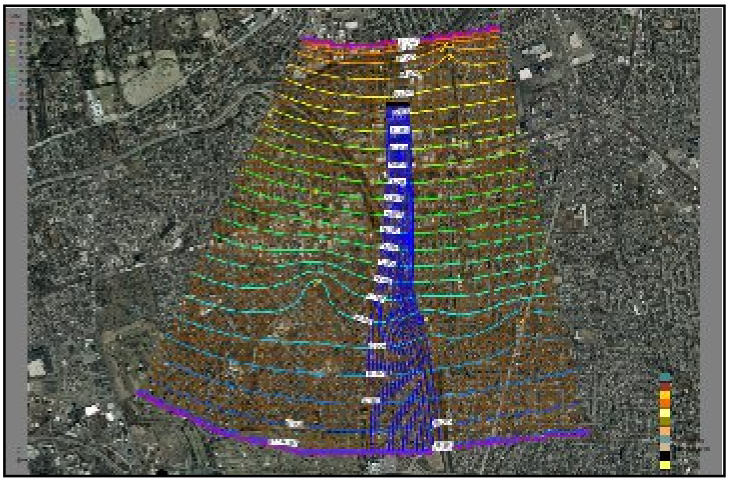

Figure 2: Plan view of particle paths simulated using regional model.

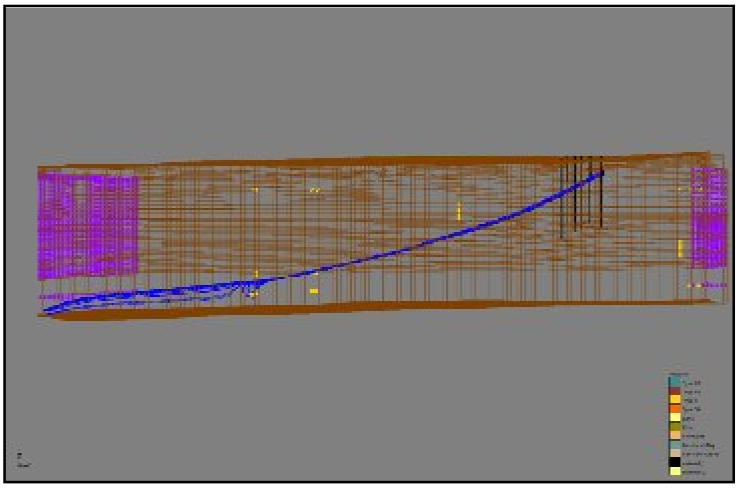

Figure 3: Cross section view of particle paths simulated using regional model.

Applied T-PROGS using Borehole Data to Develop Aquifer "Realizations"

In contrast to defining the Magothy Aquifer as a single uniform material type, the T-PROGS program (Carle, 1999) was used to develop a heterogeneous, statistically based aquifer that is developed using existing borehole information. Borehole data was generalized into each of several distinct lithological material types using boring log descriptions and recorded elevations. This information was then imported into the GMS to provide much of the input data required by the T-PROGS program. The T-PROGS program then performed transition probability geostatistics to generate multiple, equally probable models of aquifer heterogeneity. The program was used to generate a total of ten aquifer material sets, which are statistically similar, based on the likelihood of material types occurring adjacent to one another as defined by the borehole information. These ten material sets were each used to create input data for the MODFLOW groundwater model, the results of each then were used to simulate particle pathlines. Hydrogeologic properties applied to the T-PROGS developed model in the area of the Site are summarized in Table II and an oblique view of one T-PROGS aquifer system is represented in Figure 4.

Table II: Hydraulic properties used to describe model aquifer developed using T-PROGS.

Material Type	K_h (ft/day)	K_v (ft/day)
clay	0.0001	0.00001
sand	40.0	0.7
sand and clay	0.01	0.001
sand and gravel	35.0	0.6
silty sand	0.1	0.01

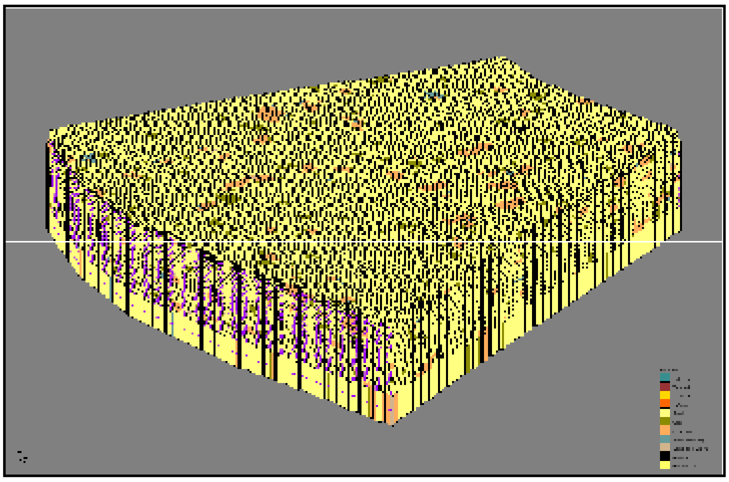

Figure 4: Oblique view of material types developed using T-PROGS and borehole data.

Simulate Particle Paths for Each of Ten "Realizations"

The resulting particle pathline tracks in the heterogeneous aquifer realizations offered insight into contaminant transport that was not obvious from evaluating pathlines simulated in the homogeneous aquifer. Pathlines developed using the T-PROGS developed aquifer realizations suggested a more tortuous route from the source area to downgradient sinks. The lateral extent of the particle pathlines tend to migrate somewhat from the average as they move downgradient and while most pathlines tend to move in the same general direction as the average pathlines, some show slight lateral deviations from the average and significant vertical deviations from the average. Also, the density of the heterogeneous aquifer pathlines generally tends to be highest right around the average pathlines and is less further from the average. The plan view and cross section view of particle pathlines from one of the T-PROGS realizations is illustrated in Figure 5 and Figure 6.

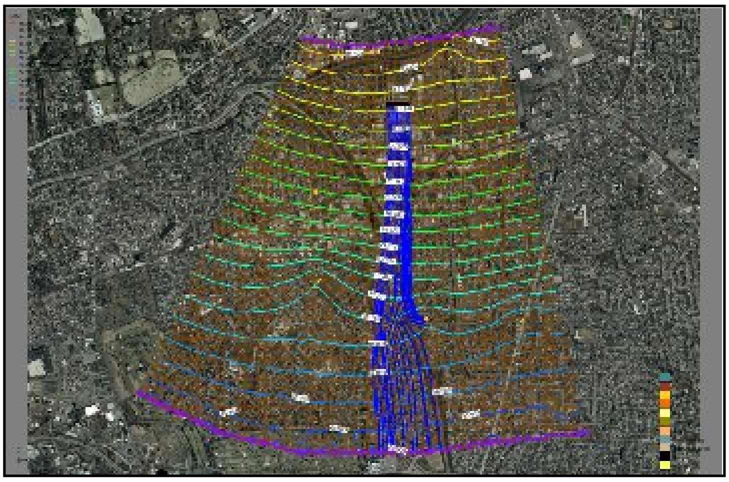

Figure 5: Plan view of particle paths simulated using T-PROGS aquifer realization.

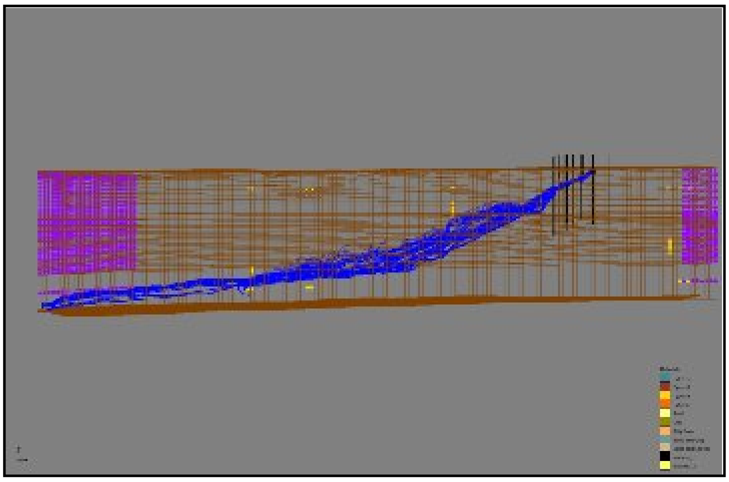

Figure 6: Cross section view of particle paths simulated using T-PROGS aquifer realization.

DISCUSSION

A comparison of particle pathlines from the heterogeneous T-PROGS developed aquifer realizations and the average aquifer indicates that generalized aquifer provides an over-simplification of particle migration. This is because of the tortuous path that simulated particles would migrate in the T-PROGS simulation as opposed to the quasi-straight path that particles would migrate in the homogeneous aquifer simulation. If a fate and transport model were being developed as part of this investigation, this spreading effect would be seen as hydrodynamic dispersion but, the degree to which would be dictated by the magnitude of the hydrodynamic dispersion coefficient. However, if only a flow model were being developed this spreading effect would not be realized by evaluating the simulated migration of particles. In the case of the Site, the development of a screening level model to locate future monitoring wells was a critical step in developing the offsite Remedial Investigation. The simulations developed using T-PROGS showed that the core of the contaminant plume likely spread laterally and even more so vertically because of the heterogeneity of the aquifer system. This distribution was more broadly dispersed further from the source and then narrowed again closer in toward the extraction wells. Without a calibrated transport simulation, particle simulation of uniform aquifer system has limited use.

CONCLUSIONS

Particle pathline simulations were developed using an aquifer with average hydrogeologic properties and again using several statistically based aquifer realizations. Simulated pathlines indicated that the more tortuous pathlines developed in the statistically based aquifer simulation show some lateral deviation from the average and a much greater vertical deviation from the average than would otherwise be noted. The screening level MODFLOW and MODPATH models developed for this FUSRAP project and used to locate monitoring wells showed a more realistic set of result and a broader vertical contaminant distribution than would otherwise be realized. Without a transport model the use of a statistically based program like TPROGS should be considered for pathline simulation in a heterogeneous aquifer.

REFERENCES

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