MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

INTEROFFICE COMMUNICATION

February 18, 2004

TO: Sybil Kolon, Project Manager, RRD, Jackson District

FROM: Rick Mandle, Groundwater Modeling Specialist, RRD, Lansing

SUBJECT: Review of Pall-Gelman Model of Capture Effectiveness of Evergreen System

The Groundwater Modeling Program has completed its review of the model used to evaluate hydraulic capture of the Evergreen System at the Pall-Gelman site. The model was developed by Fishbeck, Thompson, Carr & Huber, Inc. (FTC&H) of Kalamazoo, Michigan. The purpose of this model was to evaluate the capture effectiveness of the Evergreen System extraction wells with emphasis on the Allison Extraction well No. 1 (AE-1). On the basis of model simulations, FTC&H determined that pumping wells LB-1 and 2 at a combined rate of 175 gallons per minute (gpm) and AE-1 at a rate of 25 gpm are adequate to contain the contaminant plume in the D aquifer in this area.

In addition to re-running the numerical model, three model reports were reviewed to complete the review of the model. These reports are dated February 21, 2002; August 21, 2002; and November 18, 2002. In the model simulations described in these reports, it was assumed that groundwater contamination is restricted to the D aquifer and there is no contamination in the E aquifer that requires containment and treatment since, at the time of model development, the extent of the groundwater contamination in the E aquifer was not known.

Model Conceptualization and Assumptions

The components of the model that will have the greatest impact on simulation results will be the representation of the subsurface geology (model layering and thicknesses), the hydraulic conductivity of the different model layers, and the hydraulic gradients through the area of concern.

The conceptualization of the hydrogeology at the site is summarized in the February 21, 2002 report. In the report, the glacial sediments are divided into four model layers that are assumed to be continuous across the study area. The uppermost layer includes all of the sediment overlying the D aquifer. These sediments were represented in the previous regional model as three separate model layers. However, in this model, they are combined into a single model layer, with regionally-varying hydraulic conductivity, that behaves as a semi-confining unit for the D aquifer. The D aquifer is the second layer in the model and consists of units previously referred to as the “D2”, “D0”, “C3”, and “Western System” aquifers across the site. In the FTC&H model simulations, it is assumed that this aquifer is the primary conduit through which the 1,4-dioxane plume migrates. A very dense clay-till layer, with low hydraulic conductivity, underlies the D aquifer. The bottom-most model layer is referred to as the “E aquifer.” It is assumed that this layer overlies clay till or shale bedrock (Coldwater Shale).

The hydraulic conductivities of the different model layers were determined on the basis of lithologic descriptions, slug tests, aquifer test, and model calibration. The hydraulic conductivity distribution in the D aquifer, and the hydraulic conductivity of the clay till layer separating the D aquifer from the E aquifer will have the greatest impact on the capture simulations. In the Evergreen area, an aquifer test at LB-1 showed that the hydraulic conductivity was approximately 270 feet/day. There were no estimates of the hydraulic conductivity of the underlying till layer.

The hydraulic heads and hydraulic gradients in the D aquifer that FTC&H attempted to reproduce in their model simulations are shown in Figure 2 of the August 21, 2002 report. This figure is not reproduced in this review comment memo. The head distribution in this figure show a generally west to east hydraulic gradient with a cone of depression centered over wells LB-1 and 2, and a potentiometric surface high in the vicinity of monitoring well MW-KZ1.

Simulation of Hydraulic Heads and Gradients

FTC&H adjusted hydraulic conductivity to match measured hydraulic heads, primarily in the D aquifer. The resulting hydraulic conductivity of the D aquifer model layer in the vicinity of the Evergreen System is shown in Figure 1.

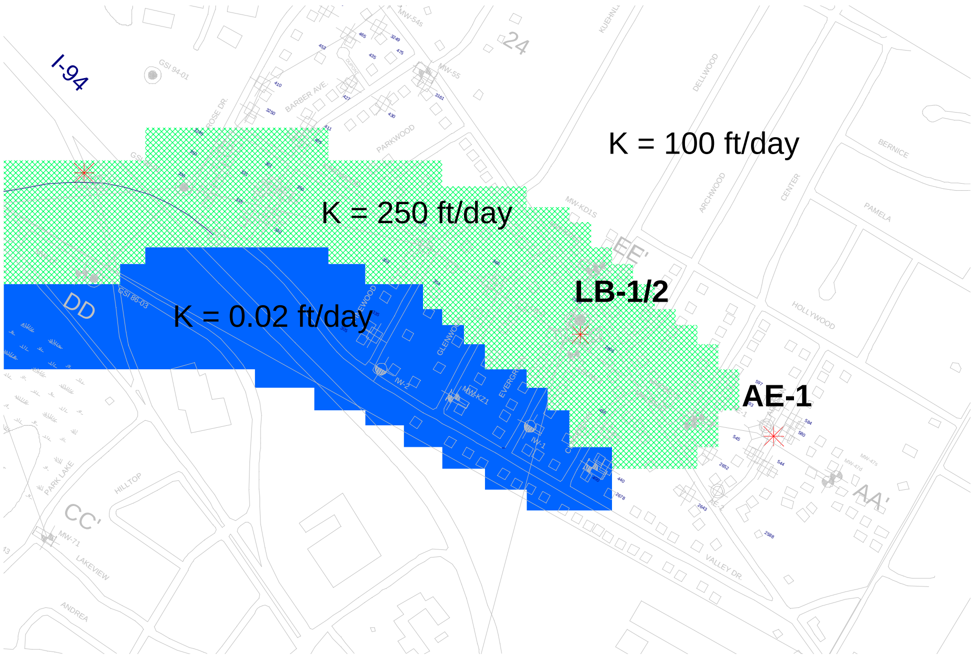

Figure 1 – Hydraulic conductivity distribution in the D aquifer.

The most interesting feature shown in this figure is the side-by-side distribution of zone of greatly different hydraulic conductivity. The central zone (hatched) has a hydraulic conductivity of 250 feet/day, while the zone to the south (dark gray) has a hydraulic conductivity of 0.02 feet/day. The remainder of the model layer has a uniform hydraulic conductivity of 100 feet/day. The hydraulic heads simulated using these hydraulic conductivities are shown in Figure 2.

The simulated hydraulic heads show an area of high heads relative to surrounding areas. In the Evergreen area, the high heads are based on measurements in two wells, MW-KZ1 and 400 Clarendon. FTC&H assumed that the hydraulic heads measured in these wells are representative of hydraulic heads in the D aquifer and are the result of a thinning of the aquifer. It is also possible that these measurements are more representative of shallower saturated sediments. FTC&H chose to reduce hydraulic conductivity in this part of the model, rather than reduce the model layer thickness or eliminate the measurements from the D aquifer dataset.

In reviewing the measured drawdowns during the testing of well LB-1, no negative boundary impacts were observed. So it is not likely that there is considerable reduction in aquifer thickness or hydraulic conductivity in this area. If we make the assumption that these wells do not represent hydraulic heads in the D aquifer or that there is no reduction in hydraulic conductivity or aquifer thickness in this area the simulated heads look considerably different. These are shown in Figure 3. In this example, the low hydraulic conductivity zone was replaced by a zone having a hydraulic conductivity of 100 feet/day.

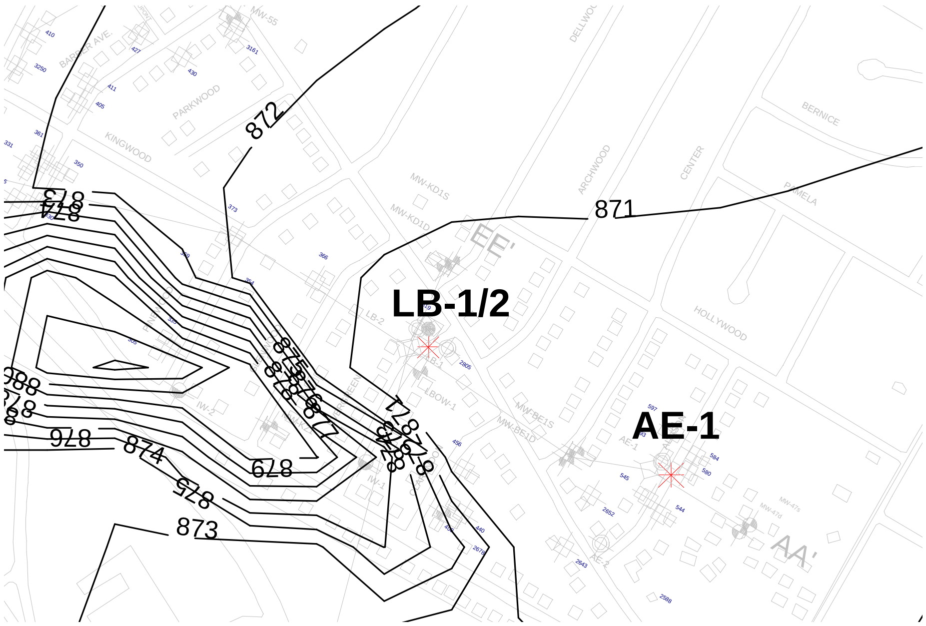

Figure 2 – Simulated heads in the D aquifer.

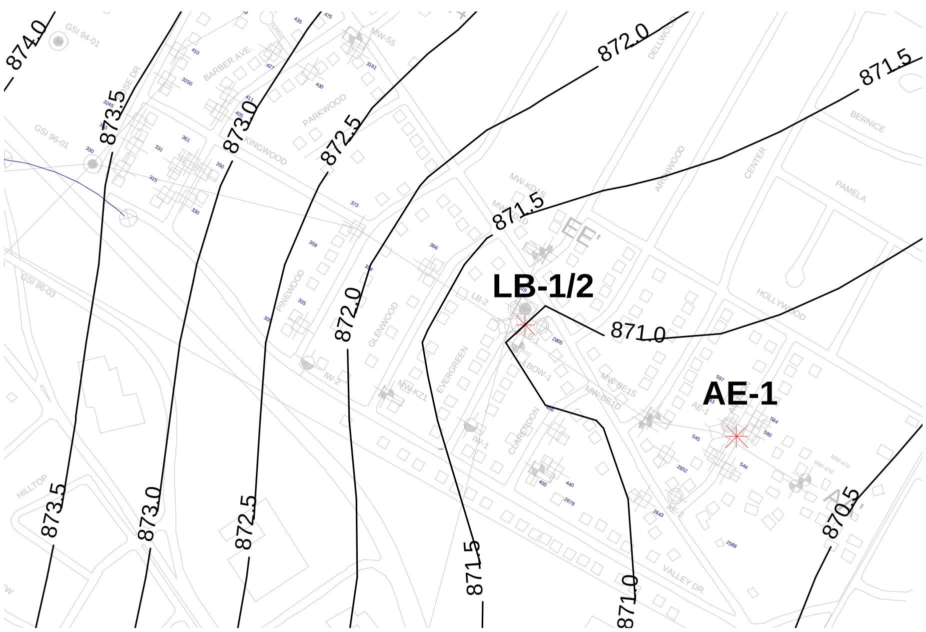

Figure 3 – Simulated heads in D aquifer without low hydraulic conductivity zone.

The simulated gradients in both figures are similar in the area of the delineated contaminant plume (not shown in either Figures 2 or 3), and are generally similar to those shown in Figure 3 of the August 21, 2002 report, in this same area.

Evaluation of Capture Effectiveness

The capture effectiveness of the Evergreen System was evaluated through particle-tracking analysis. FTC&H simulated capture effectiveness assuming pumping rates of 25 and 30 gpm for extraction well AE-1. FTC&H presented their simulation results in their November 18, 2002 report. The particle-tracking analysis for AE-1 pumping at 25 gpm and LB-1/2 pumping at a rate of 175 gpm are presented in Figure 4.

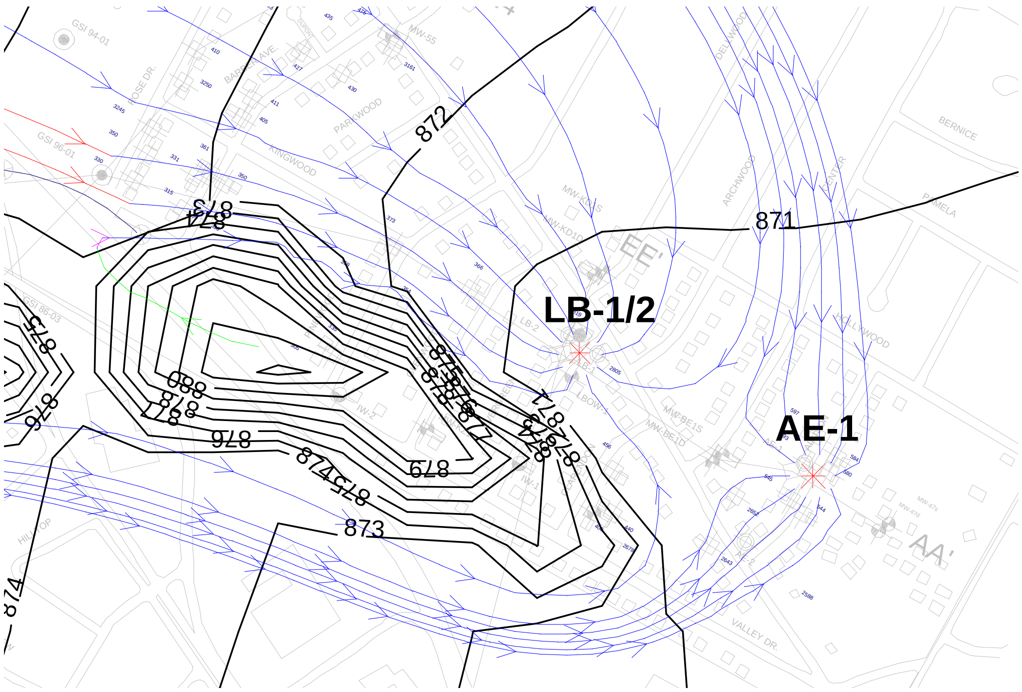

Figure 4 – Simulated particle tracking analysis.

The results of simulating the same pumping rates without the inclusion of the relatively-low hydraulic conductivity zone in the D aquifer are shown in Figure 5. As can be seen by comparing Figures 4 and 5, the simulated capture-zone widths are very similar. Initial concerns that the inclusion of the low hydraulic conductivity zone would result in an overestimation of the capture zone width do not appear to be substantiated.

In either Figure 4 or 5, the pumping from wells LB-1/2 and AE-1 appears to be adequate to capture the entire extent of the D aquifer contaminant plume that's been delineated by FTC&H in the Evergreen area. The extent of the D aquifer plume had been depicted in Figure 3 of the August 21, 2002 report.

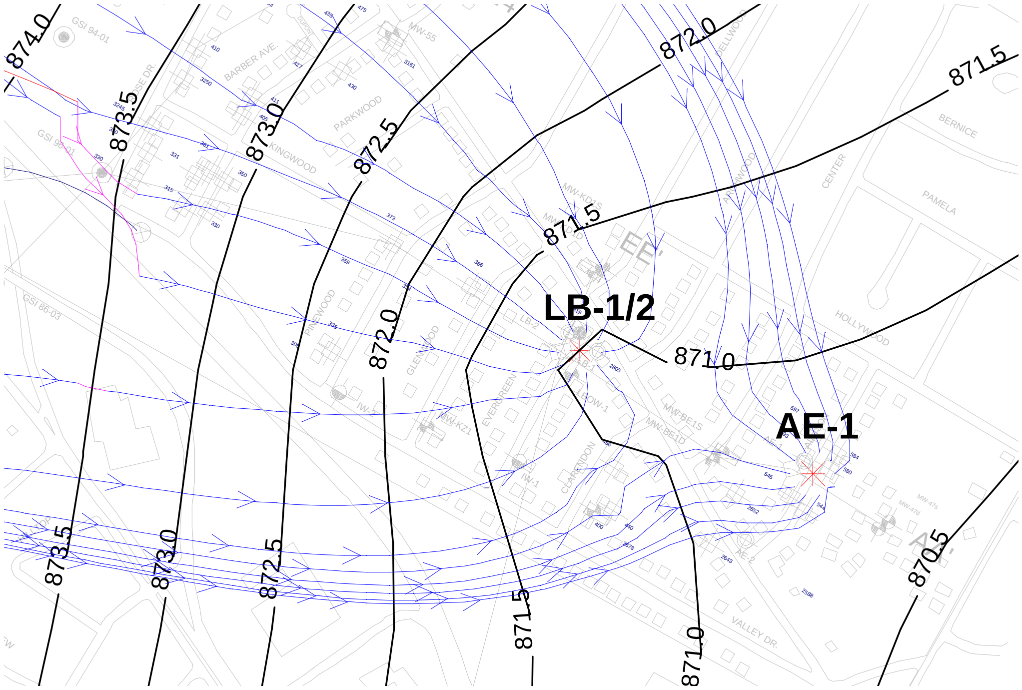

Figure 5 – Simulated particle-tracking analysis without low hydraulic conductivity zone.

Conclusions and Model Limitations

On the basis of the particle-tracking simulations, it would appear that the pumping from the Evergreen System wells should be adequate to contain the contaminant plume that FTC&H has delineated in the D aquifer. This is provided that the actual groundwater migration pathways are accurately simulated, the contaminant plume extent has been properly determined and that the plume migrates laterally within the D aquifer with no exchange of contaminants with the underlying E aquifer. There are three issues with respect to verifying plume containment that limit the model's usefulness for evaluating capture effectiveness of the D aquifer plume. The first is plume delineation, the second is proper monitoring of the performance of the extraction system to verify model simulations, and the third is whether there is vertical migration of contaminants from the D aquifer to the E aquifer.

<u>Plume Delineation:</u>

In order to determine whether the simulated capture is effective, it is necessary to know the full horizontal and vertical extent of the problem requiring containment. The plume delineated in the August 21, 2002, report was based on a limited number of vertical aquifer sampling profiles. Much of the horizontal and vertical delineation depends on existing residential wells or monitoring wells drilled to specified depths without the benefit of vertical aquifer sampling. It is possible that the contaminant plume extends farther horizontally and vertically than has been delineated, especially in light of the discovery of a widespread 1,4-dioxane plume in the E aquifer. In particular, it is possible that what is referred to as the "D aquifer plume" merges, to the south and with depth, with what is now referred to as the "E aquifer plume." The Evergreen System extraction system was not designed to capture these areas.

Performance Monitoring

Proper performance monitoring of the Evergreen extraction system is required since DEQ does not rely on model simulations as proof of remedy effectiveness. "Proof of remedy effectiveness" means the collection of physical data beyond the effective extent of treatment of the remedy. For a hydraulic containment system, hydraulic-head measurements and groundwater sample analyses are required at points beyond the estimated extent of capture. Model simulations show that a pumping rate of approximately 200 gpm will contain the delineated contaminant plume. The composite capture zone for this pumping rate is shown in particle-tracking plots in Figures 4 and 5. Currently, there is one monitoring well cluster (MW-47S and D) located downgradient of the simulated extent of capture. It is necessary to monitor more than one monitoring well cluster to verify the containment of the delineated plume in the Evergreen Area.

Evaluation of Capture in E Aquifer

The model should not be used to assess capture effectiveness within the E aquifer because there has been no calibration of the flow rates and flow directions in the E aquifer in the Evergreen area. Also, in the model, the clay layer separating the D aquifer from the E aquifer is assumed to be laterally continuous and inhibits the possible vertical migration of contaminants from the D aquifer to the underlying E aquifer. This would need to be verified by appropriate field data.

You may contact me to discuss the model simulations and performance monitoring to verify model simulations at mandler@michigan.gov or (517) 241-9001.