MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

INTEROFFICE COMMUNICATION

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Remediation and Redevelopment Division

FROM: Rick Mandle, Groundwater Modeling Specialist RSM
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DATE: June 19, 2008

SUBJECT: Pall Life Sciences, Scio Township, Washtenaw County
Review of Evergreen System Capture Effectiveness

A review of the capture effectiveness of the Evergreen System (LB-1, LB-3, and AE-3 wells) has been completed. This review has relied on: information gathered from the Pall Life Sciences' (PLS) database; the recently submitted report, *April 29, 2008 Evergreen System AE-3 Capture Analysis* (AE Capture Zone report); the *April 14, 2008 Evergreen System, Valley Drive Area Investigation* report (Valley Drive report); and other Evergreen System model analysis reports prepared and submitted by Fishbeck, Thompson, Carr, and Huber Inc. (FTC&H).

Assessment of AE-3 Capture Analysis

<u>Methodology and Findings of the April 29, 2008 Investigation</u>

FTC&H used a simple "Capture Zone" equation found in many hydrogeology textbooks to estimate the capture-zone width of well AE-3. One way to understand the calculation of the capture zone width is simply to revise Darcy's Law:

$$Q = KIA \text{ or,} \qquad 1)$$
$$Q = KIWb \qquad 2)$$

Where:

- Q = Well pumping rate (L3/T),
- K = Hydraulic conductivity (L/T),
- I = Hydraulic Gradient (L/L),
- A = Aquifer cross-sectional area (L2),
- W = Capture width (L), and
- b = Aquifer thickness (L).

Rearranging Equation 1b) to solve for capture width yields:

$$W = Q/KIb \qquad 3)$$

This equation is used to determine the full capture-zone width. The equation used by FTC&H in their report calculates one-half the capture-zone width (Grubb, 1993). Either capture-zone width method assumes uniform horizontal and vertical aquifer properties (K and b), a uniform hydraulic gradient (I), and complete capture over the vertical extent of the aquifer (whether or not the pumping well penetrates the entire aquifer thickness).

For their analysis FTC&H assumed the following parameter values:

Q = 15 gallons per minute {gpm} (2,888 ft3/day),
K = 25, 50, or 75 ft/day,
I = 0.001 (ft/ft), and
b = 90 ft.

Three values for hydraulic conductivity were used to reflect possible uncertainty in this value, as no additional work (other than a grain-size analysis) has been completed that would further define this parameter value. Using Equation 3), the calculated full capture-zone width ranged from 428 feet (K = 75 ft/day) to 1,284 feet (K = 25 ft/day). The resulting capture zones are shown on Figure 2 of the AE Capture Zone report.

<u>Comparison to Previous Capture Analyses</u>

Calculations of the capture-zone widths of wells along Allison (AE-1, AE-2, and AE-3) and Evergreen Streets (LB-1, LB-2, and LB-3) have been completed on a number of previous occasions. In these analyses, different methods of analysis were utilized. These methods have ranged from simple analytical element modeling using a single aquifer layer to numerical modeling using multiple aquifer layers. The primary deficiencies in these previous analyses were that relatively-simple models were used to represent relatively-complex hydrogeological conditions, and the failure to properly calibrate the models that were developed. Model calibration is necessary to demonstrate that the choice of the model and the associated parameter values are reasonable for the hydrogeology of this area. As a result, a variety of conceptualizations and hydraulic parameter values have been used. In previous investigations, the hydraulic conductivity in the vicinity of Allison Street has ranged from 271 ft/day in early modeling analysis to 100 ft/day in more recent model submittals. All values in these previous capture-zone analyses are considerably higher than the values used in the present analysis. Referring to equation 3), it should be apparent that as the hydraulic conductivity decreases in these analyses, the pumping rate needed to achieve the same capture-zone width decreases in a proportional manner. As an example, as K decreases by one-half, the Q needed to achieve the same capture-zone width also decreases by one half. Also, if the pumping rate of the extraction well is reduced, the hydraulic conductivity of the aquifer being pumped can be reduced proportionally in order to achieve the same capture-zone width. This assumes that the hydraulic-head gradient and aquifer thickness are the same in both analyses. It should be apparent that it is not possible to attain the same calculated capture-zone width as shown on Figure 2 (from the AE Capture Zone report) using a pumping rate equal to 15 gpm and the previous estimates of hydraulic conductivity that had ranged from 100 ft/day to 271 ft/day.

<u>Assessment of the Present Capture Analysis</u>

Our concern with these calculations is the same that we've had with previous model analyses at this site. The present capture analysis is another in a series of analyses in which an uncalibrated model is used to show hydraulic containment of the contaminant plumes at this site. While there has been additional drilling in areas north, east, and south of Allison Street to define the geology and downgradient extent of contamination, other than the aquifer test at LB-1, there has been no additional hydraulic testing or model calibration to estimate the aquifer water-yielding capabilities (transmissivity and hydraulic conductivity) where the remaining AE well, AE-3, is located. This work is needed to support a reduction in hydraulic conductivity from values used in previous analyses. Without this additional work, we have no assurance that these model simulations are any more reasonable, or more accurate, than previous model simulations.

However, as with any other contamination site, the Michigan Department of Environmental Quality (MDEQ) does not rely solely on calculations to demonstrate hydraulic containment of a dissolved contaminant plume, even if a model was reasonably calibrated. We must rely on demonstrations of hydraulic containment, through the collection of hydraulic-head data and groundwater chemical data [Cohen and others (1994), Greenwald and others (2008), and the MDEQ (2006)] The following discussion starts with an assessment of the data and plume containment at Evergreen, followed by a similar discussion for the Allison Street wells.

Plume Containment at Evergreen

The primary means of contaminant plume containment in the designed remediation system has been the extraction wells at Evergreen Street, (LB-1, LB-2, and LB-3). Hydraulic-head and chemical data must be used to determine whether these extraction wells have been successful in containing the 1,4 Dioxane plume. That is, there should be changes to the hydraulic-head gradients and 1,4-Dioxane concentration trends that demonstrate that groundwater is moving toward the extraction wells over the area of contamination and that 1,4-Dioxane concentrations are decreasing with time. The challenge at this site is that there are an insufficient number of properly spaced monitoring wells or monitoring well nests in which to measure hydraulic heads and determine hydraulic gradients, and there has been no vertical sampling of the aquifer (with the exception of the sampling of the borehole drilled during the installation of LB-3) to determine the horizontal and vertical extent of 1,4-Dioxane concentrations that require containment at Evergreen or Allison Streets.

<u>Examination of Potentiometric Surface</u>

An assessment of hydraulic gradients begins with an examination of hydraulic-head data or a potentiometric surface map. Figure 7 from the Valley Drive report shows the interpreted potentiometric surface of the “D2” aquifer. There are a couple of issues that we have with this map. The first is that head data from wells that are screened in zones that appear to be hydraulically-isolated from the aquifer within which the 1,4-Dioxane plume is found were used to prepare this potentiometric surface map. These data and the resulting potentiometric surface contours do not “make sense” given the contaminant migration direction of the 1,4-Dioxane plume that has been presented by FTC&H. The wells in question are found northwest of M-14 (along Wagner Road or Rose Drive) and along Valley Drive. It’s our opinion that these wells reflect either “perched” or local flow conditions, or zones that are not well-connected to the “D2” aquifer. Focusing on the Evergreen wells, we do not believe that the potentiometric surface “high” centered on well MW-KZ1 is representative of heads or contaminant migration directions within the “D2” aquifer in this area. The relatively-high head measured in this well shows that there is significant resistance to groundwater movement between the screened interval in this well and the contaminated aquifer. This well appears to be screened in a zone that is not well-connected to the aquifer in which the contaminant plume is found. MW-KZ1 and MW-117 (discussed below), should not be used in preparing a potentiometric surface map for this aquifer. Taking these two wells out of the dataset used to map the potentiometric surface results in a surface that looks similar to the surface shown for the deeper “E” aquifer (see

Figure 8 of the DuPont report, *Unit E2 and Deeper DuPont Area Wells Potentiometric Surface Contour Map – February 25,2008*).

The second issue is related to the drawing of a cone of depression (828-foot contour) around well LBOW-1, a non-pumping well. There does appear to be a "flattening" of hydraulic gradients in the vicinity of the LB wells, even after removing wells MW-KZ1 and MW-117. However, because the distribution of wells for monitoring hydraulic containment is not optimum or sufficient, it is difficult to determine whether a cone of depression is centered over the LB wells (the pumping wells), and whether there are hydraulic gradients toward wells LB-1 and LB-3, a necessary requirement to demonstrate hydraulic containment. The result is that the available data show no well-defined hydraulic gradients toward these extraction wells or hydraulic containment.

<u>Evaluation of Groundwater Chemical Data</u>

The 1,4-Dioxane concentration data from monitoring wells in the vicinity of, and including, LB-1, LB-2, and LB-3 were graphed and examined for temporal trends to determine whether the extraction wells have contained the contaminant plume, resulting in declining 1,4-Dioxane concentrations. The graphs of these data are shown in Figures 1 through 5 attached to this memorandum. Figure 1 shows the 1,4-Dioxane concentrations at the three LB extraction wells. From this figure, it should be apparent that these wells have removed 1,4-Dioxane contaminated groundwater from the aquifer, and that the concentrations of groundwater extracted by well LB-2 were considerably and consistently higher than either LB-1 or LB-3. Figure 2 shows the mass of 1,4-Dioxane removed per gallon of groundwater extracted (units are pounds per gallon). Since the pumping rates for each well were similar, the obvious conclusion is that the screened interval in well LB-2 was located closer to higher 1,4-Dioxane concentrations than the screens in either wells LB-1 or LB-3, and that well LB-2 was much more effective in removing 1,4-Dioxane from the aquifer than its replacement, LB-3.

Extraction well LB-2 was replaced by LB-3, a well that has a longer screen and is located to the north of LB-2. It is our opinion that the replacement well (LB-3) is not as effective as the well it replaced (LB-2) and that LB-3 is located farther from the highest 1,4-Dioxane concentrations that LB-2. We believe that this has resulted in less effective containment of the shallow contaminant plume and an increase in 1,4-Dioxane concentrations in monitoring wells that are east of Evergreen Street.

Figures 3, 4, and 5 show 1,4-Dioxane concentrations at wells 2819 Dexter, 2805 Dexter, and MW-BE-1s, respectively. Also shown on these graphs are the pumping rates for LB-1, LB-2, and LB-3 (pumping rate on right-hand y-axes). From the plot of the extraction-well pumping rates, the time at which well LB-2 stopped pumping can be determined. As pumping rates in this well decreased and eventually stopped, the 1,4-Dioxane concentrations in nearby and downgradient monitoring wells increased, even though the replacement well, LB-3, pumps at a similar rate as LB-2. Keeping in mind that LB-3 is located to the north, it's our opinion, based on an examination of the existing dataset, that the greatest 1,4-Dioxane concentrations are probably located at LB-2 or to the south of LB-2. Turning off LB-2 appears to have allowed higher contaminant concentrations to move toward the well at 2819 Dexter Road and past Evergreen Street toward the wells at 2805 Dexter Road and MW-BE-1s. Lacking hydraulic-head data, it is not entirely clear whether or not the well at 2805 Dexter Road is within the extent of capture of the LB wells; however, since the increase in 1,4-Dioxane concentrations seen at the wells at 2819 and 2805 Dexter Road is observed at MW-BE-1s, we believe that this portion of the contaminant plume is not contained by the combined pumping by LB-1 and LB-3. We also do not believe that the contamination detected at MW-BE-1s can be contained by pumping the existing LB wells.

Figure 6 shows the 1,4-Dioxane concentrations at the wells at 440 Clarendon and 456 Clarendon, along with pumping rate for the LB wells. Groundwater samples have been collected at 456 Clarendon since 1997 through the present, while sampling from the well at 440 Clarendon was stopped at the end of 2004. Data on this graph shows that concentrations of 1,4-Dioxane at 440 Clarendon and 456 Clarendon have continued to increase since 1997. Pumping from LB-1 and/or LB-2 may have had an impact on stabilizing 1,4-Dioxane concentrations at 456 Clarendon (see graph between 2001 and 2005). We believe that the increase in concentrations from 2005 to the present at 456 Clarendon may be attributed to a reduction in pumping at LB-2 and shifting the pumping to LB-3, or simply a movement of contaminants from the west and south of the LB-series wells.

With the exception of the boring at LB-3, there has been no vertical sampling of the aquifer performed near the LB extraction wells or the delineation of the horizontal or vertical extent of the 1,4-Dioxane concentrations. As a result, we cannot determine the north-to-south horizontal extent of the contaminant plume, whether the contamination is limited to the shallow portion of the aquifer (as the data from monitoring well MW-BE-1s and d would suggest), and how much of the contaminant plume actually passes the LB-series extraction wells and migrates to the east. However, it is our opinion that the current extraction-well system (LB-1 and LB-3) does not contain all 1,4-Dioxane contaminant concentrations that exceed 85 micrograms per liter (ug/L). Also, replacing well LB-2 with LB-3 appears to have resulted in a loss of capture effectiveness.

Plume Containment at Allison

It is our understanding that the extraction wells at Allison Street (AE-1, AE-2, and AE-3) were installed to capture that portion of the 1,4-Dioxane plume not contained by the Evergreen wells. The extent of 1,4-Dioxane contamination and the locations and vertical screen placements for the AE-series extraction wells along Allison Street were based entirely on the sampling of residential wells, with no vertical aquifer sampling. Well AE-1 was installed in early 1998 and began pumping in mid-1998, and was eventually replaced by well AE-3 in early 2004. Well AE-2, located to the south along Allison Street near Dexter Road, was installed in 2001 and pumped only intermittently in 2001 and 2004.

<u>Examination of Potentiometric Surface</u>

Figure 2 from the AE Capture Zone report shows contours of the interpreted potentiometric surface of the “D2” aquifer and the calculated capture-zone widths for AE-3 discussed at the beginning of this memorandum. The contours on this figure are taken from Figure 7, a regional potentiometric surface map, found in the Valley Drive report. There are concerns with the data selected to create this surface and the contouring of the hydraulic-head data on this map. FTC&H states that there is a very favorable comparison between the calculated capture-zone widths and the potentiometric surface contours shown in Figure 2. We do not agree, primarily because we believe that the manner in which the hydraulic-head data are contoured is not correct. Specifically, the 868-foot contour is shown to curve to the northeast toward MW-92, emphasizing the appearance of hydraulic containment. There are no data north of MW-92 or MW-113 that would support this manner of contouring. The two available data point values support the drawing of this contour line much closer to well MW-113, at approximately one-third the distance between MW-113 and MW-92. This would follow a trend more in line with the contouring of the potentiometric surface for the “E” aquifer (Figure 8 in the DuPont Investigation report). In addition, the contouring presented in Figure 2 would suggest that the source of the low concentrations of 1,4-Dioxane found at MW-92 is located to the northwest of MW-92 and MW-113. Clearly, this contouring is not correct.

Another concern is in using the measured hydraulic-head data from wells MW-KZ1 and MW-117. This was discussed in previous paragraphs. It’s our opinion that the relatively-high hydraulic-head measurements from these wells give an erroneous picture of groundwater-flow directions, especially when combined with hydraulic-head data from wells screened in the “D2” aquifer in Evergreen. The inferred groundwater flow direction from Figures 2 (AE Capture Zone report) and 7 (Valley Drive report) in this area would be from MW-117 and MW-KZ1 to the north toward Dexter Road. If this was correct, the 1,4-Dioxane contamination found in the “D2” aquifer at 440 Clarendon and 456 Clarendon, or in the vicinity of Dexter Road, would have originated near Valley Drive. Clearly, MW-117 is not the source, since no 1,4-Dioxane was detected during the vertical profiling of this boring. In addition, from the geologic logs for MW-KZ1 and MW-117 it does not appear that there is a continuous aquifer or groundwater contamination present in this area. As stated above, these wells (MW-KZ1 and MW-117) should not be used in preparing a potentiometric surface map for this aquifer.

Finally, there are too few monitoring wells near Allison Street to assess hydraulic gradients or hydraulic containment in the vicinity of AE-3. The hydraulic-head data that are available do not show hydraulic containment at this well.

Evaluation of Groundwater Chemical Data

All 1,4-Dioxane concentration data from monitoring wells in the vicinity of, and including, AE-1, AE-2, and AE-3 were graphed and examined. The purpose of graphing these data is to determine whether the contaminant plume has been contained by the AE extraction wells or is migrating past Allison Street. These graphs are shown in Figures 7 through 10 attached to this memorandum. As with the area surrounding the Evergreen Street wells, there are no borings upgradient of, near, or immediately downgradient of the AE extraction wells, within which vertical aquifer sampling was performed. As a result, this makes an assessment of the horizontal or vertical extent of the contaminant plume and hydraulic containment on the basis of chemical analyses difficult, especially given the known vertical variability of 1,4-dioxane concentrations at this site.

Figure 7 shows 1,4-Dioxane concentrations in sampled wells between Evergreen and Allison and the pumping rate for well LB-2. After well LB-2 was shut-down, the 1,4-Dioxane concentrations in wells at 2805 Dexter, MW-BE-1s, and 593 Allison increased. It appears that the change in the LB-series well system has resulted in a release of higher concentration 1,4-Dioxane that has migrated to Allison Street.

The mass of 1,4-Dioxane removed per gallon extracted from the Allison-series wells is shown in Figure 8. The mass removal rate, while low, had been fairly consistent until mid-2003 when removal rates started declining. Throughout 2006, the removal rate remained fairly consistent and then started increasing in 2007. The concentrations of 1,4-Dioxane in the AE-series wells and the pumping rates at LB-2 and total LB-series pumping are shown in Figure 9. There has been an increase in 1,4-Dioxane concentrations at AE-3 since early 2007, and there had been a continuous increase in 1,4-Dioxane at AE-2 until sampling stopped in 2006. It's our opinion that the increase in mass removal rates and 1,4-Dioxane concentrations is the result of a partial loss of containment by the LB-series wells.

Figure 10 shows the 1,4-Dioxane concentrations in Allison Street residential wells. As shown in this figure, except for the residential wells at 544, 545, and 593 (shown in Figure 7) Allison, all other previously sampled wells have been dropped from the sampling network. There had been a steady increase in concentrations in wells at 580, 584, and 597 Allison between early 1997 and late 2003 or 2004 when sampling each of these wells stopped. The reason for this increase is not known. The 1,4-Dioxane concentrations at 544 Allison decreased between 2001 and 2003. However, since early 2005, the 1,4-Dioxane concentrations in the wells at 544 and 545 Allison have increased steadily. This increase appears to be the result of higher 1,4-Dioxane concentrations migrating past the LB-series wells toward Allison Street.

As for the area near the AE-series wells, there has been no good long-term sampling network east of Allison Street. PLS has relied on sampling the monitoring well clusters MW-47s and d to demonstrate containment of the contaminant plume. However, as shown in cross sections 08-07 and 08-03 (Figures 2 and 4 in the Valley Drive report), these wells are very shallow and were not installed using vertical aquifer sampling techniques. We cannot be certain that these well screens are placed in the proper vertical location, especially given the downward hydraulic-head gradient at this location and the elevated 1,4-Dioxane concentrations detected in the vertical aquifer sampling in the borehole for LB-3 and at well MW-101 (see Figure 2 in the Valley Drive report). There is no demonstrated "clean zone" (as drawn by FTC&H in all previous investigation or sampling reports) that would indicate that the 1,4-Dioxane detected at MW-101 is not the result of 1,4-Dioxane moving from Evergreen toward this well.

Figure 11 shows the 1,4-Dioxane concentrations in wells downgradient of Allison Street that were installed using vertical aquifer sampling, these are MW-92, MW-101, and MW-110. The concentrations in wells MW-101 and MW-110 have shown an increase since 2007. There has not been a similar increase observed at well MW-92. Wells MW-101 and MW-110 are located in a downgradient direction from extraction well AE-3. The increase in 1,4-Dioxane concentrations in these wells may be related to the increased 1,4-Dioxane concentrations migrating toward Allison Street from Evergreen and a decrease in pumping rates at AE-3 from approximately 30 gpm to 15 gpm. Only the concentrations at MW-101 exceed 85 ug/L.

Conclusions

From our examination of the submitted reports and the available data, we've arrived at the following observations and conclusions regarding the containment of the 1,4-Dioxane plume in the Evergreen area:

- The width of the 1,4-Dioxane concentrations that exceed 85 ug/L at Evergreen Street that need containment has not been delineated using vertical aquifer sampling. The delineation of the contaminant width at this location has been estimated by sampling a handful of residential wells and monitoring wells that have not been vertically sampled.

In order to properly design a containment system, the width of the plume requiring containment must first be determined.

- Pumping the LB-series wells has resulted in the removal of 1,4-Dioxane from the contaminated aquifer and a “flattening” of hydraulic gradients in the vicinity of Evergreen Street.

- While hydraulic-head data measured in wells in the vicinity of Evergreen Street show a “flattening” of hydraulic gradients through the area, indicating that pumping LB-1 and LB-3 has had an impact on hydraulic heads. There are too few well-placed head-monitoring wells to demonstrate that a cone of depression has developed around LB-1 and LB-3 or that there are hydraulic-head gradients pointing toward the two extraction wells. The available hydraulic-head data do not conclusively show hydraulic containment of the contaminant plume.

- On the basis of mass removal rates and 1,4-Dioxane concentrations of extracted groundwater, LB-2 was the most effective extraction well and appears to have been located nearest to the highest 1,4-Dioxane concentrations than either LB-1 or LB-3.

- Even though the pumping rate from LB-3 is very similar to that of LB-2, observed chemical data from several monitoring wells located between Evergreen and Allison Streets lead us to conclude that shutting down LB-2 resulted in a release of higher 1,4-Dioxane concentrations that has migrated to the east, past Evergreen Street and toward Allison Street. In hindsight, additional vertical aquifer sampling along Evergreen near LB-2 and to the south of LB-2 along Evergreen Street, should have been completed to identify the area of highest 1,4-Dioxane concentrations in this area. As it was, the single vertical aquifer sampling profile, (borehole at LB-3), was completed north of LB-1.

- An additional extraction well located at, or south of, LB-2 is needed to contain the contaminant plume at Evergreen Street.

- As long as the LB-series wells allow 1,4-Dioxane to migrate past Evergreen at concentrations exceeding 85 ug/L, a downgradient extraction-well system must be operated and properly maintained.

- FTC&H has completed another capture-zone analysis for the AE-series wells, this time using a lower value of hydraulic conductivity than those used in previous analyses. However, they have not provided data or information (e.g. hydraulic response testing or model calibration) that would support their use of a lower value of hydraulic conductivity in their capture-zone analysis. Grain-size analyses cannot give reliable estimates of hydraulic conductivity for the aquifer surrounding AE-3. In the absence of good hydraulic response testing, there has to be complete reliance on hydraulic head and chemical data to demonstrate hydraulic containment. As discussed elsewhere, this demonstration has not been made.

- The width of the 1,4-Dioxane concentrations that exceed 85 ug/L at Allison Street has not been delineated using vertical aquifer sampling, but has been estimated by sampling a handful of residential wells along Allison Street. In order to properly design a containment system, the width of the plume requiring containment must first be determined.

- The AE-series wells were located on the basis of sampling residential wells, without vertical aquifer sampling. It's not entirely certain that the AE-series wells are optimally located, screened at the correct depth, or pump the correct rate.

- The distribution of monitoring wells around AE-3 is not optimum for demonstrating hydraulic containment. All of the wells that fall within the most recent calculated capture zones are residential wells where well screens may not be at the appropriate depth for chemical monitoring. The only well location that could be used for monitoring containment was installed without the use of vertical aquifer sampling. It's our belief that well MW-47s is screened in a shallow sand that is above a clay layer and is not useful for monitoring AE-3. MW-47d is screened immediately below this clay layer, but may be too shallow given there is a vertically downward head gradient at this location.

- The measured hydraulic heads from the existing well network may or may not show a "flattening" of hydraulic gradients in the vicinity of Allison Street. There is no indication of a cone of depression or hydraulic gradients pointed toward AE-3. At 15 gpm, it's not likely that there will be significant drawdown in the aquifer or the establishment of hydraulic gradients that reflect containment.

- The slight increase in 1,4-Dioxane concentrations at MW-110 and MW-101 coincides with a reduction in the pumping rate at AE-3 and an increase in concentrations at the well at 593 Allison. This concentration increase appears to be the result of lack of containment by the Evergreen and Allison wells. The concentrations at MW-101 exceed 85 ug/L.

- The elevated (>85 ug/L) 1,4-Dioxane contamination detected at MW-101 may be deeper contamination that has migrated from Evergreen. There are no vertical profile borings north of MW-107, and between LB-3 and MW-101 that establish a "clean zone" between contaminations that has been labeled "Evergreen" and the contamination at MW-101. An additional vertical aquifer sampling borehole is needed to verify the "clean zone" drawn by FTC&H on all "D2" or combined "D2" and "E" unit plume maps that are submitted to the MDEQ.

- Data collected during the vertical sampling of MW-117 do not support the northward migration of 1,4-Dioxane contamination from south of Valley Drive.

- Data collected during the vertical sampling of MW-113 do not support the northward migration of elevated 1,4-Dioxane contamination at this location. The depicted width of elevated 1,4-Dioxane concentrations of the "D2" unit contaminant plume in the Evergreen area is 300 to 500 feet, if accurate. The distance between wells MW-55 and MW-113 is approximately 1,250 feet, and between MW-113 and MW-92 is approximately 1,350 feet. Additional vertical sampling borings will be needed to verify that there is no northward migration of this contaminant plume.

These conclusions are based on an examination of the existing dataset. A more complete dataset that is based on vertical aquifer sampling and nested monitoring wells might result in slightly different conclusions.

You may contact me to discuss these review comments at mandler@michigan.gov or 517-241-9001.

RM/KJ

Attachments

References

Cohen, R.M., A.H. Vincent, J.W. Mercer, C.R. Faust, and C.P. Spalding (1994): Methods for Monitoring Pump-and-Treat Performance. EPA/600/R-94/123: U.S. EPA, ORD, R.S. Kerr Environmental Research Laboratory, Ada, OK; 110 pages.

Greenwald, R., Y. Zhang, and D. Sutton (2008): A Systematic Approach for Evaluation of Capture Zones at Pump and Treat Systems. EPA/600/R-08/003: U.S. EPA ORD, National Risk Management Research Laboratory, Ada, OK; 166 pages.

Grubb, S. 1993. Analytical Model for Estimation of Steady-State Capture Zones of Pumping Wells in Confined and Unconfined Aquifers; Ground Water, Vol. 31, No. 1, pp. 27 - 32.

Michigan Department of Environmental Quality (2006): RRD Operational Memorandum No. 4; Site Characterization and Remediation Verification – Attachment 7 Groundwater Modeling. Interim Final May 2006; 45 pages.

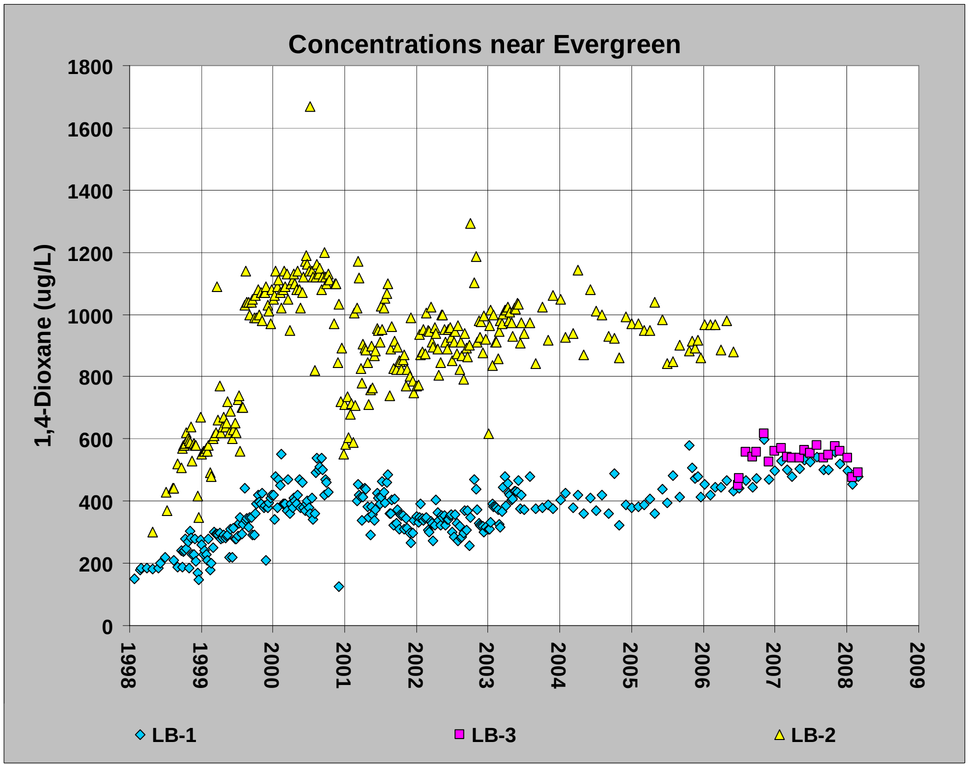

Figure 1 – 1,4-Dioxane concentrations at LB wells.

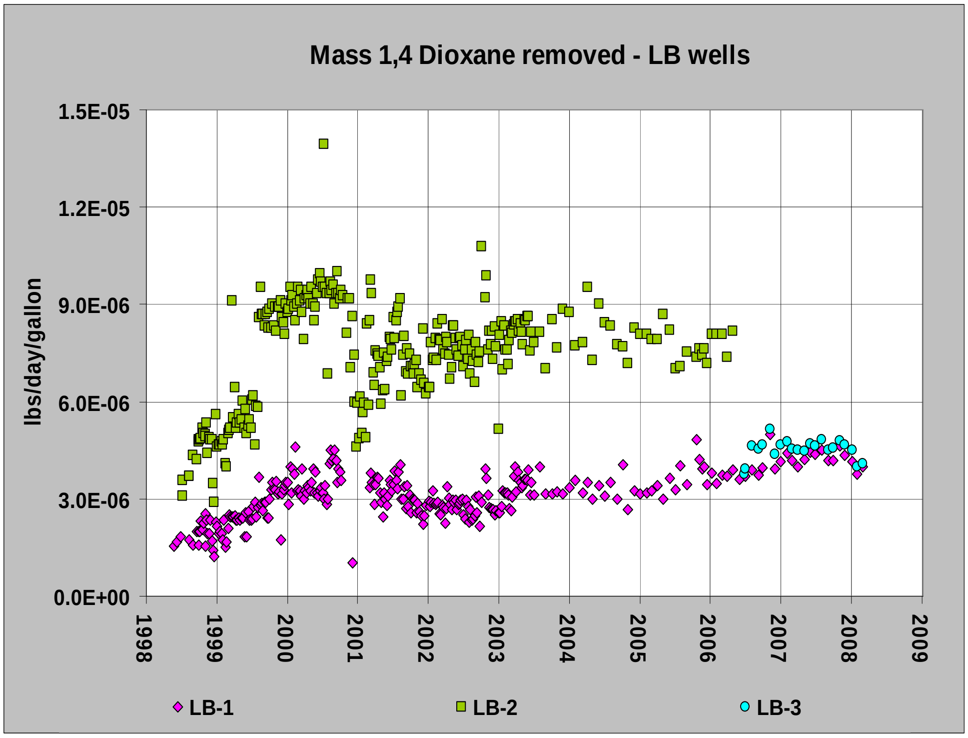

Figure 2 – Mass 1,4-Dioxane removed per gallon pumped.

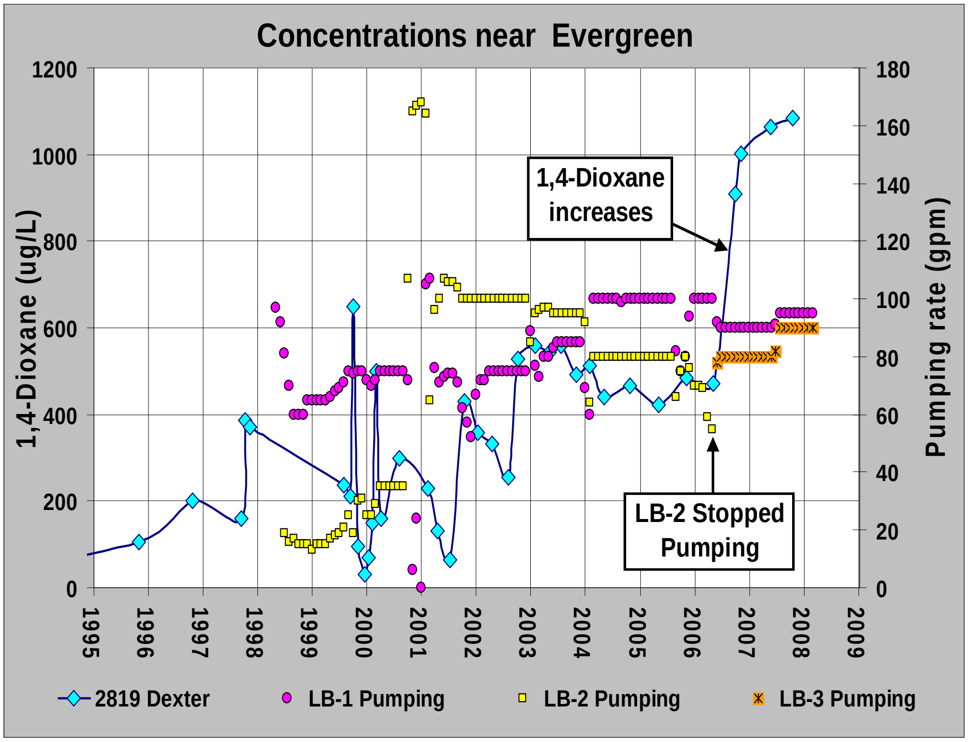

Figure 3 – 1,4-Dioxane Concentrations at 2819 Dexter.

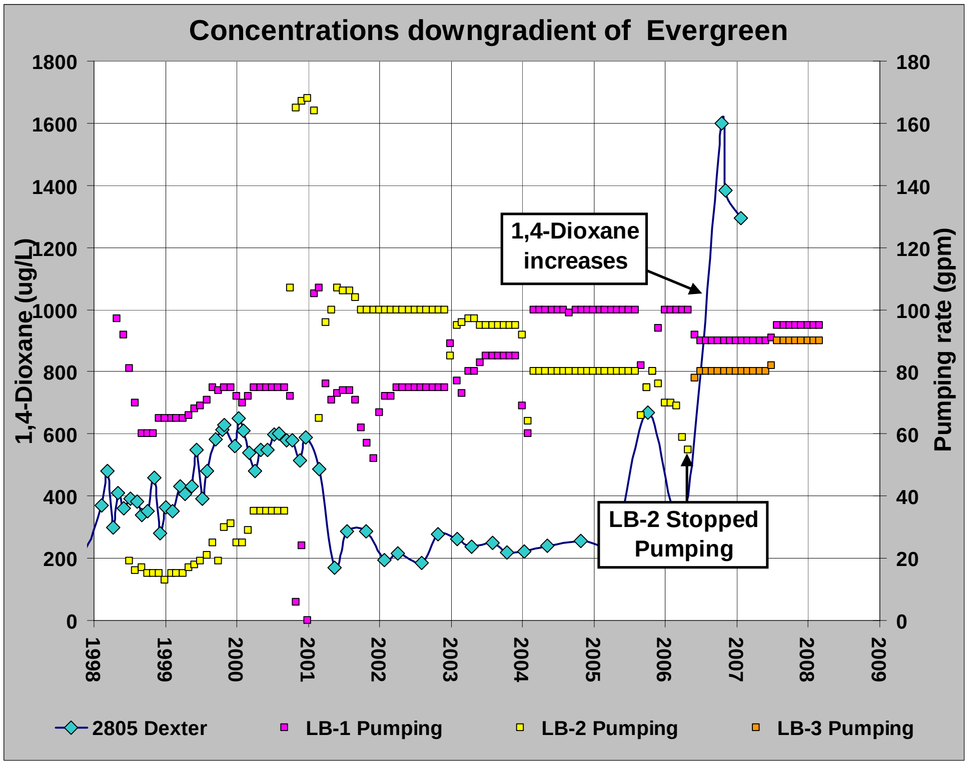

Figure 4 – 1,4-Dioxane Concentrations at 2805 Dexter.

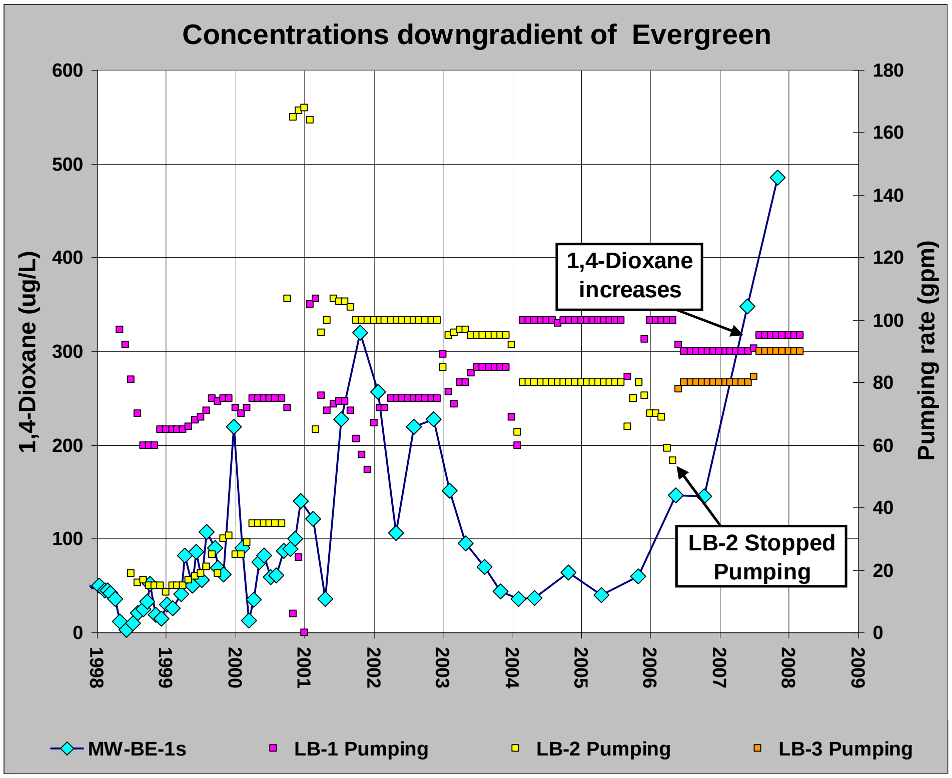

Figure 5 – 1,4-Dioxane Concentrations at MB-BE-1s, MW-BE-1d, and 2652 Dexter.

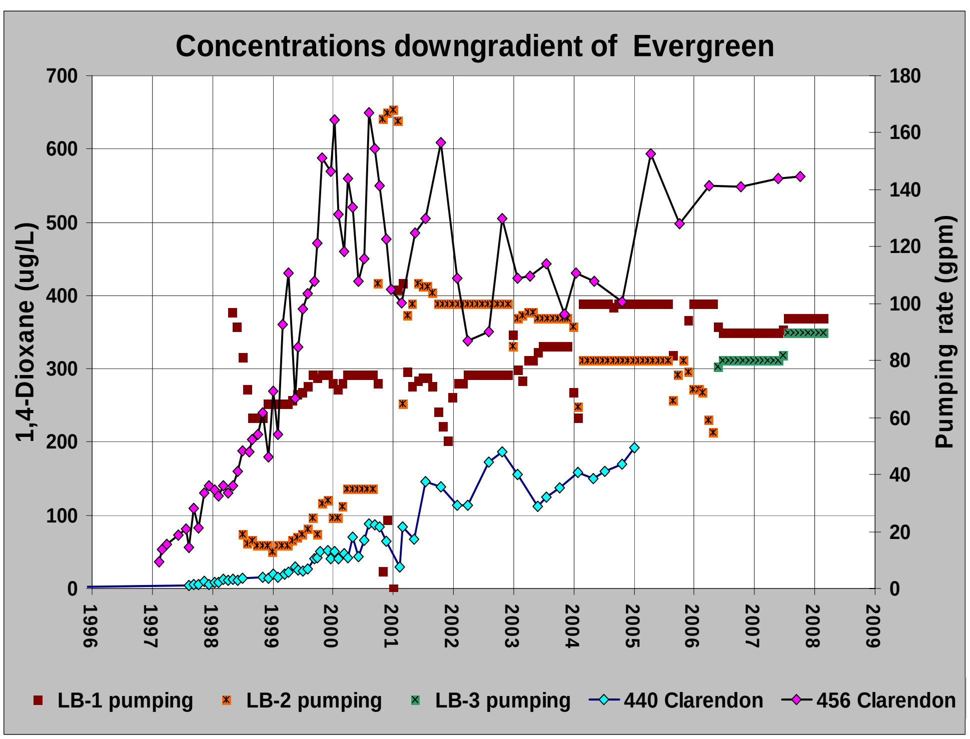

Figure 6 – 1,4-Dioxane Concentrations at 440 Clarendon and 456 Clarendon.

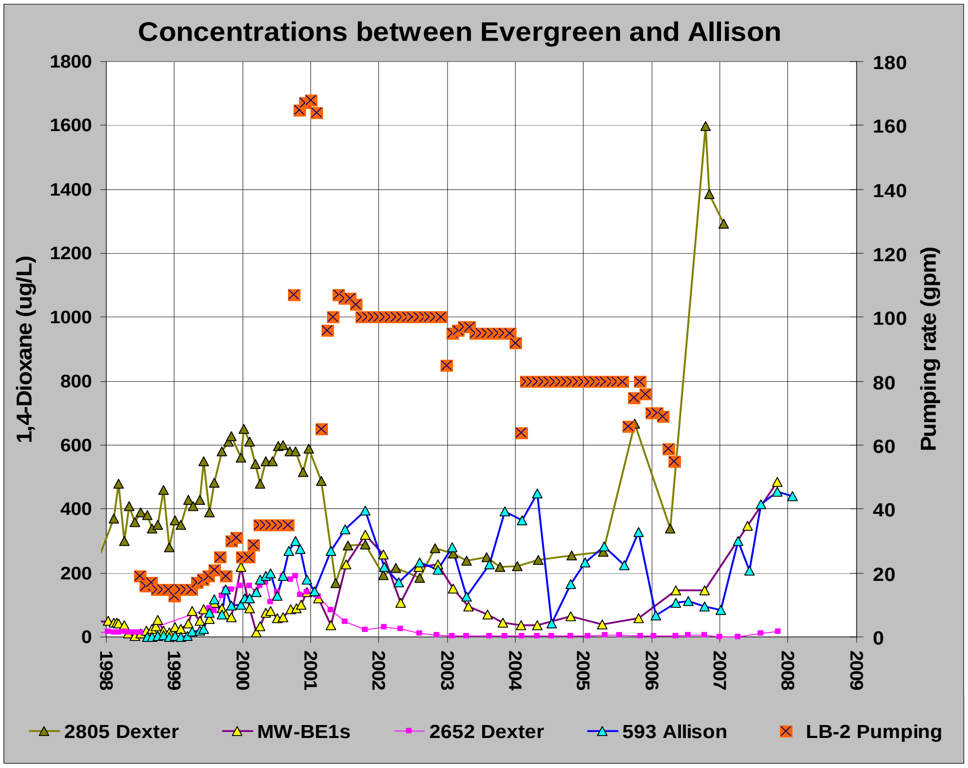

Figure 7 – 1-4-Dioxane Concentrations between Evergreen and Allison.

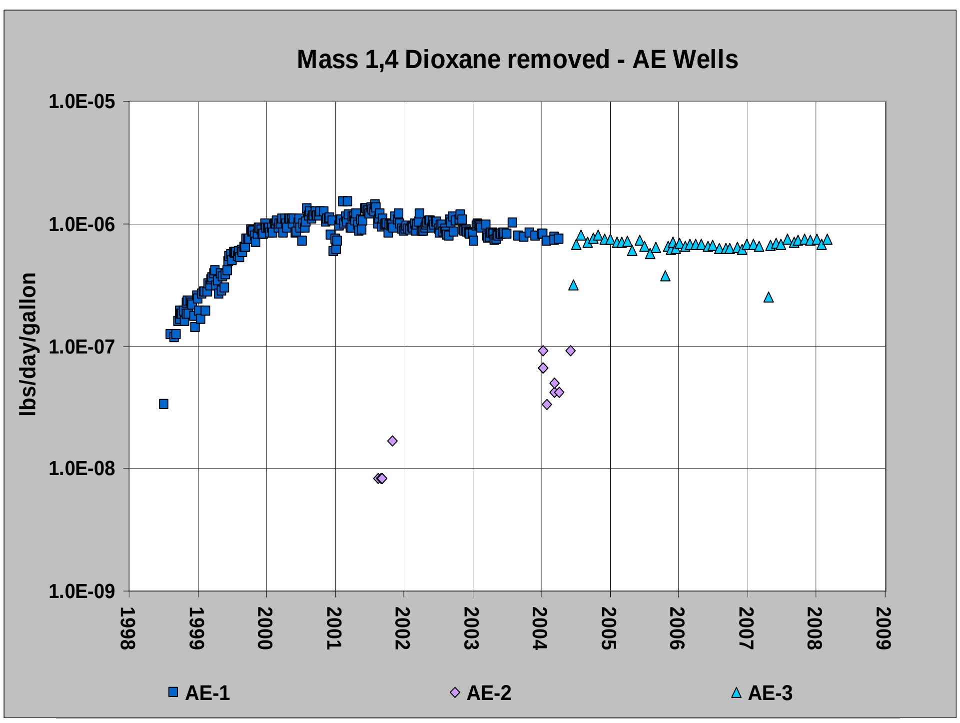

Figure 8 – Mass 1,4-Dioxane removed per gallon pumped.

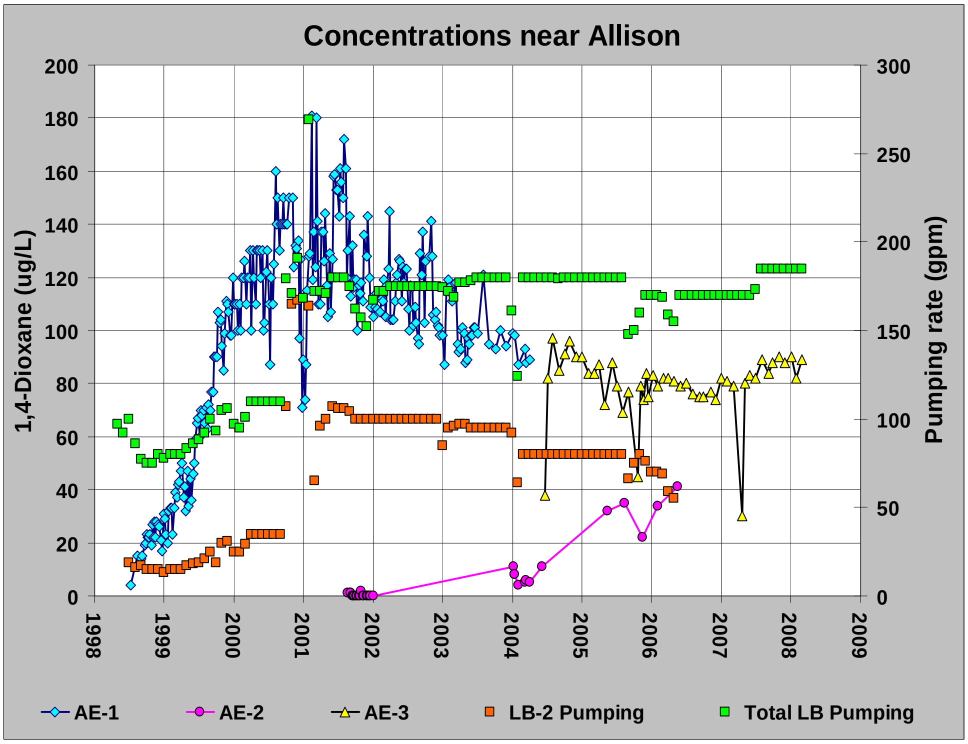

Figure 9 – 1,4-Dioxane Concentrations at AE-1, AE-2, and AE-3.

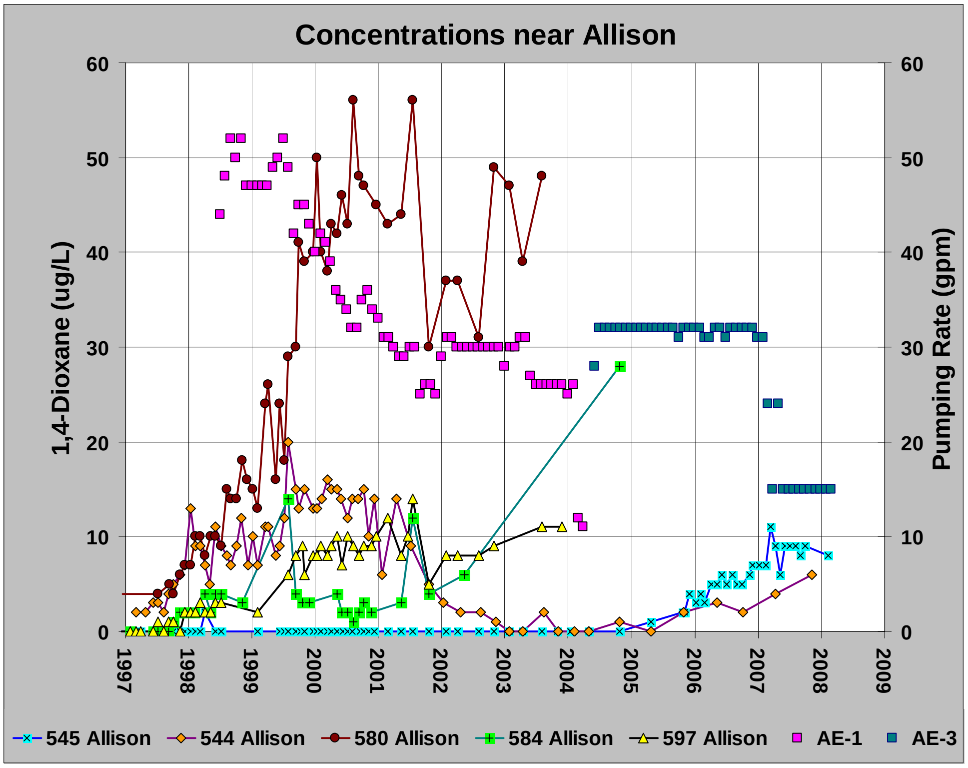

Figure 10 – 1,4-Dioxane Concentrations at Allison Street residential wells.

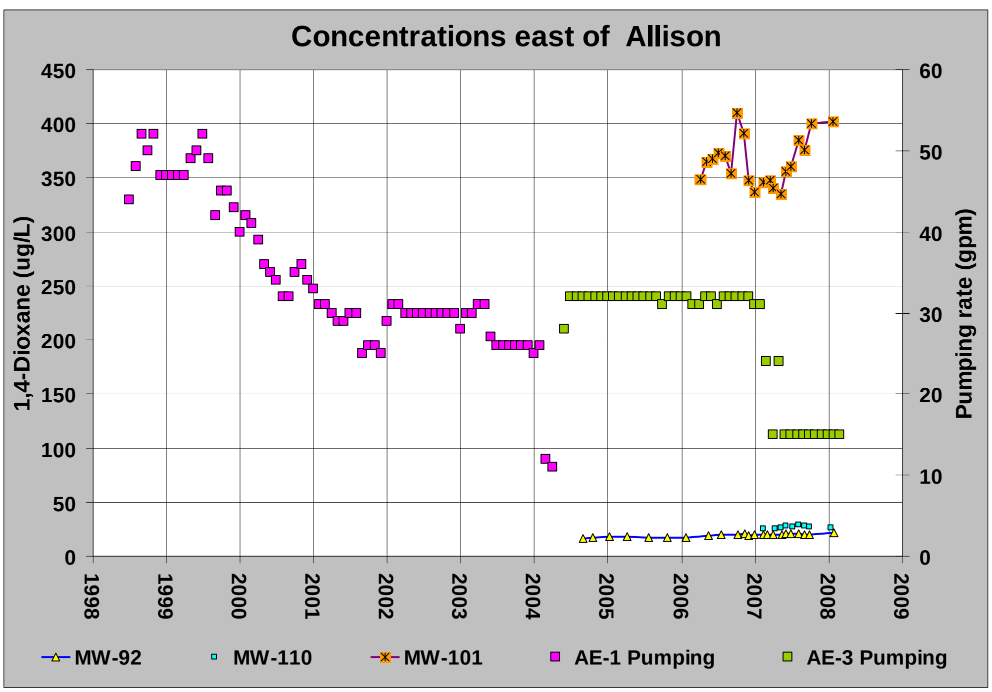

Figure 11 – 1,4-Dioxane Concentrations downgradient of Allison.