REPORT ON
WATER LEVEL TESTING
UNDER REDUCED FLOW CONDITIONS
PALL LIFE SCIENCES - EVERGREEN AREA

PALL LIFE SCIENCES
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BACKGROUND

Pall Life Sciences, Inc. (PLS) has proposed reducing the combined extraction rate of the Evergreen System purge wells to accommodate other proposed changes to the groundwater remediation program. The Michigan Department of Environmental Quality (MDEQ) asked PLS to conduct a water level monitoring test (test) in the Evergreen Area in order to assist the parties in evaluating whether the proposed changes would cause any significant changes in groundwater flow direction. PLS recently completed the MDEQ-approved testing program to evaluate how water levels in monitoring and extraction wells responded to reductions in extraction rates at extraction wells LB-1, LB-3, and AE-3. This report sets forth the data gathered during the course of the test and the conclusions that PLS has drawn from these data.

PLS currently operates the Evergreen System extraction wells at a combined extraction rate of approximately 200 gallons per minutes (gpm). PLS is proposing to reduce these rates to accommodate additional flow from the Maple Road extraction well, which would be conveyed by a new transmission pipeline PLS proposes to install. The proposed pipeline would connect the Maple Road extraction system to the Evergreen System and the deep transmission line that currently conveys water from the Evergreen System to the Wagner Road facility for treatment. The deep transmission line has a capacity of approximately 200 gpm. Consequently, PLS would have to reduce purging from the Evergreen System wells before water from the Maple Road system could be added. The primary purpose of this work is to determine whether reduced extraction rates would result in significant changes in groundwater flow directions currently observed in the Evergreen System Area.

HYDROGEOLOGICAL SETTING

The hydrogeological setting of the Evergreen Area has been described in several reports, the most recent report being the Evergreen Review, dated May 10, 2007. Since the preparation of that report, new borings/monitoring wells have been installed (MW-120s/d, MW-121s/d, and MW-122s/d), providing additional insight into the hydrostratigraphy and 1,4-dioxane distribution in the Evergreen Area. (For this report, we refer to a shallow and a deep aquifer. In previous reports, these aquifers have been categorized as Unit D_2 and Unit E, respectively.)

Updated cross-sections have been prepared using data from the new wells. These cross-sections, along with a figure showing the test borings/monitoring wells and cross-section locations, are provided in Appendix 1.

As depicted in the attached cross-sections, there is a distinct separation between these two shallow and deep aquifers in most of the Evergreen Area. To the extent that these two aquifers communicate, it would be in the area of Rose and Valley. The shallow aquifer is the primary aquifer associated with the transport of 1,4-dioxane in the Evergreen Area. The deeper aquifer generally lies above bedrock and is not present at all of the well/boring locations in the Evergreen Area and is poorly developed (low transmissivity) at other locations, such as MW-122d.

Data from the recent deeper wells in the Evergreen Area have brought clarity to the question of whether the Dupont Area wells were completed in the shallow or deep aquifer. There appears to be a "split" within the shallow aquifer in the northwest portion of the Evergreen Area, near Dupont and the intersection of Dexter and Rose. This area is shown on Cross-Section D-D'. Wells completed in the lower portion of the shallow aquifer are MW-121d, 465 Dupont, MW-77, MW-54d, and MW-55. The lower and upper portions of the shallow aquifer appear to merge to the east, near MW-122d and 373 Pinewood.

MW-100 is the only well in the deep aquifer in the Evergreen Area where 1,4-dioxane at concentrations above 85 micrograms per liter has been detected. 1,4-Dioxane from this area has not migrated toward the north, as evidenced by the absence of 1,4-dioxane at 373 Pinewood, MW-113 (4 parts per billion detected during the test boring), MW-117 (test boring), MW-120d, and MW-122d.

DATA COLLECTION AND PROCESSING

TEST DESIGN

This work was proposed in a work plan provided by PLS to the MDEQ on December 8, 2008. The MDEQ provided PLS with its comments on December 12, 2008. These comments were incorporated into the plan or otherwise resolved by PLS in subsequent e-mail exchanges.

The test involved monitoring atmospheric pressure and water level data during three periods of different extraction conditions. The dates and extraction conditions during these periods are detailed in 1.

Table 1 – Testing Periods

Test Period	Start Date/Time	End Date/Time	Flow Rate LB-1 (gpm)	Flow Rate LB-3 (gpm)	Flow Rate AE-3 (gpm)
Pre-Testing	1/21/09 AM	1/29/09 12:00 PM	100	85	15
Reduced Flow – Period 1	1/29/09 12:00 PM	2/5/09 12:00 PM	50	50	0
Reduced Flow – Period 2	2/5/09 12:00 PM	2/16/09	0	0	0

The data collection was generally as proposed in the work plan. Water levels were recorded using both hand measurements and pressure transducers. Transducers were installed in some wells originally scheduled for water level measurements to be collected by hand. Table 2 indicates which wells were used for the testing and the types of measurements obtained from the wells. The wells used in the test are shown on Figure 1.

Table 2 – Evergreen Area Water Level Test, Wells and Measurement Method

Pressure Transducer and Electric Tape	Electric Tape Only
373 Pinewood - Shallow	AE-3
LB-1	LB-3
LBOW-1	MW-104
MW-100	MW-110
MW-101	MW-118

MW-107	MW-17
MW-113	MW-400 Clarendon
MW-117	MW-47s
MW-120d	MW-54d
MW-120s	MW-54s
MW-121d	**MW-72d**
MW-121s	MW-72s
MW-122d	MW79s
MW-122s	MW-81
MW-47d	MW-88
MW-77	MW-91
MW-92	MW-BE-1d
MW-98s	MW-KD-1s
MW-BE-1s	
MW-KD-1d	
MW-KZ-1	

Bold = Wells Interpreted to be in the Deep Aquifer

BAROMETRIC DATA

Water level data often respond to barometric pressure changes. To understand the influence that barometric pressure had on water levels during the test, two In-Situ BaroTroll transducers were placed near LB-1. The BaroTroll transducers were synchronized with the pressure transducer to record at a frequency of two minutes. Electronic files of the barometric pressure data is provided in digital form in Appendix 2.

The raw barometric data required no adjustments. Barometric data are represented graphically, as a backdrop on water level hydrographs prepared for this report.

WATER LEVEL DATA

Water level data collected during the test using transducers are provided digitally in Appendix 2. Field recording sheets for water level data collected by hand are provided in Appendix 3. Groundwater elevation data are provided in Table 3.

Recording Devices

Water level data were collected using two methods: hand measurements using an electric water level indicator and pressure transducers. The hand measurements were collected using either a KECK or QED water level indicator. The pressure transducers used for the study were either the In-Situ MiniTroll Pro or the In-Situ LevelTroll 300. Specifications of the pressure transducers used during the test are provided in Appendix 4.

Pressure Transducer Measurements

Pressure transducers were installed in 21 selected wells in the Evergreen Area. The LevelTrolls were secured to a stretch-resistant line and tied to a hanger (thinly-sliced 2-inch PVC pipe), which was set onto the top of the well. This allowed the level trolls to hang in the center of the well and be removed and reset at the same depth (after periodic transducer downloading). The MiniTrolls were set using the supplied vented cable. The MiniTrolls were hung from the top of the well, consistent with the Level Trolls; however, the MiniTrolls were not removed once they were installed, as they could be downloaded by connecting the In-Situ Communication cable directly to the vented cable.

The pressure transducers were synchronized to a field laptop computer and programmed to collect data at two-minute intervals. The raw digital data for the 21 pressure transducers is provided in digital form in Appendix 2.

The MiniTrolls are vented or "gauged" pressure sensors; a vent tube in the cable applies atmospheric pressure to the back of the strain gauge. Vented sensors thus exclude the atmospheric or barometric pressure component; therefore, no barometric compensation was applied to data from the MiniTrolls.

Data from the non-vented LevelTrolls is in "absolute" pressure and, therefore, required barometric compensation (subtraction of barometric data from the BaroTrolls) to exclude the barometric pressure component. The compensation was done using software provided with the BaroTrolls. The difference between absolute and gauged measurements may be represented by a simple equation: $P_{gauge} = P_{absolute} - P_{atmosphere}$

Water Level Indicator Measurements

The water-tight caps on the selected test wells were opened on January 20, 2009, to allow for equilibration to atmospheric conditions. A full round of static water level measurements were collected on January 21, 2009, from the selected test wells. This data represents the pretest conditions. An electric water level indicator was lowered into each well to a depth corresponding to the water level surface. The depth to water relative to the surveyed top-of-casing at each well was recorded onto the static water level field sheet.

A second round of static water level measurements was completed on February 3, 2009. This event was performed to monitor the groundwater levels approximately five days after the first test period, where the pumping rates in both LB-1 and LB-3 were reduced to 50 gpm and AE-3 was reduced to 0 gpm.

The third and fourth rounds of static water level measurements were collected on February 10 and 16, 2009, respectively. These monitoring events were completed to monitor the groundwater levels approximately five and eleven days after the pumping rates in LB-1 and LB-3 were reduced to 0 gpm (AE-3 was still at 0 gpm). Static water level measurements were collected by hand on January 21 and February 3, 10, and 16, 2009, from the selected test wells.

The groundwater elevation data collected by hand measurements have been compared to the groundwater elevation data obtained from the pressure transducer measurements. The comparison is provided as Table 4.

NOTABLE EVENTS DURING THE TEST

During the testing period, a significant rain event occurred and there was a significant loss of snow cover. Almost all the wells used for the testing are flush mounted. Although the wells are normally sealed with water-tight caps, the wells had to be left open during the test. There is some indication that, at limited well locations, water from surface runoff entered into the well during the test period. This was an unavoidable circumstance of the weather conditions during the test. The best indicator for this occurring was a temperature change in the well recorded by the transducers. Wells that clearly experienced some water infiltration include: MW-100, MW-101, MW-113, MW-120d, MW-120s, MW-121, MW-122d, and MW-47d. At all wells, except MW-122d, these changes were very minor and easily accounted for in the analysis. At MW-122d, water entered the casing and rendered portions of the data collected from this well during the test temporarily unusable.

DATA ANALYSIS

The data from the test have been processed to produce hydrographs and potentiometric surface maps.

HYDROGRAPHS

Hydrographs of water level data collected during the test have been prepared and are provided in Appendix 5. A summary hydrograph, compiling all the individual well hydrographs, has also been prepared and is provided in Appendix 5.

The barometric pressure during the test is shown on all the hydrographs. During the testing period, the barometric pressure ranged from approximately 28.26 to 29.52 inches of mercury (31.92 to 33.35 feet of water).

It is clear from the hydrographs that the wells responded to barometric pressure changes, which varied considerably through the test. Recovery trends in water levels can be somewhat difficult to observe in the hydrographs due to the influence barometric pressure changes have on the water levels.

The response of the wells to changes in extraction rates is evident on many of the hydrographs. These changes are initially seen as an inflection in the graphs at the time flow changes occurred. All the shallow wells appeared to respond to the test. The only exceptions are MW-KZ-1, MW-117, and MW-98s (MW-98s was used as a background well). The testing supports the conclusion that MW-KZ-1 and MW-117 are not hydraulically connected to either of the aquifers. This disconnect is also indicated by the wells' anomalously high water levels. MW-117 has been shown in a previous analysis to be completed in hydrofacies higher in elevation. MW-KZ-1 is completed in an area where the shallow aquifer is poorly developed and/or absent. Data from MW-117 and MW-KZ-1 were not contoured in the shallow potentiometric surface maps based on the findings made from this test.

In the deeper wells, the response to the testing was more subtle. There are indications of recovery at both MW-120d and MW-100. Water entering the well casing at MW-122d made data from that well unusable in determining whether recovery occurred at this location.

As expected, the data suggest there was some recovery occurring at the end of each phase of the test. This is consistent with the fact that the testing period was, by necessity, relatively short compared to the length of time the extraction wells have been operating. It does not appear, however, that any remaining recovery would affect groundwater flow directions.

POTENTIOMETRIC SURFACE MAPS

Potentiometric surface maps have been prepared for the shallow aquifer to assist in the analysis of the water level data. The maps were prepared using water level measurements collected from the monitored groundwater wells. Extraction well water level data are also shown on the potentiometric surface maps. These data have not been corrected for well losses, because the primary purpose of this testing was to look at how water levels responded to changes in extraction rates. Water level data for the deep aquifer has been plotted, but no potentiometric surface maps have been prepared for this aquifer. Although potentiometric surface maps for the deep aquifer have been prepared in the past, these maps included data from the Dupont Area wells. The recent investigations discussed above have revealed that the Dupont Area wells are properly included in the shallow aquifer. After excluding the water level data from the Dupont wells, there are insufficient data points in the deep aquifer (four total) to support a potentiometric surface depiction for this aquifer.

The following potentiometric surface maps and water level data plots have been prepared:

- Figure 2 is a potentiometric surface map for the shallow aquifer and Figure 3 is a water level data plot for the deep aquifer prepared using pretest data collected on January 21, 2009.

These maps represent the head conditions after LB-1, LB-3, and AE-3 have been running at their current extraction rates for a considerable period of time.

- Figure 4 is a potentiometric surface map for the shallow aquifer and Figure 5 is a water level data plot for the deep aquifer prepared using data collected on February 3, 2009, five days after the initial flow rate reduction.

- Figure 6 is a potentiometric surface map for the shallow aquifer and Figure 7 is a water level data plot for the deep aquifer prepared using data collected on February 10, 2009, five days after the extraction wells were shut off.

- Figure 8 is a potentiometric surface map for the shallow aquifer and a Figure 9 is a water level data plot for the deep aquifer prepared using data collected on February 16, 2009, eleven days after the extraction wells were shut off.

SUMMARY OF FINDINGS

The primary purpose of this testing was to determine what effect, if any, a reduction in flow would have on the groundwater flow directions in the Evergreen Area. More specifically, the parties sought to determine whether the proposed extraction rate reductions would create conditions that would allow the plume to migrate in a direction significantly different than its current path. As set forth below, the testing data indicate that reducing or even terminating groundwater extraction from the Evergreen System extraction wells (LB-1, LB-3, and AE-3) would not significantly affect the direction of groundwater flow in this area.

POTENTIAL FOR CHANGES IN FLOW DIRECTIONS - SHALLOW AQUIFER

Pretesting data, collected prior to extraction well flow reductions, show a relatively steep hydraulic gradient from the northwest portion of the Evergreen Area (MW-121s/d and MW-120s) toward the southeast. Wells east of the extraction show a hydraulic gradient to the east. There is no indication of a flow component to the north or northeast.

Potentiometric surface maps prepared under reduced flow conditions have a similar overall configuration to the pretesting map. Even when allowing for additional recovery in wells influenced by pumping, no significant changes are expected in the potentiometric surface configuration. In particular, no northern or northeastern flow is expected; in part, because groundwater levels in the wells north of the plume area remain significantly higher than water levels to the south.

POTENTIAL FOR CHANGES IN FLOW DIRECTIONS – DEEPER AQUIFER

There are a limited number of wells completed in the deeper aquifer in the Evergreen area. These data were plotted but not contoured for this analysis. In previous PLS contour maps, deeper data from the Dupont area had been included in potentiometric surface maps for this aquifer. Data from newer borings in this area indicate that the Dupont area contamination is located within the shallow aquifer. As such, data from wells in this area are not shown on the deep aquifer maps.

In the deeper wells, the response to the testing was less dramatic than in the shallow aquifer wells. There are, however, indications of recovery at both MW-120d and MW-100. Water entering the well casing at MW-122d made data from this well unusable in determining if recovery occurred at this location.

The data from the deep aquifer wells suggest that that flow in the deep aquifer will be more to the east under reduced flow conditions. Consequently, reducing or terminating extraction from the Evergreen System purge wells will likely reduce the potential that 1,4-dioxane in the area of MW-100 might migrate north or northeast within the deep aquifer.

CONCLUSIONS

Data collected from this test indicate that reducing or terminating groundwater extraction from the Evergreen extraction wells will not cause a significant change in the groundwater flow directions in the Evergreen Area in the shallow aquifer, which is the primary conduit for 1,4-dioxane in this area. This interpretation is supported by and reflected in the potentiometric surface maps attached to this report. The water level data suggests any portion of the shallow plume migrating beyond the capture of the Evergreen System wells will migrate to the east under reduced flow conditions and ultimately merge with the Unit E plume. There are no data that suggest that the Evergreen plume is currently migrating to the northeast, or that it would migrate to the northeast if groundwater extraction from the Evergreen System purge wells is reduced or terminated.

Similarly, there are no data gathered from the deep aquifer wells during this investigation that suggest that reducing or terminating extraction from the Evergreen System purge wells will cause groundwater in the deep aquifer to flow to the north or northeast. The groundwater quality data from the recently installed wells in the deep aquifer (MW-120d and MW-122d), along with data from 373 Pinewood, indicate 1,4-dioxane has not migrated north of MW-100 with the Evergreen System extraction wells operating at full capacity. This is also supported by the boring drilled at MW-117. The data gathered during this investigation indicate that flow in the deep aquifer may be more to the east under reduced flow conditions. Consequently, to the extent reduced or terminated extraction affects groundwater flow in the deep aquifer, it is likely to reduce the potential that 1,4-dioxane in the area of MW-100 might migrate north or northeast. The most probable flow path for the 1,4-dioxane at MW-100 under reduced flow conditions would continue to be to the east, where the head in the deeper aquifer declines considerably.

Geological data from the installation of MW-120s/d, MW-121s/d, and MW-122s/d have also provided better insight into the relationship between the Dupont Area wells (465 Dupont, MW-77, MW-54d, and MW-55) and the shallow and deep aquifers. It has become even more evident that these wells are in an area where the shallow aquifer is "split." East of the Dupont aquifer, the aquifer merges to form one aquifer (see Cross-Section D-D'). This test and previous pump tests have shown that this area responds hydraulically to pumping changes at the extraction wells. Data from MW-121s/d have now demonstrated that 1,4-dioxane in the Dupont Area does not migrate northwest. Groundwater flow away from the Dupont Area is clearly toward the east (extraction wells), not to the north, where there is a considerably higher hydraulic high in the same aquifer (MW-120s). Data from this test suggest this flow condition will not change under reduced flow conditions.