STATE OF MICHIGAN

IN THE CIRCUIT COURT FOR THE COUNTY OF WASHTENAW

ATTORNEY GENERAL for the
STATE OF MICHIGAN, et al,
MICHIGAN NATURAL RESOURCES
COMMISSION, MICHIGAN WATER
RESOURCES COMMISSION, and
MICHIGAN DEPARTMENT OF NATURAL
RESOURCES,

Plaintiffs,

vs

GELMAN SCIENCES INC.,
a Michigan corporation,

Defendant.

Case No. 88-34734-CE

Hon. Donald E. Shelton

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Affidavit of Neven Kresic, P.G., Ph.D.

AFFIDAVIT OF NEVEN KRESIC, P.G., Ph.D.

I, Neven Kresic, P.G., Ph.D., declare as follows:

1. The matters set forth in this declaration are of my personal knowledge, unless indicated otherwise, and if called upon to do so I could competently testify to the truth of the matters in this affidavit.

2. I am a Senior Principal Hydrogeologist at MACTEC Engineering and Consulting, Inc. (MACTEC) located at 21740 Beaumeade Circle, Suite 150, Ashburn, Virginia. MACTEC is engineering, construction, science, and consulting company that has been in business for over 60 years, and has approximately 3,500 employees in more than 80 offices throughout the United States.

3. I have a Ph.D. degree in Geology from the University of Belgrade; a M.S. degree in Hydrogeology from the University of Belgrade; and a B.S. degree in Hydrogeologic Engineering from the University of Belgrade.

4. I am a registered professional geologist in the states of Pennsylvania, Georgia, and Virginia; I am a professional hydrogeologist certified by the Certification Board of the American Institute of Hydrology; I am a Certified Ground Water Professional by the National Ground Water Association.

5. I was professor at Belgrade University, Yugoslavia and Texas Christian University, Fort Worth, Texas where I taught courses in Hydrogeology, Hydrology, Groundwater Modeling, Groundwater Development and Groundwater Remediation. I have also taught courses in Advanced Quantitative Hydrogeology at Georgia State University, and short professional courses in Groundwater Modeling, Groundwater Remediation, and Surface Water-Groundwater Interactions for the National Ground Water Association.

6. In 1991, I was granted Senior Fulbright Scholarship for research at the National Center of the United States Geological Survey in Reston, Virginia, and the George Washington University, Washington, D.C.; the research was related to groundwater modeling and characterization of contaminant fate and transport.

7. I am a founding member of the Ground Water Modeling Interest Group sponsored by the National Ground Water Association, a Co-Chair of the Karst Commission of the International Association of Hydrogeologists, and member of the International Water Association where I serve as a committee member of the Groundwater Restoration and Management Specialty Group. I have authored more than 50 papers and six books including *Groundwater Resources: Sustainability, Management, and Restoration* (published by McGraw Hill in 2009) and *Hydrogeology and Groundwater Modeling, Second Edition* (published by CRC Press/Taylor & Francis in 2007).

8. In 2006 I was elected Vice-President for International Affairs of the American Institute of Hydrology.

9. I have been previously deposed and provided expert testimony in the contested case administrative proceeding involving Gelman Sciences, Inc. (d/b/a Pall Life Sciences ("PLS") and various petitioners regarding issues related to groundwater – surface water interactions in presence of a 1,4-dioxane groundwater plume.

10. My Curriculum Vitae setting forth my education and experience in the fields of geology, hydrology, hydrogeology, and groundwater modeling is attached as Exhibit A to this affidavit.

BACKGROUND

11. I prepared an expert report, dated August 05, 2009, that sets forth in detail the opinions I have formed regarding this matter and the bases for those opinions; the report is attached as Exhibit B to this affidavit.

12. In formulating my opinions presented herein and in the above-referenced report, I have relied upon:

a. my education and experience in the fields of geology, hydrogeology, hydrology, and groundwater modeling;
b. my experience in the assessment of groundwater flow and contaminant migration;
c. site reports regarding the characterization and remediation of groundwater contamination;
d. my personal review and MACTEC staff review, under my direct supervision, of documents prepared by others concerning the matters at hand; and
e. reference texts accepted and considered reliable by experts in the fields of environmental engineering and hydrogeology.

OPINIONS

12. Opinion 1 The analysis of the historic groundwater elevations recorded in the D2 aquifer, as well as the hydrogeologic conditions in the subsurface, indicates that possibility for groundwater flow direction toward northeast in the Evergreen area is nonexistent. Groundwater flow directions in the D2 (shallow) aquifer in the Evergreen area are actually away from the proposed northern boundary of the expanded "Prohibition Zone". They are converging from the topographic highs and groundwater recharge areas generally located to the north and south of the D2 plume

in this area. This is true for both pumping and nonpumping conditions at groundwater extraction wells LB-1, LB-3 and AE-1. Groundwater flow in the D2 aquifer leaves the Evergreen Area in the easterly direction, with or without pumping of the three extraction wells.

13. Opinion 2 The regional groundwater flow direction in the Unit E (deep) aquifer in the Evergreen Area is generally to the east-southeast, i.e., toward the regional discharge area represented by the Huron River, for both pumping and non-pumping conditions in the Unit D2 aquifer. Based on the hydraulic gradients between the area of the current 1,4-dioxane plume footprint in the Unit E aquifer and the proposed new northern limits of the prohibition zone, there would be no migration of 1,4-dioxane across this boundary, for either pumping on non-pumping conditions in the Unit D aquifer.

14. Opinion 3 Geologic, hydrogeologic, and hydrodynamic conditions in the Evergreen area, Ann Arbor, Michigan clearly show existence of two distinct aquifers named “D2” and “E”, or “shallow” and “deep” aquifer respectively. These two aquifers are separated by a low-permeable confining unit and behave as two separate hydraulic entities with a limited hydraulic connection. Groundwater elevations recorded in monitoring wells screened in the two aquifers are different and clearly reflect the existence of the confining layer that separates them and the groundwater recharge conditions. For this reason any contouring of groundwater elevations and subsequent analyses of either local or regional groundwater flow directions cannot be made by using groundwater level measurements in wells screened in different aquifers and at different depths.

15. Opinion 4 The analysis of groundwater flow direction in the Evergreen Area performed by Michigan Department of Environmental Quality (DEQ) fails to account for the geologic, hydrogeologic, and hydrodynamic conditions in the subsurface. Groundwater elevations recorded in the monitoring wells are interpreted

incorrectly, and groundwater contour maps are created by arbitrary excluding various monitoring wells. DEQ also suggest using groundwater elevations recorded in monitoring wells screened in two distinct aquifers interchangeably thus ignoring standard industry practice in interpreting results of geologic, hydrogeologic, and hydrodynamic investigations. The results of the reduced pumping test are interpreted incorrectly including failure to account for the influence of barometric pressure on groundwater elevations recorded in monitoring wells. Among other things, these analytical errors have led the DEQ to discount valid data from the MW-120s monitoring well.

16. Opinion 5 For all of the above mentioned reasons, the DEQ interpretation of possible groundwater flow directions in the Evergreen area, including under hypothetical scenarios, is not based on widely accepted industry practices and scientific principles of groundwater flow. Interestingly, however, all groundwater contour maps for the Evergreen area enclosed with the DEQ analysis (Figures 1 through 5), including those created by DEQ, clearly show that groundwater flow leaving the Evergreen area is ultimately toward east, in both D2 (shallow) and E (deep) aquifers.

I declare under penalty of perjury under the laws of the United States of America that the foregoing is true and correct and can testify to the above if called as a witness in this matter. Executed this 12 day of August, 2009 in Ashburn, VA.

By: Neven Kresic
Neven Kresic, Ph.D.

Subscribed and sworn to before
me this 12th day of August, 2009.

Beverly Lukowski Atkins

Notary Public, Beverly Lukowski Atkins Loudoun County, Virginia
My commission expires: June 30, 2012

Analysis of Groundwater Flow Direction
Evergreen Area, Ann Arbor, Michigan

Prepared by:

MACTEC

MACTEC Engineering and Consulting, Inc.
3200 Town Point Drive NW, Suite 100
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August 05, 2009

MACTEC Project No. 6122090054

Analysis of Groundwater Flow Direction
Evergreen Area, Ann Arbor, Michigan

Prepared by:
MACTEC Engineering and Consulting, Inc.
Kennesaw, Georgia

Neven A. Kresic, Ph.D.

John M. Quinn

August 05, 2009

MACTEC Project No. 6122090054

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ATTACHMENT A

1.0. INTRODUCTION

MACTEC Engineering and Consulting, Inc. (MACTEC) was retained to assess the groundwater flow directions in the Evergreen area, a part of the Pall Life Sciences (PLS) site in Ann Arbor, Michigan. Additionally, MACTEC was requested to review and comment on an analysis of groundwater flow direction in the Evergreen area performed by Michigan Department of Environmental Quality (DEQ).

The groundwater contamination with 1,4-dioxane at the PLS site has been investigated in detail for more than two decades, and aggressively remediated with an extensive groundwater extraction and above-ground treatment ("pump-and-treat") system consisting of vertical and horizontal pumping wells. The site contains numerous investigative borings and monitoring wells installed to characterize the underlying geologic conditions (lithology), hydrogeologic conditions including groundwater flow directions, and the groundwater contamination with 1,4-dioxane.

For the preparation of this report MACTEC has reviewed information on the investigative borings and monitoring wells from an extensive database maintained by PLS including historic and most recent (July 2009) measurements of groundwater elevations. We have also reviewed various reports prepared by PLS including "Comprehensive Proposal to Modify Cleanup Program" (PLS, 2009a), and "Report on Water Level Testing Under Reduced Flow Conditions, Pall Life Sciences – Evergreen Area" (PLS, 2009b).

The main objective of this analysis was to evaluate if the groundwater flow in two main aquifers underlying the Evergreen area, under reduced pumping conditions, can leave the area to the north-northeast thus crossing a newly proposed prohibition zone. The northern limit of this exclusion zone is along Henry Street and Sequoia Parkway (which continues as North Circle to the east), or approximately 600 feet north of the MW-123 monitoring well cluster shown in Figure 1. For reference, the monitoring well cluster MW-120 shown in Figure 1 is located on the northern perimeter of the proposed prohibition zone, adjacent to Sequoia Parkway.

2.0. PHYSICAL SETTING

2.1. Site Location and Setting

The Evergreen area is located generally east of the intersection of highway I-94 and state highway 14 in Ann Arbor, Michigan (Figure 1). The same figure includes monitoring wells installed by PLS including several wells with their identification names for orientation. The major portion of the Evergreen area corresponds roughly to topographic lows generally south of Dexter Road and extending parallel to it (green shades on the map). Land surface elevation increases north and south of the central valley, reaching 995 feet above North American Vertical Datum of 1988 (NAVD 88), or approximately 90 feet higher than the central topographic low. The site topography is depicted in three dimensions and from various view angles in Attachment A.

2.2. Site Geology and Hydrogeology

There are two major water-bearing units present in the Evergreen area. In descending order (from land surface downward), they are the D2 aquifer (Unit D2) and the E aquifer (Unit E). At other portions of the site, Unit D2 is connected to shallower aquifers (such as the C3 in the PLS site area). To the east and south of Valley Drive (such as near MW-72s/d), an aquifer of similar depth and geologic characteristics as the D2 has been referred to in previous reports as the E1 unit. These various names represent laterally different areas of the PLS site in Ann Arbor, but are all hydraulically equivalent to the shallow D2 aquifer. The D2 aquifer is generally comprised of sands and gravels.

Unit E is the lower regional aquifer and generally also consists of sand and gravel. This aquifer is often positioned immediately above the bedrock surface, and is thin or not present in some portions of the site area. In the Evergreen area, the two aquifers (Unit E and D2) are separated by a confining layer (aquitard) of predominantly clayey sediments and dense till. This confining layer in the Evergreen area is fairly thick and continuous except in two isolated locations discovered during drilling and installation of monitoring wells.

Overlying the shallow aquifer system (Unit D2) is the upper semi-confining unit generally consisting of low permeable fine-grained sediments (silts and clays).

Figures 2 through 4, and Attachment A illustrate the general subsurface geology of the study area, depicting configuration and thickness of the confining unit separating the shallow (Unit D2) and deep (Unit E) aquifers. The three-dimensional model of the subsurface was constructed using information from 57 borings and wells that penetrated into or through the confining unit. As can be seen, the confining unit ranges in thickness from about 6-10 feet in the vicinity of monitoring well MW-54D, to more than 100 feet in the far northwest and south-southeast portions of the mapped area (Figure 3). The confining unit becomes progressively thinner in the east-southeast and it eventually disappears further east of MW-72D where Units D2 and E apparently merge into one regional aquifer.

At the locations of monitoring well MW-95 (far southwest corner of the mapped area) and soil boring GSI-96-01 the confining unit is absent. It is likely that the groundwater contamination with 1,4-dioxane in the Unit E (deeper) aquifer is a result of the contaminant migration from the Unit D2 (shallow) aquifer through the confining unit where the confining unit it is relatively thin and/or absent. This migration is facilitated by a generally downward vertical hydraulic gradient between the two aquifers, as explained in Section 4.0.

3.0. GROUNDWATER FLOW DIRECTIONS

3.1. Unit D2 Aquifer

The groundwater flow directions in the Unit D2 (shallow) aquifer in the Evergreen area represent a textbook example of the influence of natural groundwater recharge areas as explained in a public outreach circular by the United States Geological Survey (USGS). This publication, which describes general principles of groundwater flow and interactions between surface water and groundwater, clearly states that aquifer recharge is dominant in topographically high areas and groundwater flow is away from such areas, from higher hydraulic heads toward lower hydraulic heads, i.e., in a downgradient direction

(Winter, C., et al., 1998). In the Evergreen area, for example, this is evident from the higher groundwater elevation recorded at monitoring well MW-120s which is the closest to the topographic high and the major recharge area north of it (see Figure 1). As groundwater in the shallow aquifer flows away from the northern recharge area and MW-120s, the hydraulic head decreases in the southerly direction so that all other wells screened in the D2 (shallow) aquifer south of MW-120s have lower groundwater elevations. At the same time, the slope of the underlying confining layer over which this shallow groundwater flow is taking place is also from the north to the south as shown in three-dimensional views in Figure 4 and Attachment A.

Similarly, groundwater flow is away from the topographic high located around Hilltop and Highlake Streets, i.e., the flow direction is northerly from this major recharge area towards the centrally located low-lying valley roughly parallel to Dexter Road. In other words, the groundwater flow in the D2 aquifer is converging from the topographic highs and groundwater recharge areas generally located to the north and south of Dexter Road (see Figures 5 and 6). In the topographically lower central valley, the groundwater flow direction is to the east, towards the city of Ann Arbor and Huron River, which is the regional groundwater discharge zone. This decrease in groundwater elevations to the east generally follows the slope of both the topographic relief and the underlying confining layer as shown in Figure 1 and Figure 2.

Locally around groundwater extraction (remediation) wells LB-1 and LB-3 the groundwater flow direction in the D2 aquifer is diverted towards these pumping centers as shown in Figure 5. However, as described above, further to the east, i.e., east of MW-47 and MW-92, the flow direction is easterly for both pumping and non-pumping conditions as demonstrated in Figures 5 and 6.

In summary, the groundwater flow directions in the D2 (shallow) aquifer in the Evergreen area are away from the proposed northern limit of the expanded prohibition zone toward the south. The analysis of historic groundwater elevations recorded in the D2 aquifer and the results of the reduced pumping test (see Section 4.0), as well as the hydrogeologic conditions in the subsurface, indicate that possibility for groundwater flow direction toward northeast and across the new proposed prohibition zone is nonexistent.

3.2. Unit E Aquifer

As depicted in Figures 7 and 8, the groundwater flow directions in the Unit E (deep) aquifer in the Evergreen area are generally to the east-southeast, i.e., the regional discharge area represented by the Huron River. In the westernmost portion of the mapped area the local flow direction is from monitoring well MW-100 toward monitoring well MW-122d, i.e., from south to north. At the same time, however, the groundwater elevations at MW-120d are higher than at MW-122d for both pumping (Figure 7) and non-pumping (Figure 8) conditions. This results in the overall regional flow direction in the Evergreen area to the east-southeast as shown with arrows on both maps.

The most convincing evidence that the overall groundwater flow in the Unit E aquifer is not to the north-northeast under reduced or non-pumping conditions and that the current plume footprint will not migrate to the northern limit of the proposed prohibition zone is that:

(1) the cessation of pumping at the three extraction wells screened in the Unit D2 aquifer does not result in substantially different groundwater flow directions in the Unit E aquifer (Figure 8) when compared with the pumping conditions (Figure 7); in fact, the map in Figure 8 (non-pumping conditions) shows an even more pronounced easterly flow component;

(2) the shallow (Unit D2) aquifer is the primary aquifer associated with the transport of 1,4-dioxane in the Evergreen area, not the Unit E. The only well in the deep (Unit E) aquifer in the Evergreen area that has 1,4-dioxane at concentrations above 85 micrograms per liter is MW-100. 1,4-dioxane from this area has not migrated toward the north under past non-pumping and current pumping conditions, as evidenced by the absence of 1,4-dioxane at all Unit E wells to the north of MW-100: 373 Pinewood, MW-117 (test boring), MW-120d, MW-122d, and MW-123d (PLS, 2009b).

(3) the current 1,4 dioxane plume perimeter in the Unit E aquifer, i.e., where 1,4-dioxane is non-detect, is more than 2,000 feet south of the new proposed prohibition zone Absent a dramatic

change of groundwater flow direction – which all data show will not occur – it is not possible for the plume in the Unit E (deeper) aquifer to approach the new prohibition zone limit.

As indicated earlier, the Unit E and Unit D2 aquifers merge generally eastward where the confining unit that separates them becomes progressively thinner and eventually disappears altogether. In this portion of the PLS site the groundwater flow direction is also to the east-southeast and the regional groundwater discharge zone along the Huron River.

Hydrogeologic cross-sections in Figures 9 through 13 illustrate the relationship between the two aquifers in the Evergreen area including groundwater flow directions for both the pumping and non-pumping conditions. As can be seen, the changes in groundwater elevations and regional groundwater flow directions caused by the cessation of pumping are minimal in both aquifers.

4.0. SIGNIFICANCE OF HISTORIC AND RECENT WATER LEVEL MEASUREMENTS IN MONITORING WELLS

Over the course of more than two decades PLS has systematically collected an impressive amount of information on groundwater elevations measured in tens of monitoring wells screened in various water-bearing zones (aquifers) and at various depths, covering an area of several square miles. The regular monitoring program tracks the influence of the pump-and-treat groundwater remediation system and changes in groundwater elevations caused by seasonal variations in aquifer recharge. PLS has also conducted numerous aquifer pumping tests during which the groundwater elevations were measured in real time for several days or weeks. Most recently (in January-February of 2009), PLS performed a reduced pumping test in the Evergreen area designed to evaluate how water levels in monitoring and extraction wells responded to temporary reductions in extraction rates at extraction wells LB-1, LB-3, and AE-3, including a complete cessation of pumping for 11 days.

In general, groundwater elevations in the shallow (Unit D2) aquifer are generally higher than in the deeper (Unit E) aquifer and reflect the influence of groundwater recharge and the separation of the two aquifers by the confining unit. These differences are more pronounced closer to the topographic highs (main recharge areas), to the north and south of the low-lying area parallel to Dexter Road (Figure 1). The confining unit is also significantly thicker closer to the topographic highs and thinner in the low-lying portion of the Evergreen area (see Figure 3) which is an additional factor contributing to the differences in groundwater elevations recorded at the shallow and deep monitoring wells. For example, this difference at the monitoring well cluster MW-120, which is the closest to the northern recharge area, was 2.82 and 2.48 feet in February 2009 and July 2009 respectively, whereas at the monitoring well cluster MW-122 which is close to the low-lying area and has a thin confining layer, the difference was minimal: -0.03 and -0.07 feet respectively.

One additional factor that may be influencing variable differences between the groundwater elevations recorded in the shallow and deep aquifers is the ongoing pumping from the Unit D2 (shallow) aquifer. This pumping lowers the groundwater elevation in the shallow aquifer around the pumping centers (extraction wells LB-1, LB-3, and AE-1) which are located along Dexter Road, i.e., close to both the thinnest portions of the confining layer and the topographical lows where the natural hydraulic separation between the shallow and deep aquifers is the weakest. As a consequence, there may locally be a slight upward gradient from the Unit E (deep) aquifer to the Unit D2 (shallow) aquifer as in the case of monitoring well cluster MW-122. The cessation of pumping causes a slight redistribution of the groundwater elevations in the Unit E aquifer as shown in Figures 7 and 8.

A comparison of long-term and seasonal fluctuations of groundwater elevations at monitoring wells screened in the shallow and deep aquifers is shown in Figures 14 and 15 respectively. Regardless of the spatial location relative to the main recharge areas and the thickness of the confining unit, all monitoring wells screened in the shallow (Unit D2) aquifer show a remarkably similar and consistent response, confirming that they belong to the same hydraulically connected aquifer and clearly reflect the groundwater recharge pattern. As the groundwater elevation at individual wells increases or decreases seasonally and over the years, the differences between the individual wells do not significantly change in time. This means that the hydraulic gradients and groundwater flow directions also remain fairly constant in time, regardless of the general long-term and seasonal recharge conditions (e.g., prolonged droughts or wet periods). Monitoring wells screened in the deep (Unit E) aquifers show the same general pattern of groundwater level fluctuations (Figure 15), with the same conclusion.

As depicted in Figures 14 and 15, there is a clear upward trend of groundwater elevations recorded in both aquifers, starting in early 2008 and increasing in 2009 through July 2009, the last month with available data. This long-term recovery is unrelated to any changes in remedial groundwater extraction in the Evergreen area (at wells LB-1, LB-3, and AE-1/3), including during the reduced pumping test in January-February 2009 (the groundwater extraction with full pumping rates resumed in February 2009).

The following discussion relates the strong recovery of groundwater elevations in both aquifers with long-term aquifer recharge, and their importance for assessing current and possible future groundwater flow directions in the Evergreen area.

Fleck (1980) reported an average of approximately 20 percent of the average annual precipitation infiltrates glacial deposits and recharges the aquifers in the study area. Table 1 shows recorded annual precipitation in Ann Arbor for the last 20 years (1989-2008). During this period the average precipitation was 37.8 inches. 2007 was an average year, whereas 2008 had precipitation 10 percent higher than average. All years between 2002 and 2005 were lower than average, with year 2002 having the lowest recorded precipitation of 30.8 in. or 20 percent below average. The recovery of Unit D2 and Unit E aquifers from long-term low levels caused by the below-average precipitation in the period 2002-2005 was initiated during 2006 which had the highest recorded precipitation of 47.6 in. or 26 percent above average. Since both aquifers are overlaid by less-permeable sediments, the recovery has been delayed as the newly recharged water was migrating through these sediments. The full effects of the regional aquifer recovery (increased recharge) are reflected in a clear upward trend of the groundwater elevations starting in 2008, as recorded in monitoring wells screened in the two aquifers. As of July 2009, groundwater elevation recovered more than one foot from low levels recorded in early 2007 at all wells shown in Figures 14 and 15. In comparison, the recovery of groundwater elevations attributable to the complete cessation of pumping during the reduced pumping test in January-February 2009 was less than 0.5 feet at the wells monitored during the test and shown in Figures 14 and 15.

This analysis shows that the hydrogeologic characteristics including hydraulic gradients and interrelationships between various monitoring wells in the two aquifers, and therefore the resulting groundwater flow directions remain the same for a variety of hydrodynamic conditions including periods of prolonged droughts, natural aquifer recovery, and varying groundwater extraction at the three remediation wells in the Evergreen area.

5.0. ANALYSIS BY MICHIGAN DEPARTMENT OF ENVIRONMENTAL QUALITY

The analysis of groundwater flow direction in the Evergreen area performed by Michigan Department of Environmental Quality (DEQ, 2009) fails to account for the role of geologic, hydrogeologic, and hydrodynamic conditions in the subsurface. Groundwater elevations recorded in various monitoring wells are interpreted incorrectly, and groundwater contour maps are created by arbitrarily excluding various monitoring wells and/or mixing data from wells screened in different aquifers.

DEQ does not recognize the influence of aquifer recharge in the topographically high areas and the fact that groundwater flow is away from such areas, from higher hydraulic heads toward lower hydraulic heads, i.e., in a downgradient direction. Consequently, the groundwater elevation recorded at monitoring well MW-120s is interpreted as anomalously high by DEQ even though this well is the closest to the recharge area in the north where the higher hydraulic head is expected by default.

The suggested mixing of groundwater elevations recorded in monitoring wells which are screened in two distinct aquifers separated vertically by a confining layer ignores standard industry practice in interpreting results of geologic, hydrogeologic, and hydrodynamic investigations. In such cases groundwater elevations recorded at monitoring wells screened in the shallower aquifer should be contoured separately from the groundwater elevations recorded in the deeper aquifer. The groundwater flow boundary conditions including aquifer recharge, and the resulting groundwater flow directions in the two aquifers are different by default, and the suggested interchangeable use of data from monitoring wells in different aquifers would by default provide an erroneous potentiometric map which would not be representative of true groundwater flow directions in either shallow or deep aquifers.

The results of the reduced pumping test performed by PLS are interpreted incorrectly by DEQ, including failure to account for the natural aquifer recovery due to increased recharge and the influence of barometric pressure on groundwater elevations recorded in monitoring wells. Consequently, DEQ erroneously concludes that "the groundwater level recovery in well MW-120d was almost twice that observed in MW-120s (0.76 feet vs. 0.45 feet) indicating a greater degree of hydraulic connection to the deeper aquifer in which MW-120d was screened than to the interval over which MW-120s was screened" (Michigan DEQ, 2009).

The influence of barometric pressure changes on water levels in Wells MW-120s and MW-120d were removed from data collected during the reduced pumping aquifer test by calculating a barometric efficiency for the well and then using this efficiency to calculate and remove the influence from each water level data point. The barometric efficiency is a simple ratio of the water level change occurring in the well to the magnitude of corresponding barometric pressure change. First a plot of well water level and barometric pressure versus time was reviewed to identify periods when large barometric pressure changes occurred and appear to correlate with water level responses. The magnitudes of the respective changes during each of these periods were used to calculate barometric efficiencies using the following equation from Walton (1962):

Barometric Efficiency (BE) = Change in Water Level (ΔWL)/Change in Barometric Pressure (ΔBP)

Water levels were then corrected to remove barometric influence by multiplying the BE times the change in barometric pressure from a reference point (the start of data collection in this case), and then adding the result to the raw water level elevation. This correction results in an increase in water level to offset an increase in barometric pressure, or a decrease in water level to offset a decrease in pressure.

It should be noted that during the testing period, a major rain event occurred and there was a significant loss (melting) 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. At several well locations including MW-120s and MW-120d water from surface runoff entered into the well during the testing period (note the related label on the graphs in Figures 16 through 18). 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 (PLS, 2009b).

The impact of the barometric pressure on groundwater elevations recorded at MW-120s and MW-120s, and the effects of its removal are shown in Figures 16 through 18. As can be seen in Figure 18, both wells are reacting identically to the changes (fluctuations) of various hydrodynamic conditions acting upon the two aquifers during the testing period, including the regional natural background recovery (the increasing linear trend) and the oscillating or changing pumping rates. It is therefore apparent that MW-120d did not react in a significantly different manner than MW-120s during the test as speculated by DEQ.

In conclusion, the DEQ interpretation of possible groundwater flow directions in the Evergreen area, including under hypothetical scenarios, is not based on widely accepted industry practices and scientific principles of groundwater flow. Interestingly, however, all groundwater contour maps for the Evergreen area enclosed with the DEQ analysis and shown in Figures 1 through 5 of the DEQ document (Michigan DEQ, 2009), including those created by DEQ, clearly show that groundwater flow leaving the Evergreen area is ultimately toward the east, in both the Unit D2 (shallow) and Unit E (deep) aquifers.

6.0. CONCLUSIONS

Geologic, hydrogeologic, and hydrodynamic conditions in the PLS Evergreen area clearly show existence of two distinct aquifers named "Unit D2" and "Unit E", or "shallow" and "deep" aquifer respectively. In the Evergreen area, these two aquifers are separated by a low-permeable confining unit and behave as two separate hydraulic entities with limited hydraulic connection. Groundwater elevations recorded in monitoring wells screened in the two aquifers are different and clearly reflect the groundwater recharge conditions and existence of the confining layer that separates them.

Groundwater flow directions in the Unit D2 (shallow) aquifer in the Evergreen area are away from the proposed new limits of the prohibition zone. They are converging from the topographic highs and main groundwater recharge areas generally located to the north and south of the Evergreen D2 plume. This is true for both pumping and non-pumping conditions at groundwater extraction wells LB-1, LB-3 and AE-3. Groundwater flow in the Unit D2 aquifer leaves the Evergreen area in the easterly direction, with or without pumping of the three extraction wells. The analysis of the historic groundwater elevations recorded in the Unit D2 aquifer and the hydrogeologic conditions in the subsurface indicate that possibility for groundwater flow toward northeast and the proposed new limits of the prohibition zone is nonexistent.

The regional groundwater flow direction in the Unit E (deep) aquifer in the Evergreen area is generally to the east-southeast, i.e., the regional discharge area represented by the Huron River, for both pumping and non-pumping conditions in the Unit D2 aquifer. Based on the hydraulic gradients between the area of the current 1,4-dioxane plume footprint in the Unit E aquifer and the proposed new northern limits of the prohibition zone, there would be no migration of 1,4-dioxane across this boundary, for either pumping on non-pumping conditions in the Unit D2 aquifer.

The analysis of groundwater flow direction in the Evergreen area performed by Michigan Department of Environmental Quality (DEQ) fails to account for the geologic, hydrogeologic, and hydrodynamic conditions in the subsurface. Groundwater elevations recorded in the monitoring wells are interpreted incorrectly, and groundwater contour maps are created by arbitrary excluding various monitoring wells. The analysis also ignores standard industry practice in interpreting results of geologic, hydrogeologic, and hydrodynamic investigations. For these reasons, the DEQ interpretation of possible groundwater flow directions in the Evergreen area, including under hypothetical scenarios, is erroneous and not representative of either the shallow (Unit D2) or deep (Unit E) aquifers.

7.0. LIST OF CITED REFERENCES

PLS, 2009a. Comprehensive Proposal to Modify Cleanup Program. Pall Life Sciences, Ann Arbor, Michigan.

PLS, 2009b. Report on Water Level Testing Under Reduced Flow Conditions, Pall Life Sciences – Evergreen Area. Pall Life Sciences, Ann Arbor, Michigan.

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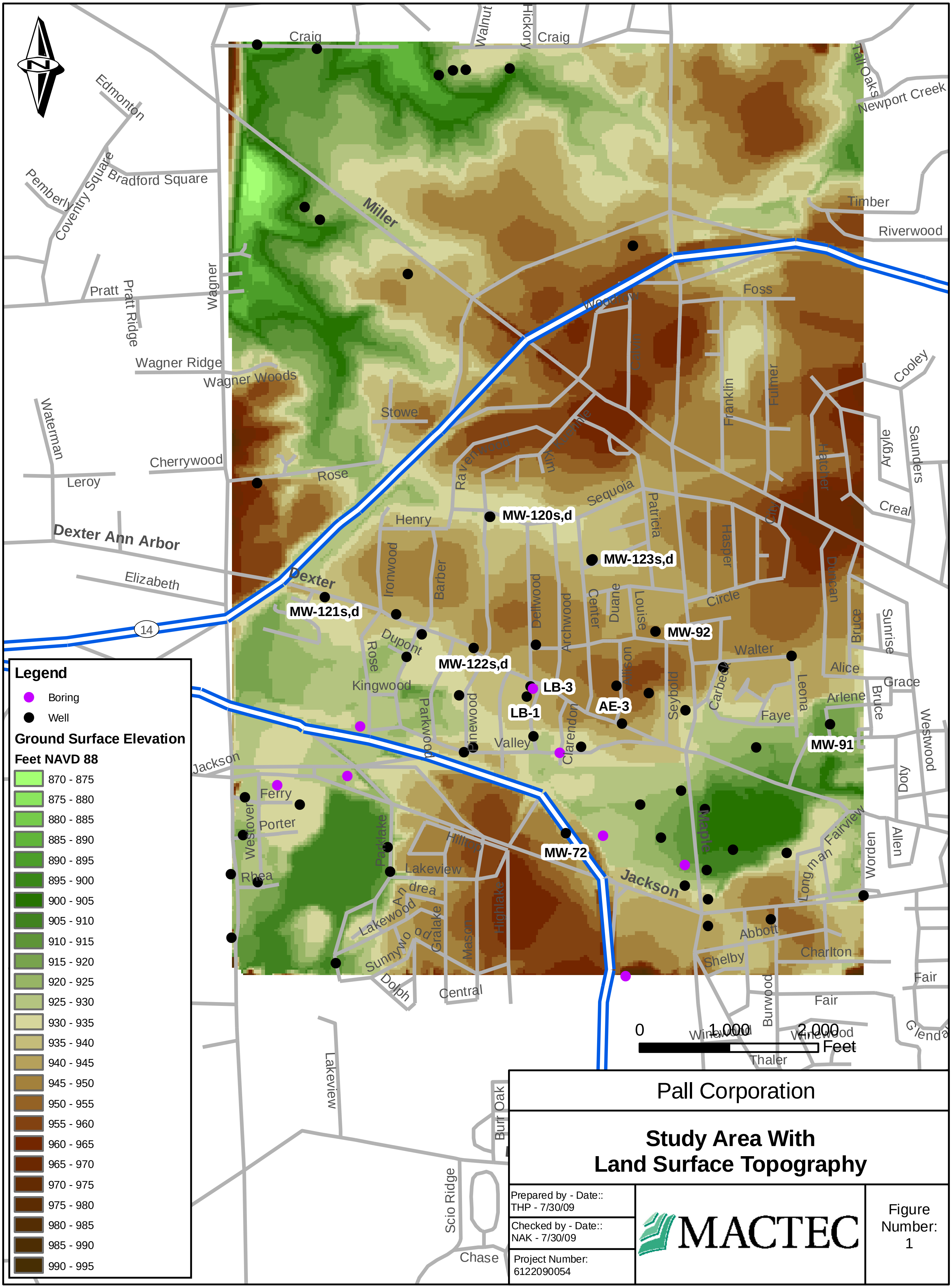
Table 1 Annual Precipitation at Ann Arbor University of Michigan Cooperative Station ID Number 200230, Washtenaw County, Michigan; Latitude N 42 degrees 17 minutes, Longitude West 83 degrees 42 minutes. (Data From: US Department of Commerce National Climatic Data Center, NOAA National Data Centers (NNDC); URL: http://www.ncdc.noaa.gov/oa/ncdc.html.)

Year	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
in.	36.0	47.2	32.8	39.0	34.6	34.3	34.8	34.0	39.7	39.2	36.3	45.9	38.3	30.8	35.8	35.1	35.3	47.6	36.7	41.7

FIGURES



Pall Corporation

Study Area With
Land Surface Topography

Prepared by - Date::
THP - 7/30/09

Checked by - Date::
NAK - 7/30/09

Project Number:
6122090054

MACTEC

Figure Number:
1

Map Document: (G:\Pall Corp\mxds\final_mxds\report mxds\Fig_1_study_area.mxd)
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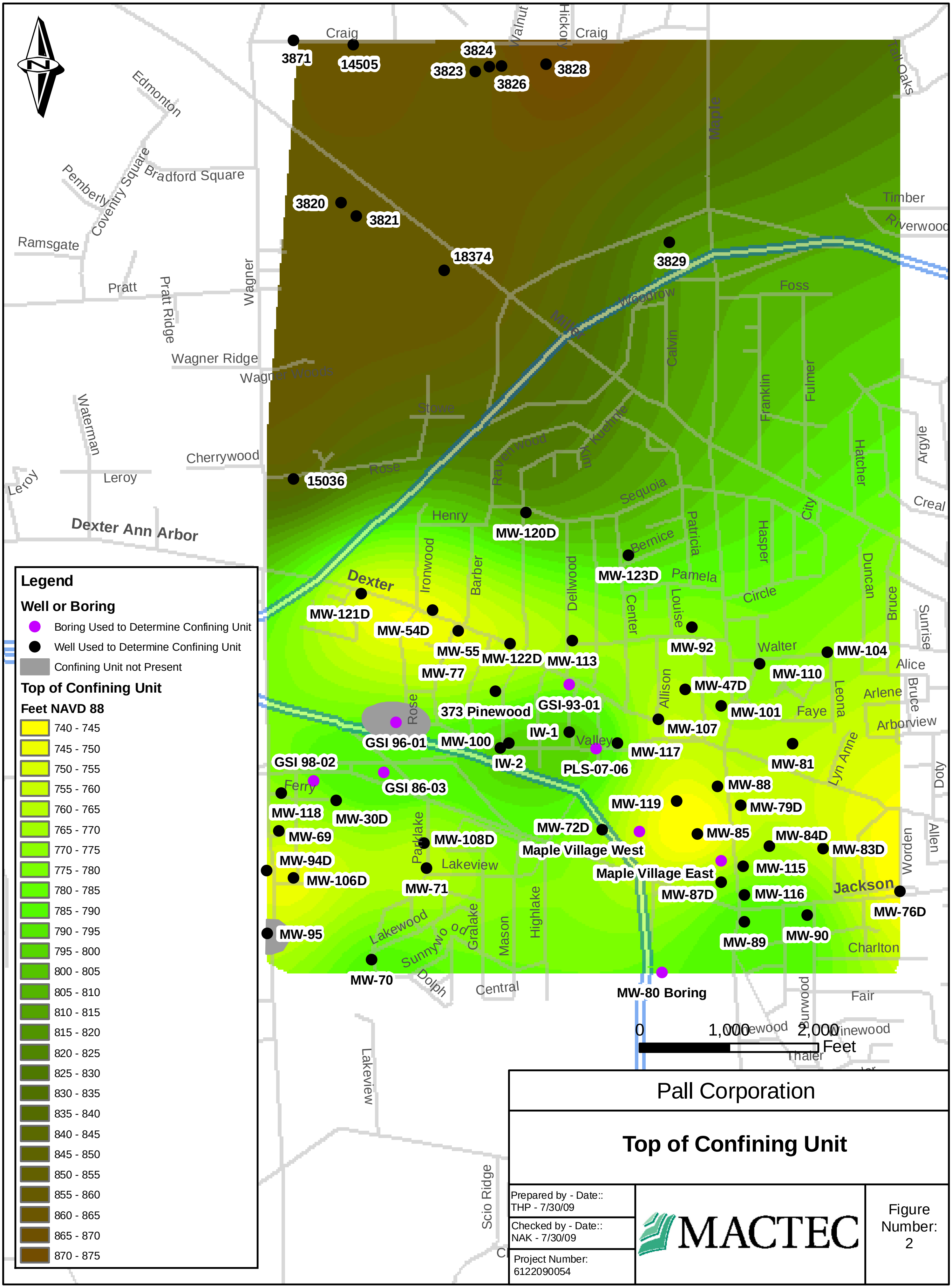

Pall Corporation

Top of Confining Unit

Prepared by - Date::
THP - 7/30/09

Checked by - Date::
NAK - 7/30/09

Project Number:
6122090054

MACTEC

Figure Number:
2

Map Document: (G:\Pall Corp\mxds\final_mxds\report mxds\Fig_2_top_of_con_unit.mxd)
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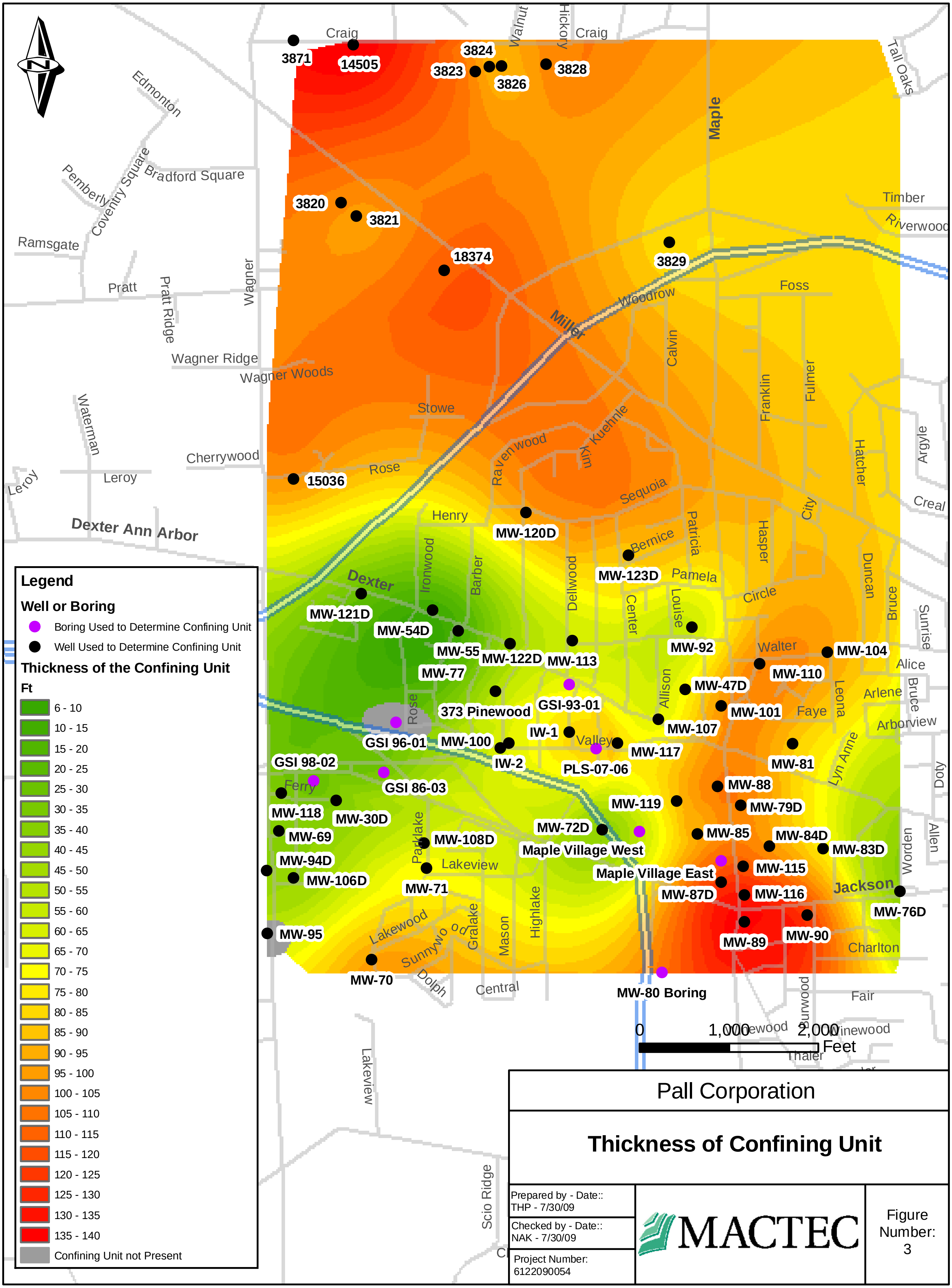

Pall Corporation

Thickness of Confining Unit

Prepared by - Date:: THP - 7/30/09	MACTEC	Figure Number: 3
Checked by - Date:: NAK - 7/30/09		
Project Number: 6122090054		

Map Document: (G:\Pall Corp\mxds\final_mxds\report mxds\Fig_3_thick_of_con_unit.mxd)
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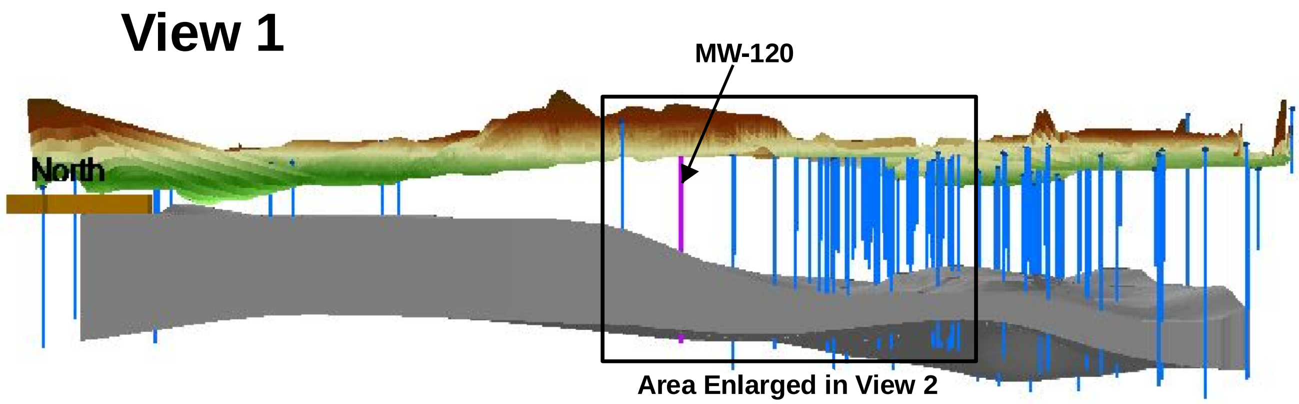
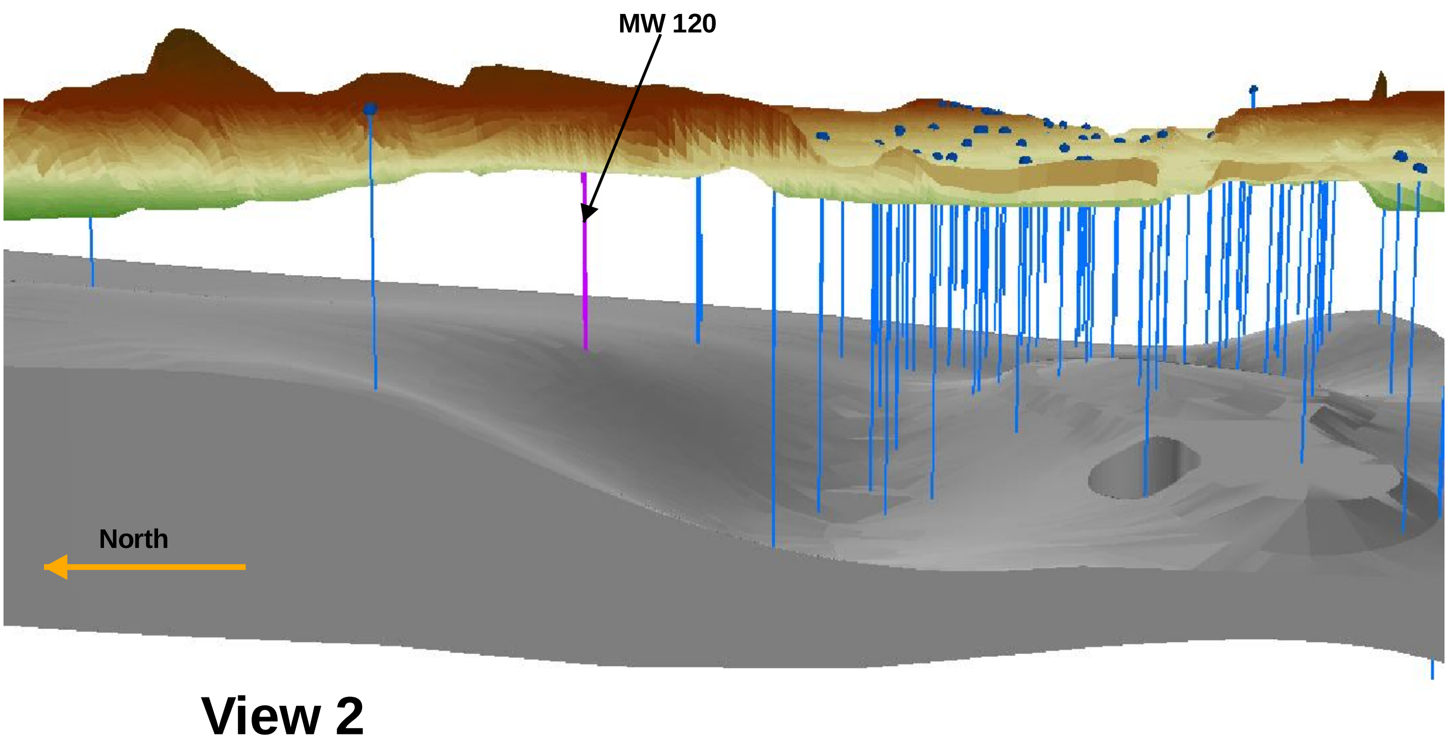


Scale varies in these perspectives

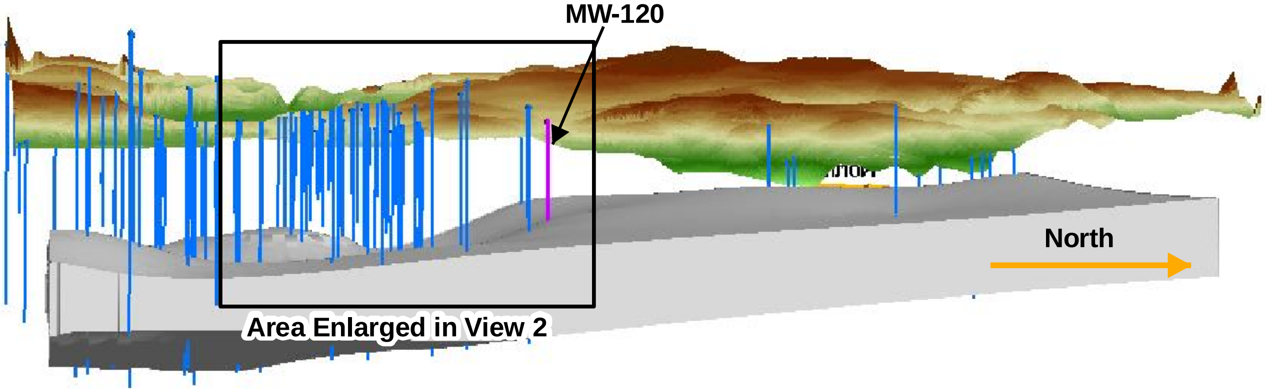


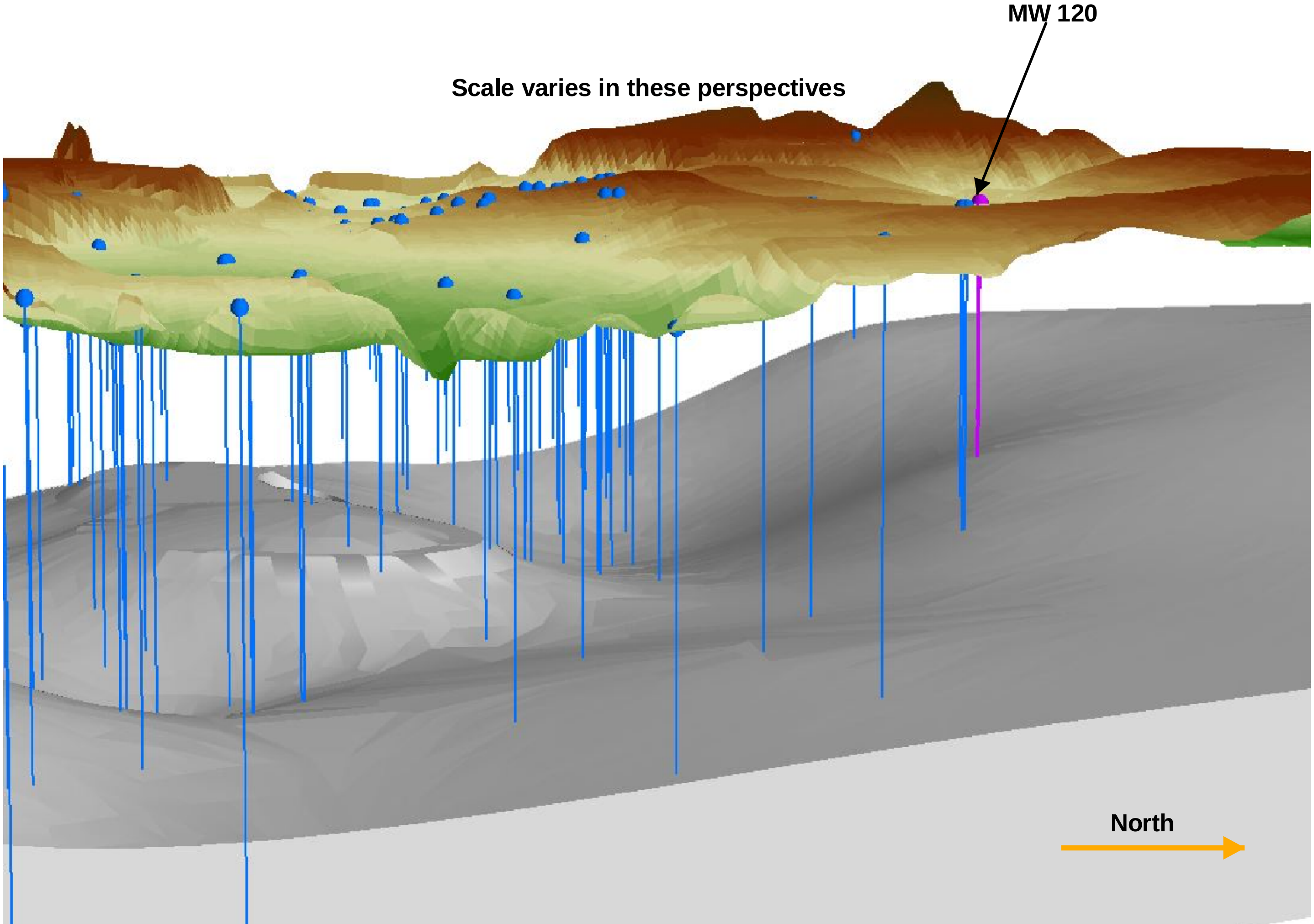
Pall Corporation

Three-Dimensional Views of the Subsurface Geology in the Study Area

Prepared by - Date:: THP - 7/30/09	MACTEC	Figure Number: 4a
Checked by - Date:: NAK - 7/30/09		
Project Number: 6122090054		

View 1





View 2

Pall Corporation

Three-Dimensional Views of the Subsurface Geology in the Study Area

Prepared by - Date:: THP - 7/30/09	MACTEC	Figure Number: 4b
Checked by - Date:: NAK - 7/30/09		
Project Number: 6122090054		

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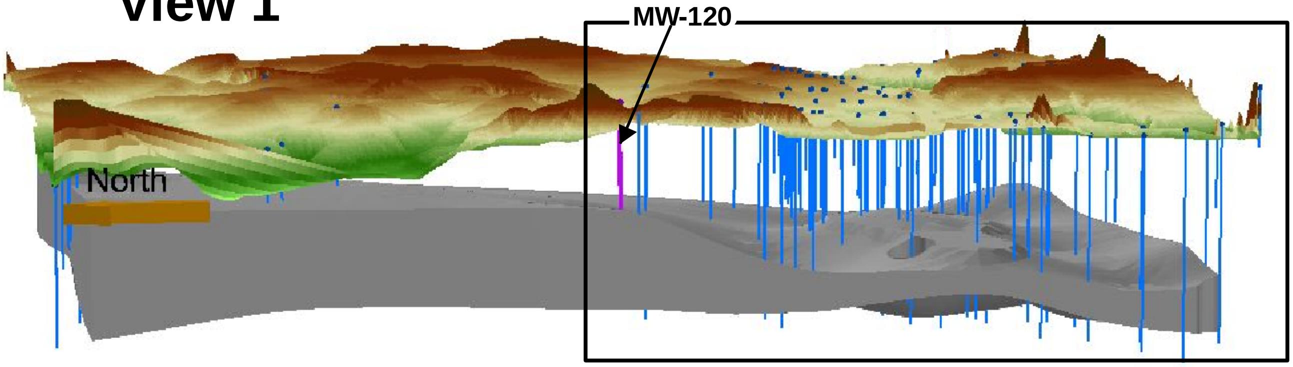
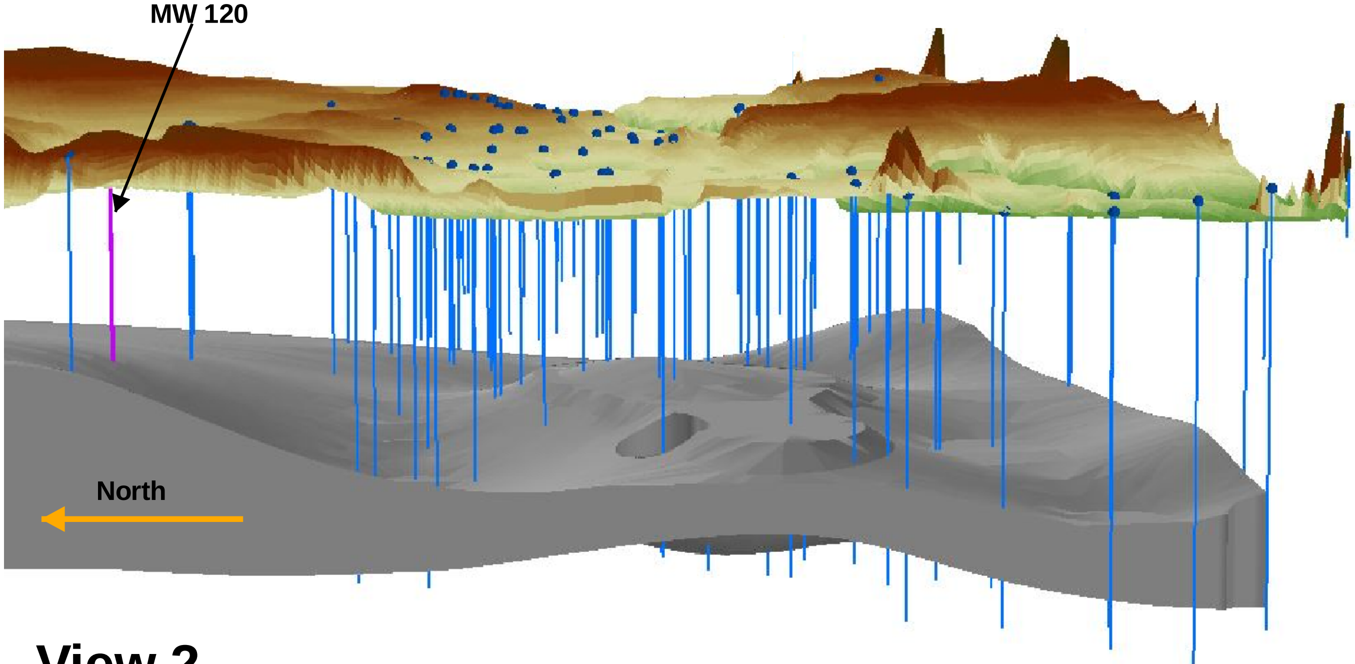
View 1



Scale varies in these perspectives



View 2

Pall Corporation

Three-Dimensional Views of the Subsurface Geology in the Study Area

Prepared by - Date:: THP - 7/30/09	MACTEC	Figure Number: 4c
Checked by - Date:: NAK - 7/30/09		
Project Number: 6122090054		

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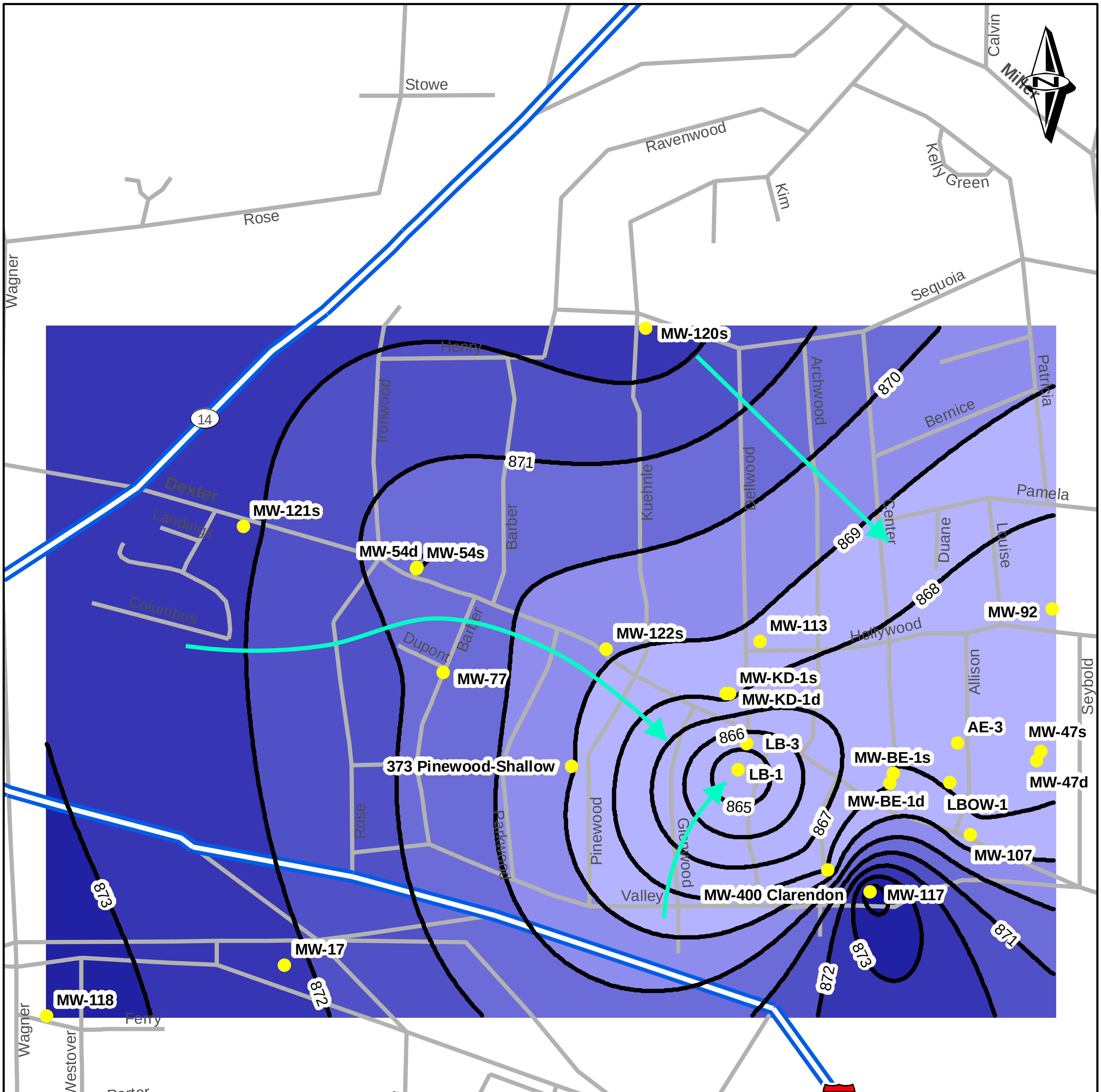

Legend

D2 Well

Potentiometric Surface of the D2 Aquifer Jan 21, 2009

Feet NAVD 88

- 868 - 869
- 869 - 870
- 870 - 871
- 871 - 872
- 872 - 873
- 873 - 874
- 874 - 875
- 875 - 876

Groundwater Flow Direction

0 500 1,000 Feet

Pall Corporation

Potentiometric Surface for D2 Aquifer Jan 21, 2009 with D2 Wells Pumping

Prepared by - Date:: THP - 7/30/09	MACTEC	Figure Number: 5
Checked by - Date:: NAK - 7/30/09		
Project Number: 6122090054		

Map Document: (G:\Pall Corp\mxds\final_mxds\report mxds\Fig_5_D_1_21_pot.mxd)
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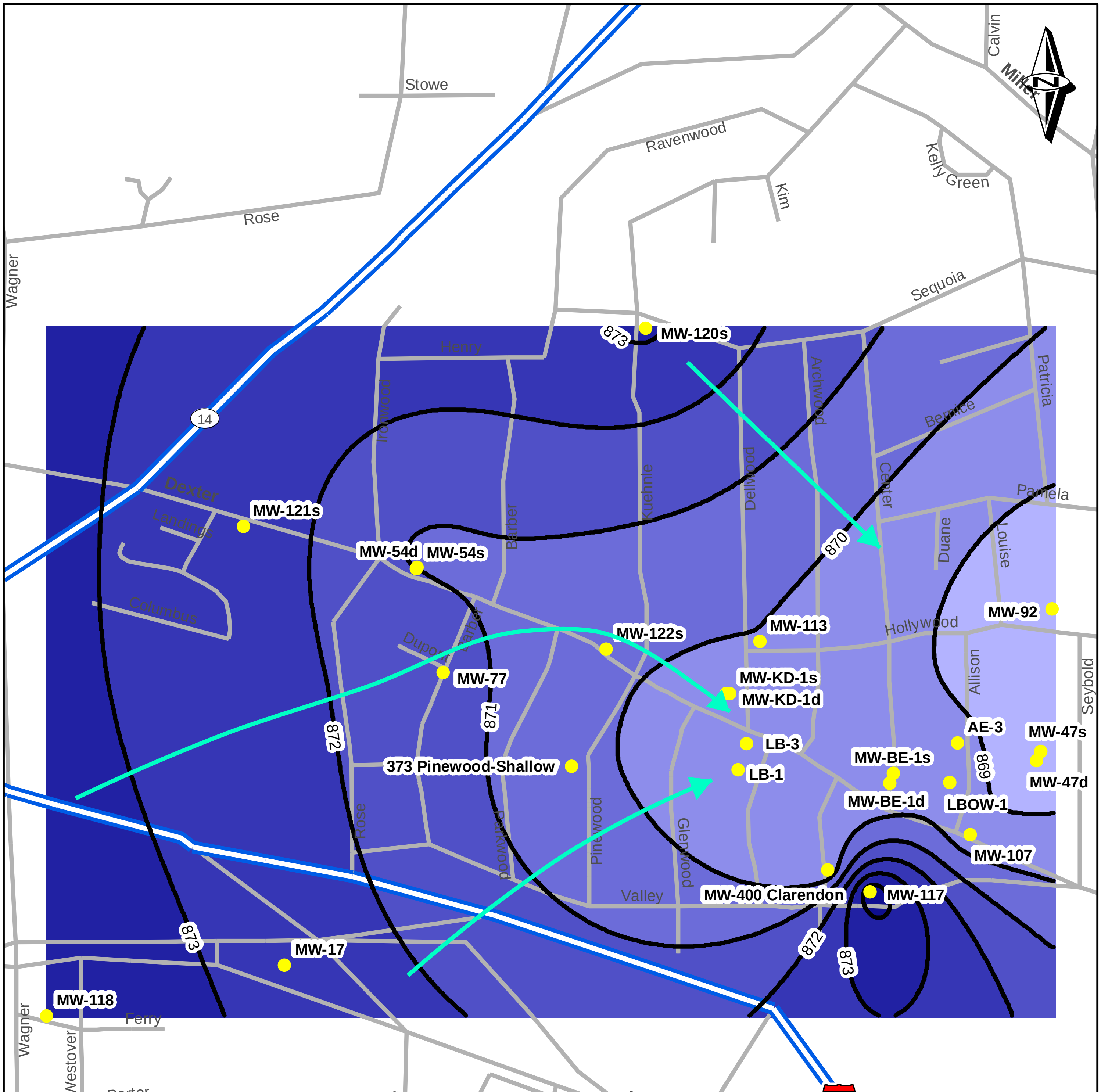

Legend

D2 Well

Potentiometric Surface of the D2 Aquifer Feb 16, 2009

Feet NAVD 88

- 868 - 869
- 869 - 870
- 870 - 871
- 871 - 872
- 872 - 873
- 873 - 874
- 874 - 875
- 875 - 876

Groundwater Flow Direction

0 500 1,000 Feet

Pall Corporation

Potentiometric Surface for D2 Aquifer
Feb 16, 2009 with D2 Wells Not Pumping

Prepared by - Date:: THP - 7/30/09	MACTEC		Figure Number: 6
Checked by - Date:: NAK - 7/30/09			
Project Number: 6122090054			

Map Document: (G:\Pall Corp\mxds\final_mxds\D_2_16_pot.mxd)
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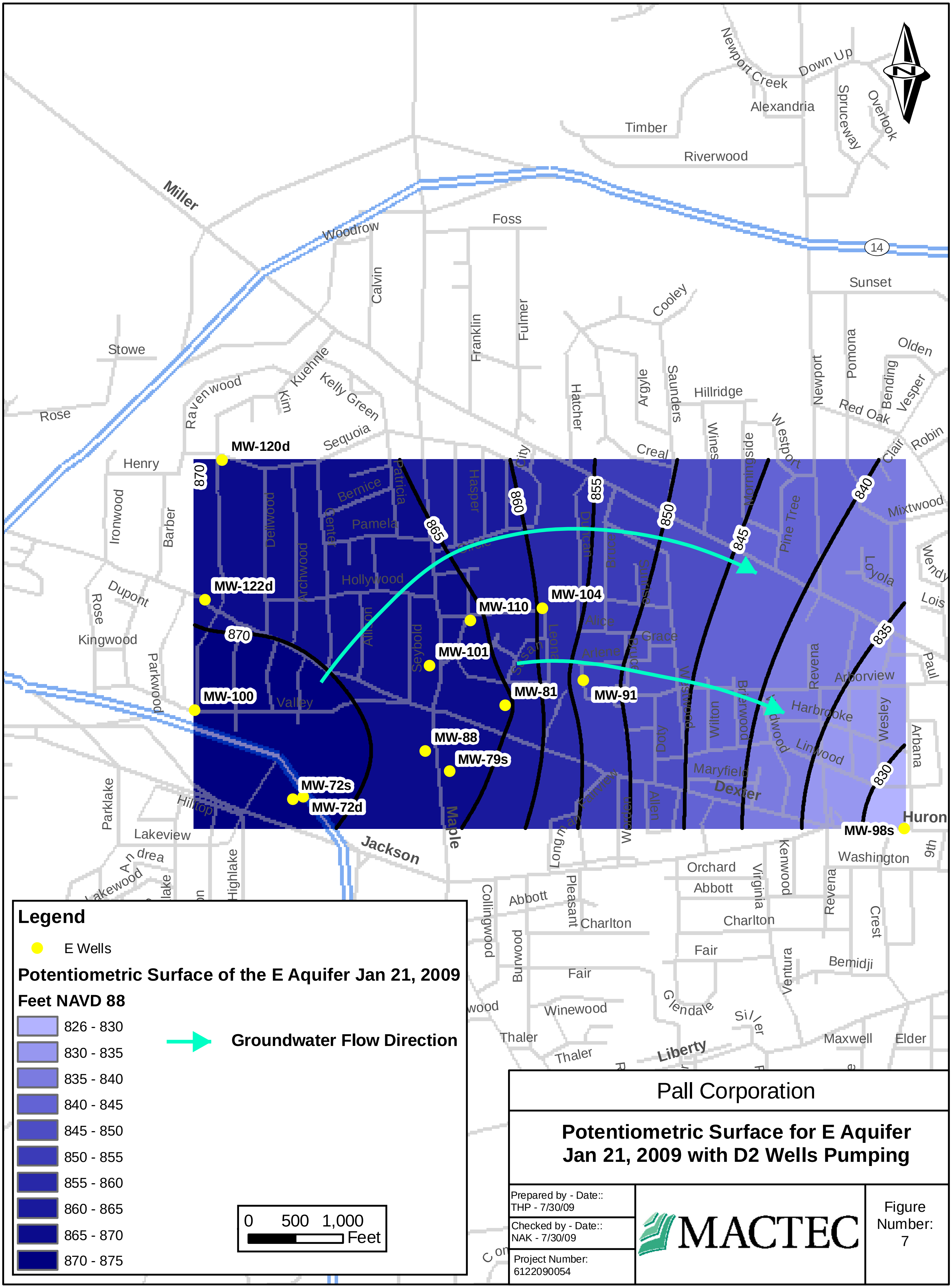

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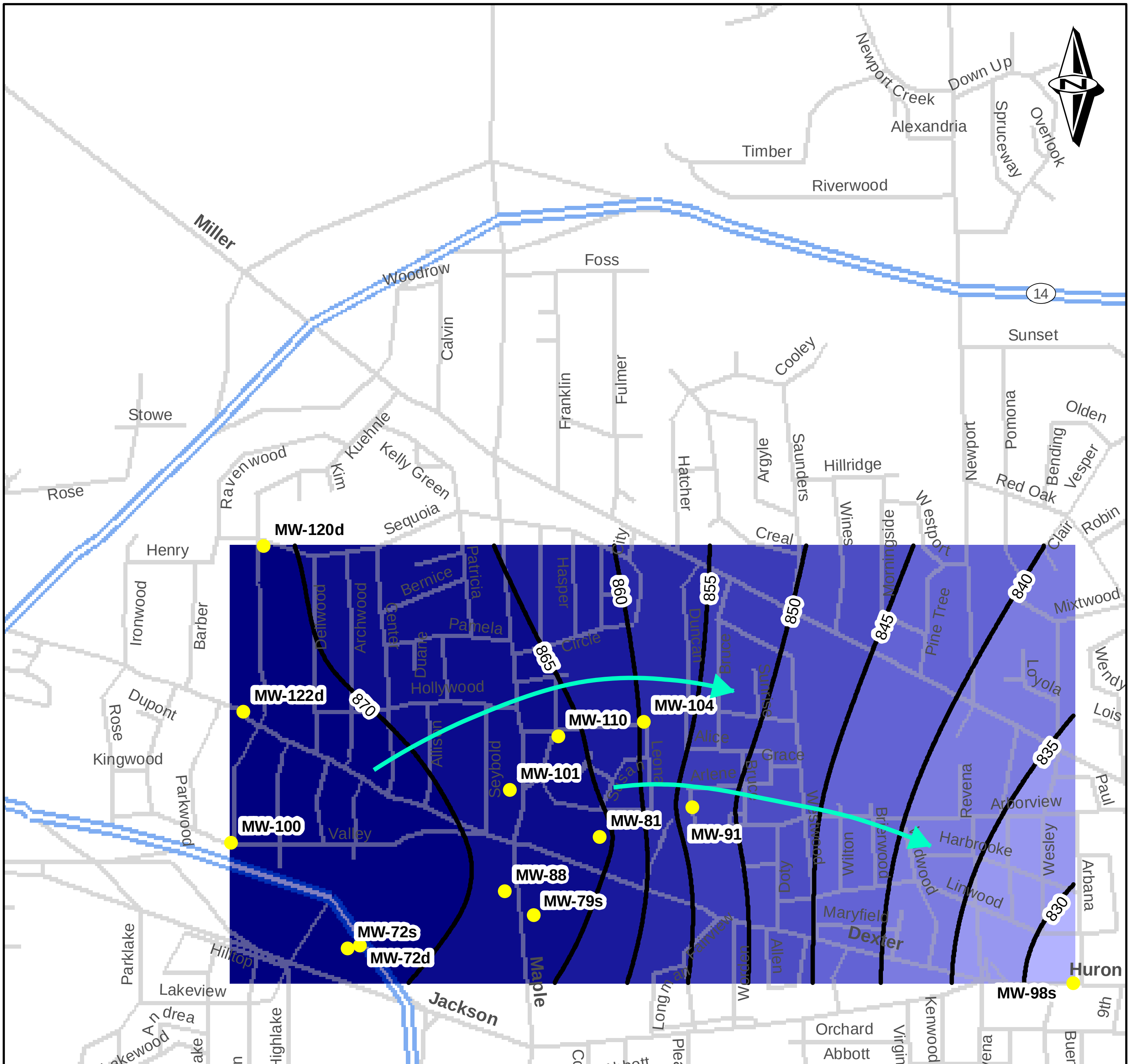


Legend

E Wells

Potentiometric Surface of the E Aquifer Feb 16, 2009

Feet NAVD 88

- 826 - 830
- 830 - 835
- 835 - 840
- 840 - 845
- 845 - 850
- 850 - 855
- 855 - 860
- 860 - 865
- 865 - 870
- 870 - 875

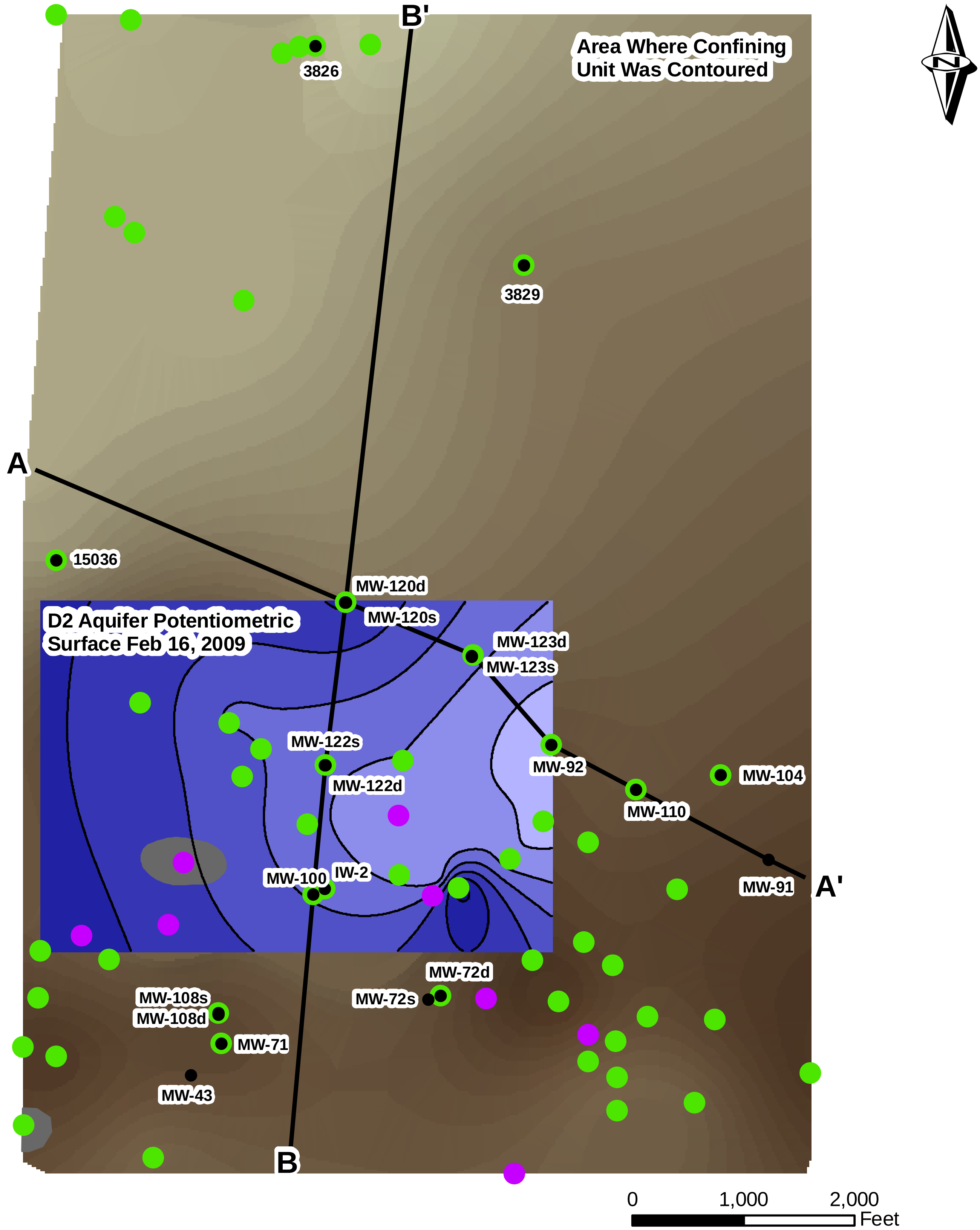
Groundwater Flow Direction

0 500 1,000 Feet

Pall Corporation

Potentiometric Surface for E Aquifer Feb 16, 2009 with D2 Wells Not Pumping

Prepared by - Date:: THP - 7/30/09	MACTEC	Figure Number: 8
Checked by - Date:: NAK - 7/30/09		
Project Number: 6122090054		



Legend

- ● Wells Shown on Cross Section
- ● Boring Used to Determine Confining Unit
- ● Well Used to Determine Confining Unit
- — Cross Section Location
- ■ Confining Unit not Present

Pall Corporation		
Cross Section Locations and Potentiometric Surface of D2 Aquifer Feb 16, 2009		
Prepared by - Date:: THP - 7/30/09 Checked by - Date:: NAK - 7/30/09 Project Number: 6122090054	MACTEC	Figure Number: 9

Map Document: (G:\Pall Corp\mxds\final_mxds\X_sect_loc_D_2_16.mxd)
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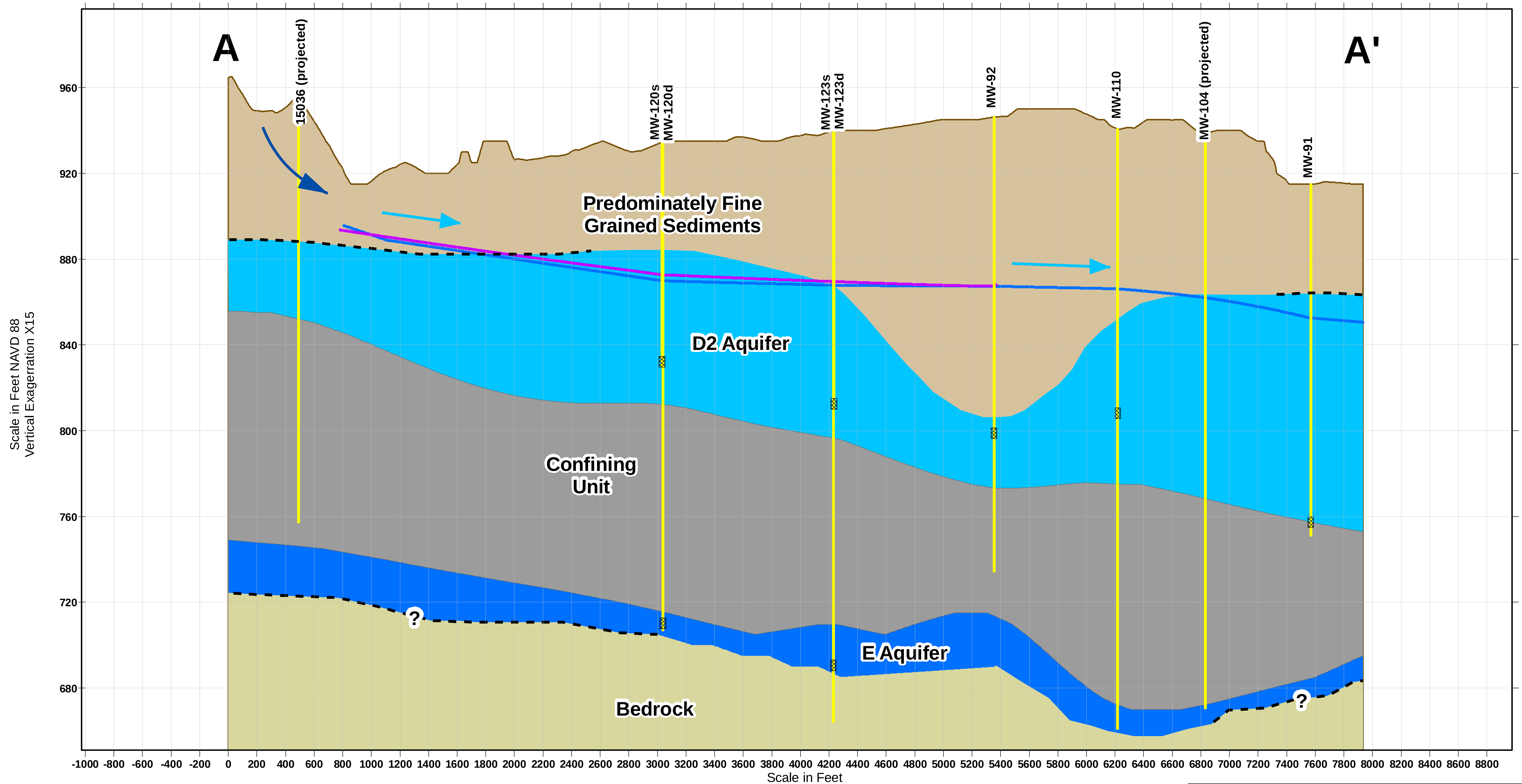
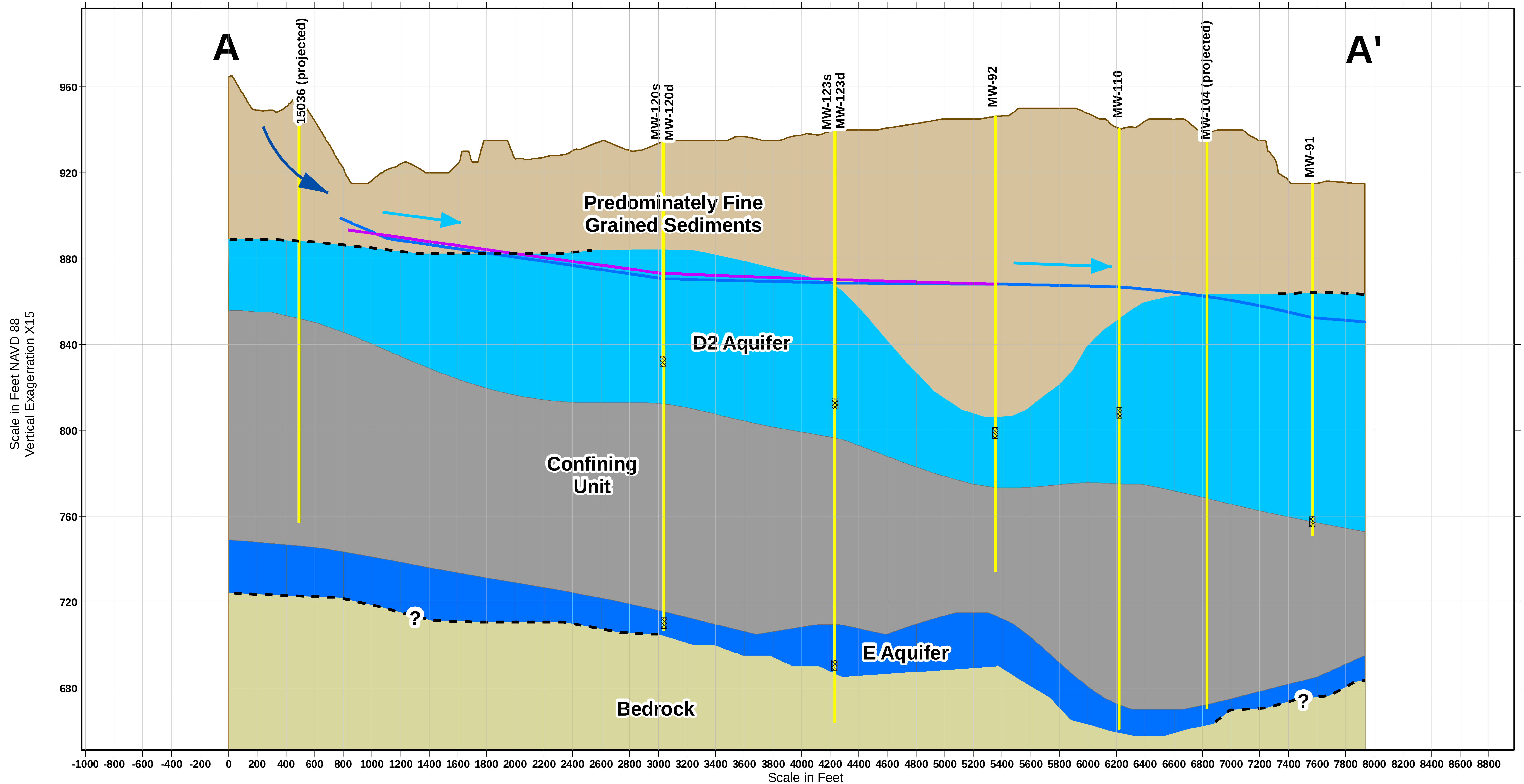


Legend

- Monitoring Well
- Well Screen
- D2 Aquifer Potentiometric Surface Jan 21, 2009
- E Aquifer Potentiometric Surface Jan 21, 2009
- Groundwater Recharge
- Groundwater Flow Direction
- D2 Aquifer
- E Aquifer
- Predominately Fine Grained Sediments
- Confining Unit
- Bedrock

Map Document: (G:\Pall Corp\mxds\final_mxds\Fig_10_AA_X_sect_jan_21.mxd)
8/3/2009 -- 12:10:27 PM

Pall Corporation		
Hydrogeologic Cross-Section A-A', Jan 21, 2009 with D2 Wells Pumping		
Prepared by - Date:: THP - 7/30/09 Checked by - Date:: NAK - 7/30/09 Project Number: 6122090054	MACTEC	Figure Number: 10



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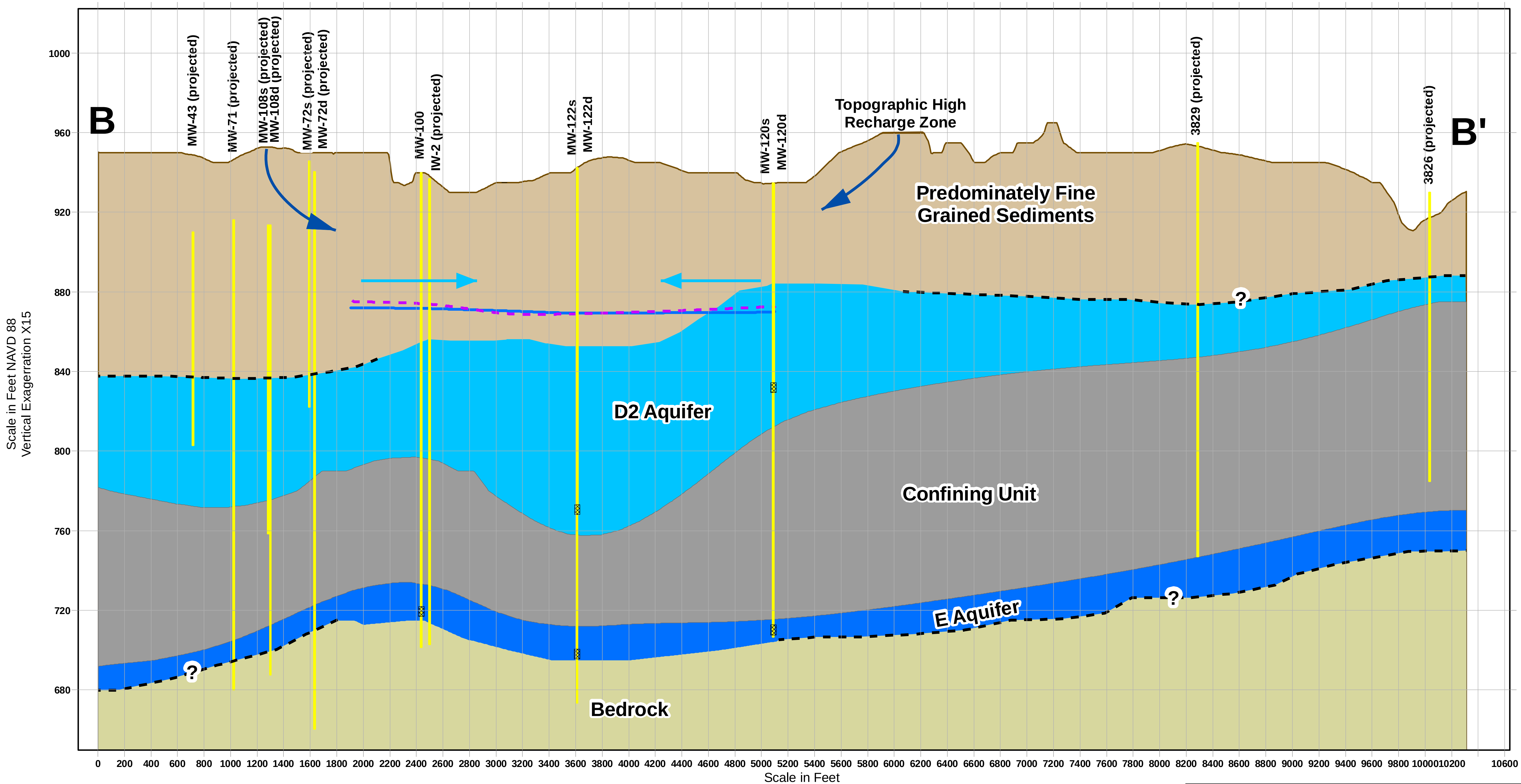
Legend

- Monitoring Well
- Well Screen
- D2 Aquifer Potentiometric Surface Feb 16, 2009
- E Aquifer Potentiometric Surface Feb 16, 2009
- Groundwater Recharge
- Groundwater Flow Direction
- D2 Aquifer
- E Aquifer
- Predominately Fine Grained Sediments
- Confining Unit
- Bedrock

Pall Corporation		
Hydrogeologic Cross-Section A-A', Feb 16, 2009 with D2 Wells Not Pumping		
Prepared by - Date:: THP - 7/30/09 Checked by - Date:: NAK - 7/30/09 Project Number: 6122090054	MACTEC	Figure Number: 11



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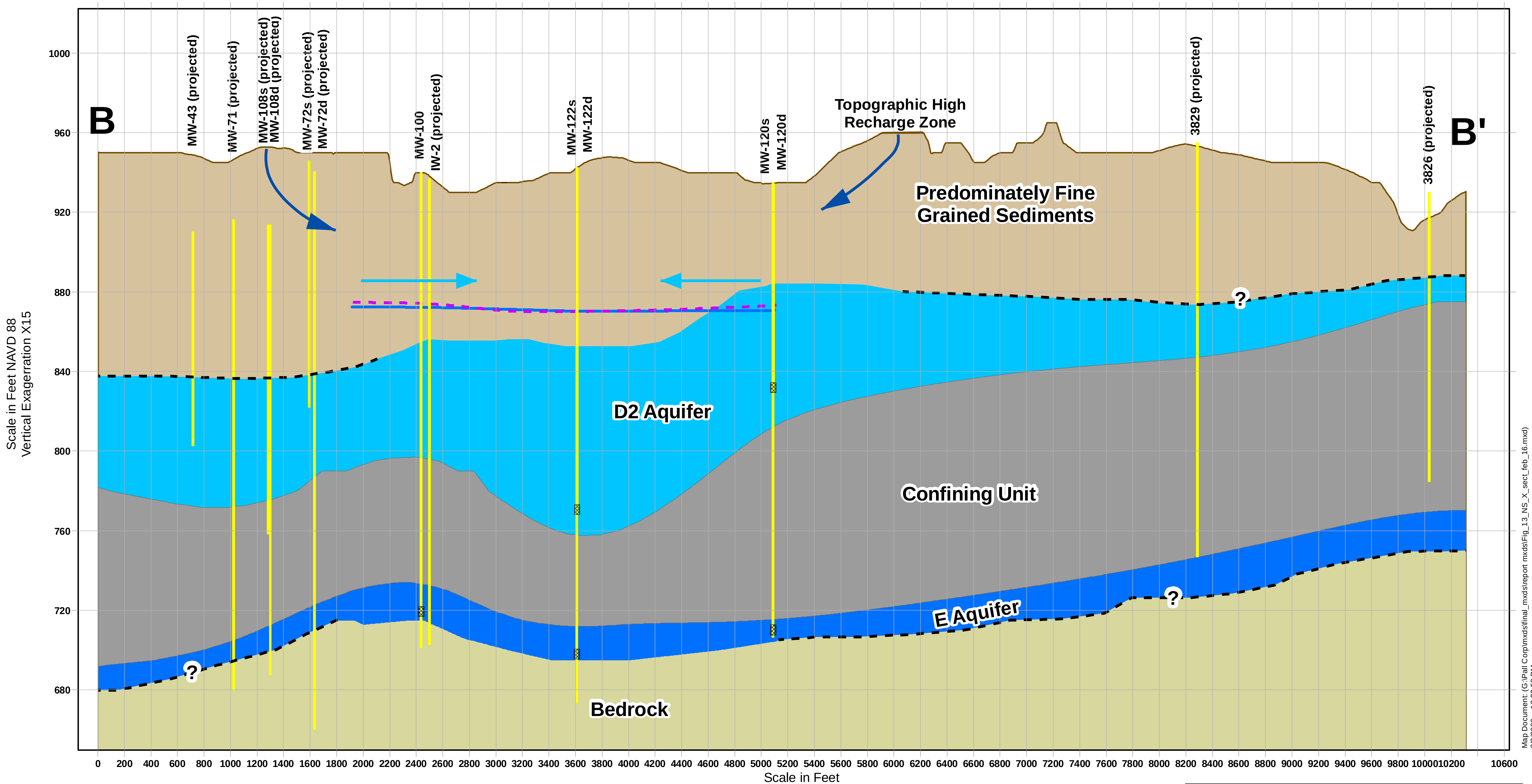
Legend

- Monitoring Well
- Well Screen
- D2 Aquifer Potentiometric Surface Jan 21, 2009
- E Aquifer Potentiometric Surface Jan 21, 2009
- Groundwater Recharge
- Groundwater Flow Direction
- D2 Aquifer
- E Aquifer
- Predominately Fine Grained Sediments
- Confining Unit
- Bedrock

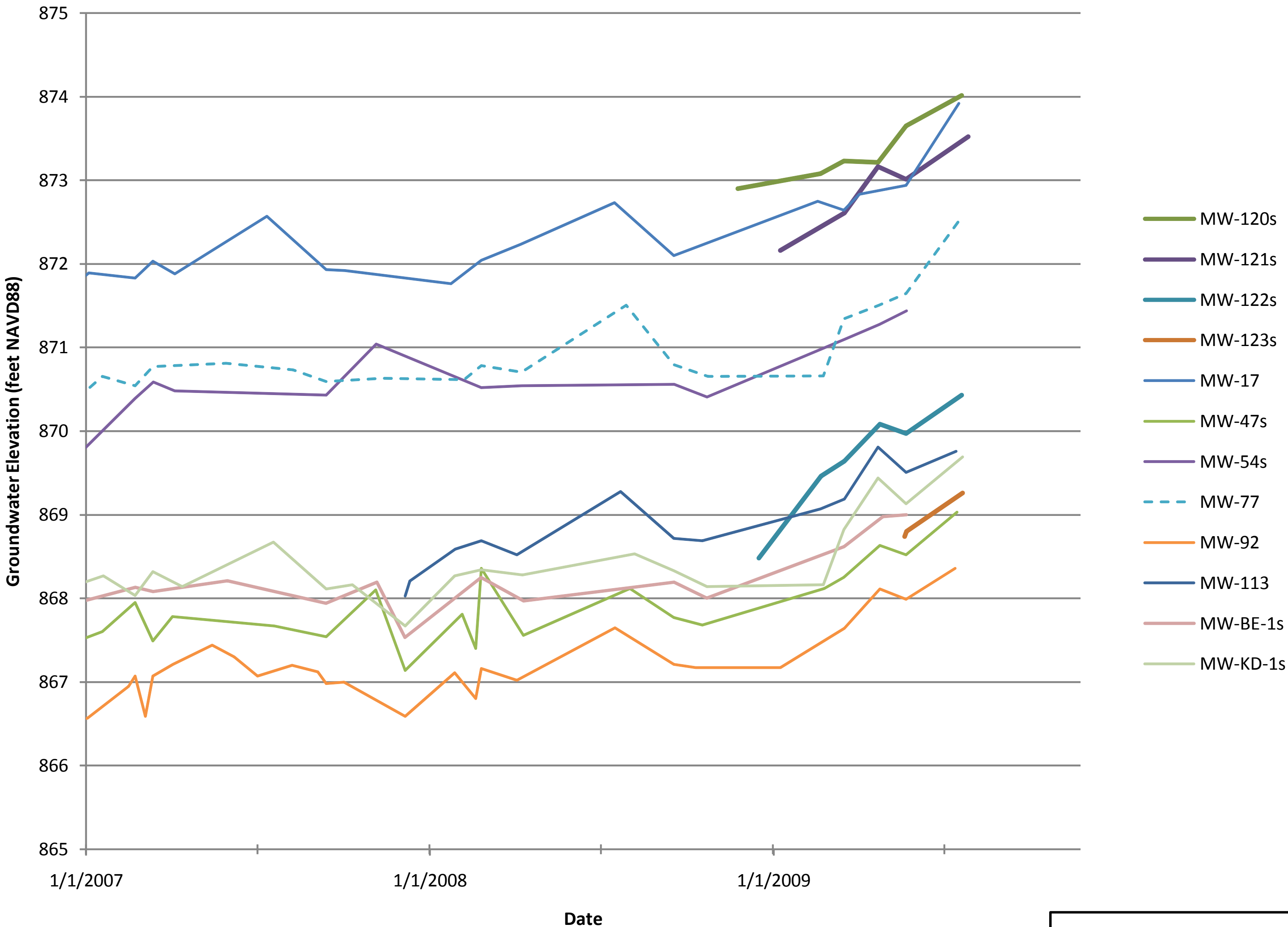
Pall Corporation		
Hydrogeologic Cross-Section B-B', Jan 21, 2009 with D2 Wells Pumping		
Prepared by - Date:: THP - 7/30/09 Checked by - Date:: NAK - 7/30/09 Project Number: 6122090054	MACTEC	Figure Number: 12



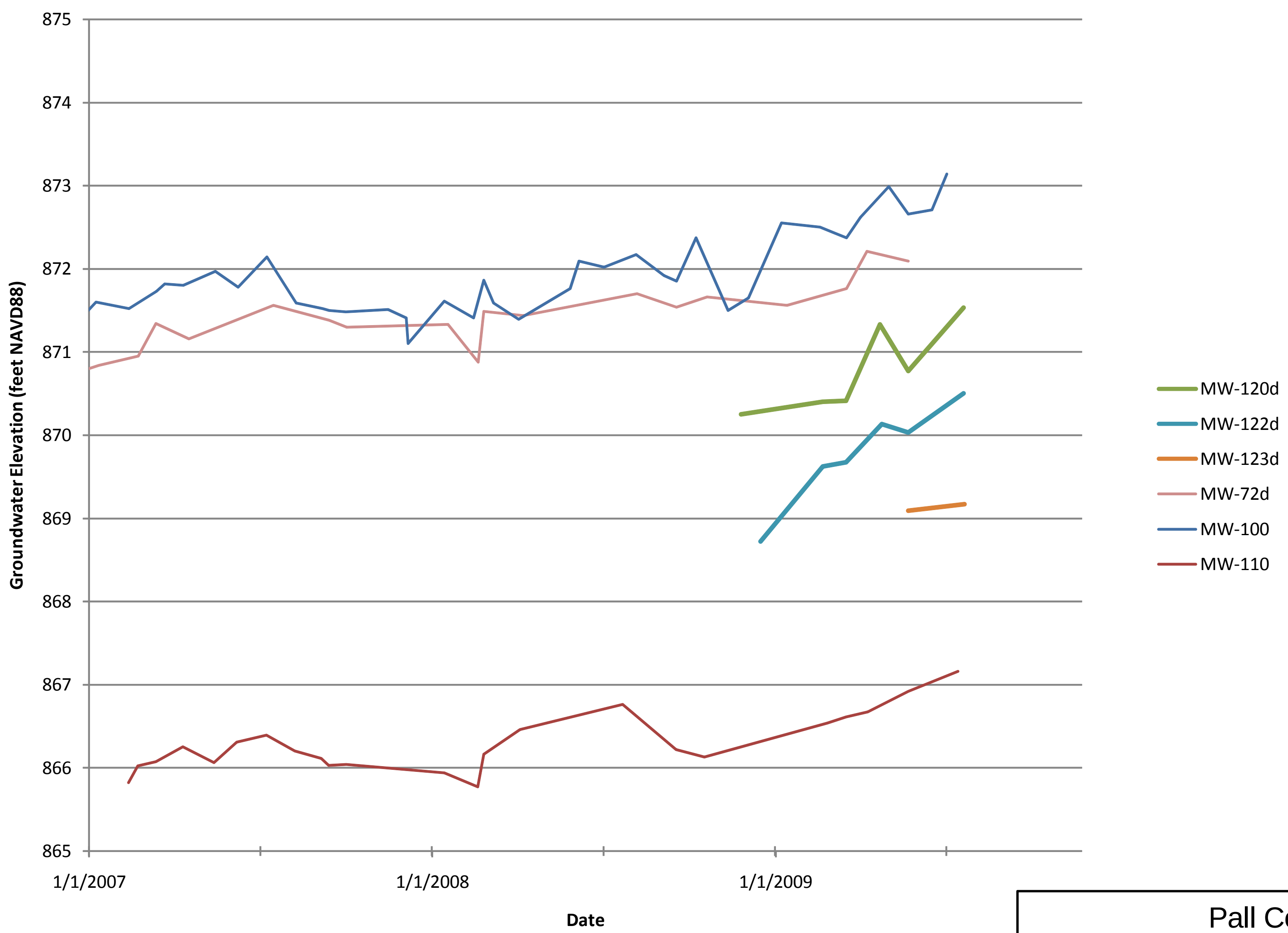
Legend

- Monitoring Well
- Well Screen
- D2 Aquifer Potentiometric Surface Feb 16, 2009
- E Aquifer Potentiometric Surface Feb 16, 2009
- Groundwater Recharge
- Groundwater Flow Direction
- D2 Aquifer
- E Aquifer
- Predominately Fine Grained Sediments
- Confining Unit
- Bedrock

Pall Corporation		
Hydrogeologic Cross-Section B-B', Feb 16, 2009 with D2 Wells Not Pumping		
Prepared by - Date:: THP - 7/30/09	MACTEC	Figure Number: 13
Checked by - Date:: NAK - 7/30/09		
Project Number: 6122090054		



Pall Corporation		
Comparison of Groundwater Elevations Recorded in Monitoring Wells Screened in the D2 Aquifer		
Prepared by - Date:: THP - 7/30/09	MACTEC	Figure Number: 14
Checked by - Date:: NAK - 7/30/09		
Project Number: 6122090054		



Pall Corporation

Comparison of Groundwater Elevations Recorded in Monitoring Wells Screened in the E Aquifer

Prepared by - Date:: THP - 7/30/09

Checked by - Date:: NAK - 7/30/09

Project Number: 6122090054

MACTEC

Figure Number: 15

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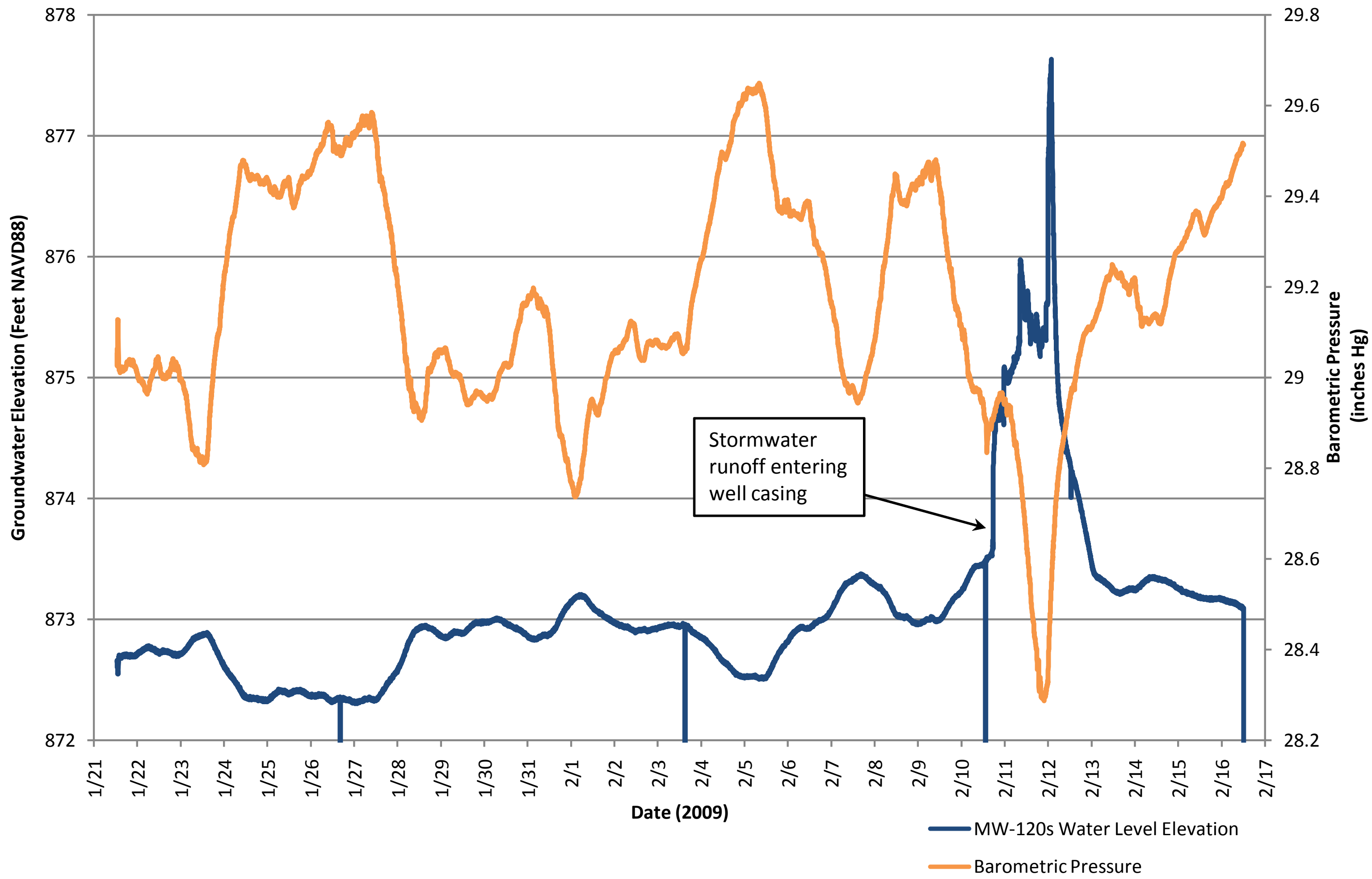

Pall Corporation

Water Level Elevation at MW-120s Compared to Barometric Pressure

Prepared by - Date:: THP - 7/30/09	MACTEC	Figure Number: 16
Checked by - Date:: NAK - 7/30/09		
Project Number: 6122090054		

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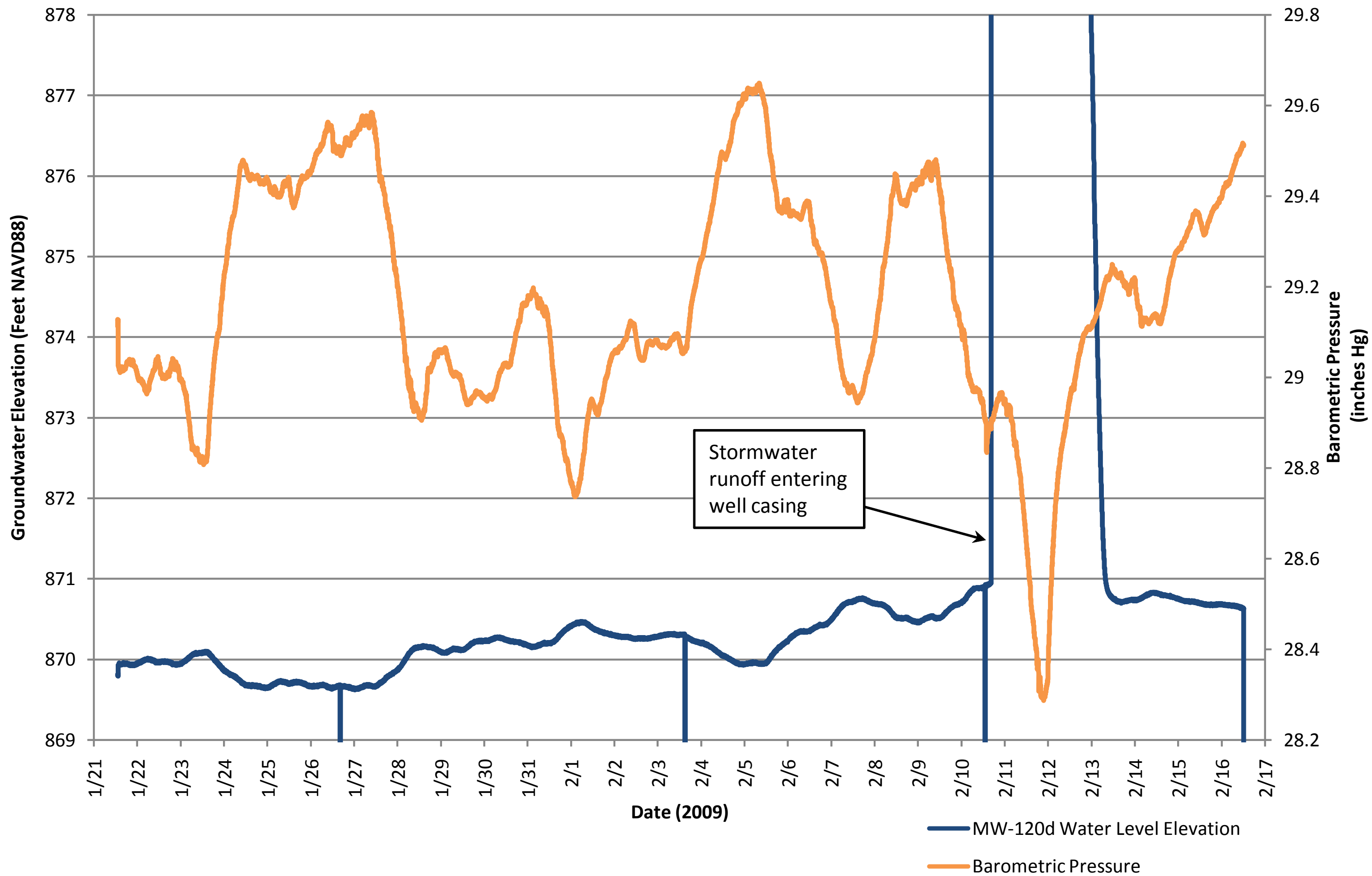

Pall Corporation		
Water Level Elevation at MW-120d Compared to Barometric Pressure		
Prepared by - Date:: THP - 7/30/09	MACTEC	Figure Number: 17
Checked by - Date:: NAK - 7/30/09		
Project Number: 6122090054		

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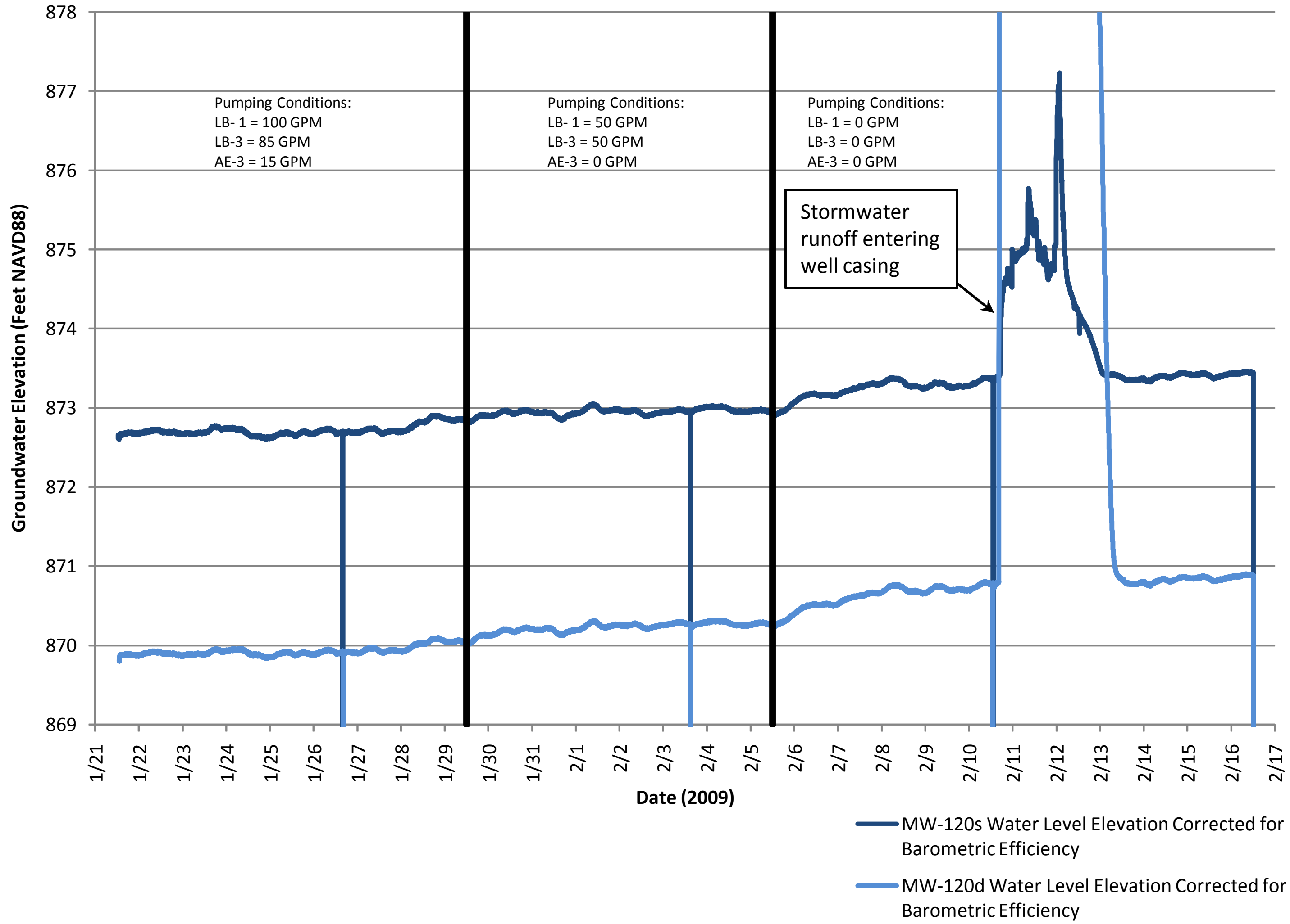

Pall Corporation

Water Level Elevations at MW-120s and MW-120d Corrected for Barometric Efficiency

Prepared by - Date:: THP - 7/30/09

Checked by - Date:: NAK - 7/30/09

Project Number: 6122090054

MACTEC

Figure Number: 18

Map Document: (G:\Pall Corp\mxds\final_mxds\report mxds\Fig_18_120sd_corrected.mxd)
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