Environmental Consultants
and Contractors

2830 Dairy Drive
Madison, WI 53718-6751

608 224-2830
FAX 608 224-2839
www.scsengineers.com

SCS ENGINEERS

October 13, 2017
File No. 25216167

Mr. Joe DeMorett
Madison Water Utility
119 East Olin Avenue
Madison, Wisconsin 53713-1431

Subject: PCE Plume Evaluation Report
Unit Well 8, 615 Welch Avenue, Madison, Wisconsin

Dear Mr. DeMorett:

The enclosed report documents SCS Engineers' (SCS's) evaluation of the potential for documented chlorinated solvent contamination in groundwater in the area of the Madison-Kipp Corporation to impact water quality at the Madison Water Utility's Unit Well #8. SCS prepared the report at the request of the Madison Water Utility under purchase order 15004005-00. Please contact us at (608) 224-2830 if you have any questions regarding the report.

Sincerely,

Eric Oelkers, PG
Senior Project Manager/Hydrogeologist
SCS ENGINEERS

Sherren Clark, PE, PG
Vice President
SCS ENGINEERS

EO/jsn/SC

Enclosures: PCE Plume Evaluation Report, Unit Well 8

I:\25215167.00\Reports\MWU Well 8 Plume Study\171016_DeMorett_report cover.docx

SCS ENGINEERS







PCE Plume Evaluation

Unit Well 8
615 Welch Avenue, Madison Wisconsin

Prepared for:

Madison Water Utility

119 East Olin Avenue
Madison, Wisconsin 53713
(608) 261-9243

Prepared by:

SCS ENGINEERS
2830 Dairy Drive
Madison, Wisconsin 53718-6751
(608) 224-2830

October 2017
File No. 25215167.00

PCE Plume Evaluation
Unit Well 8
615 Welch Avenue, Madison, Wisconsin

Prepared for:

Madison Water Utility
119 East Olin Avenue
Madison, Wisconsin 53713

Prepared by:

SCS ENGINEERS
2830 Dairy Drive
Madison, Wisconsin 53718-6751
(608) 224-2830

October 2017
File No. 25215167.00

Table of Contents

Section **Page**

Table

Figures

Contents (Continued)

Figures (Continued)

Appendices

I:\25215167.00\Reports\MWU Well 8 Plume Study\PCE Plume Report_171013_Final.docx

EXECUTIVE SUMMARY

This report documents SCS Engineers' (SCS's) evaluation of potential for documented chlorinated solvent contamination, primarily tetrachloroethylene (PCE), in groundwater in the area of the Madison-Kipp Corporation (MKC), to impact water quality at the Madison Water Utility's (MWU's) Unit Well #8 (UW8). In recent years, MWU has used UW8 only on a limited seasonal basis in response to elevated levels of iron and manganese.

Previous work by Arcadis U.S., Inc. (Arcadis) completed in 2014 on behalf of MKC concluded that the PCE contamination plume was stable and unlikely to impact water quality at UW8. An independent evaluation by Dr. Jessie Meyer concluded that although the plume does not appear to be moving rapidly, there remains an unacceptable level of uncertainty regarding the potential for impacts to UW8.

The SCS evaluation included the following areas of inquiry:

- Current PCE concentration trends based on additional groundwater monitoring data collected since Arcadis completed their plume evaluation;
- Distribution of monitoring points with respect to contaminant concentrations and aquifer units;
- Capture zone of the groundwater extraction and treatment system operating on the MKC facility;
- Fracture transport (CRAFLUSH) modeling performed by Arcadis;
- History of chlorinated volatile organic compounds detected in UW8;
- Advective particle tracking simulations using the Dane County groundwater flow model; and
- Potential locations for an additional monitoring well to assess the deep aquifer.

The SCS evaluation produced these conclusions:

- Although most of the 61 groundwater monitoring points installed for the MKC investigation where PCE has been detected appear to show stable or declining PCE, the PCE plume appears to be continuing to expand to the north.

- Based on the limited data available it is difficult to evaluate the extent to which fractures in the bedrock are controlling the migration of the PCE contamination plume in groundwater. The horizontal extent of contamination is greatest in the Wonewoc Formation, and relatively few monitoring points are located at the base of the Wonewoc.

- Contamination beyond the capture zone of the extraction well will likely remain subject to migration along head and concentration gradients.

- The value of CRAFLUSH groundwater predictions regarding contaminant transport in fractured bedrock is limited by both the amount of available calibration data in the targeted zones and site-specific values for model input parameters.

- The evidence that the documented MKC contamination is responsible for the detection of cis-1,2-dichloroethylene (DCE) in UW8 is unclear at best. Based on the monitoring data from UW8, it does not appear that breakthrough of the PCE plume at this well has occurred.

- Simulations performed using the Dane County groundwater flow model suggest that the un-retarded travel times to UW8 from various locations within the MKC contamination plume range from 6 to 46 years.

- The particle flow paths simulated by the groundwater model suggest that the movement of contamination below the MKC site is primarily vertical. If the plume were to penetrate the Eau Claire aquitard, un-attenuated contaminants could migrate toward UW8 within as few as 5 years.

- Model simulations of an open test well penetrating the Eau Claire aquitard near UW8 show little if any impact of such a well on anticipated particle (contamination) arrival times at UW8.

- Based on the current understanding PCE distribution in groundwater and the results of groundwater flow model particle tracking scenarios, the issue of greatest concern to MWU likely is PCE penetration through the Eau Claire aquitard at points closer to MKC than to UW8.

- In addition to ongoing review of the monitoring data that MKC is reporting to Wisconsin Department of Natural Resources (WDNR), SCS recommends that MWU consider installing a new groundwater monitoring well, open to the Mt. Simon Formation, at a location no closer to UW8 than the existing MW-25 well nest, but at least 500 feet downgradient from MW-17.

1.0 INTRODUCTION

This report presents the SCS evaluation of potential for documented chlorinated solvent contamination in groundwater in the area of the MKC to impact water quality at MWU's UW8. MKC is located at 201 Waubesa Street, in Madison, Wisconsin, approximately 1,500 feet northwest of UW8 (see TRC Figure 1 in **Appendix A**). Environmental investigations completed by MKC have identified soil and groundwater contamination attributed to releases of a degreasing solvent, PCE, from historical operations at the facility. The MKC investigations have generally defined the extent of solvent contamination as required by the WDNR and have suggested that UW8 is unlikely to be impacted by the contamination.

In recent years, MWU has used UW8 only on a limited seasonal basis in response to elevated levels of iron and manganese. MWU is contemplating making improvements to UW8 and retained SCS to perform an independent evaluation of the status of groundwater contamination and the potential for contamination to impact water quality at UW8.

This report provides a brief history of the groundwater contamination at MKC, summarizes the findings of MKC investigation work completed to date, evaluates the results in the context of potential water quality impacts to UW8, and presents recommendations for additional investigation.

2.0 BACKGROUND AND SCOPE

Background information reviewed by SCS included documents associated with the following:

- Site investigation and monitoring
- MKC plume stability evaluation
- Meyer evaluation of Arcadis report

Relevant documents were obtained from the WDNR Bureau for Remediation and Redevelopment (BRRTS) website, paper files maintained at the WDNR South Central Region office, and the MWU. Brief summaries of these documents are presented in the following sections, and complete references are listed in **Section 7.0**.

2.1 SITE INVESTIGATION AND MONITORING

The apparent PCE source area at the MKC facility is located approximately 2,000 feet northwest of UW8. The presence of PCE in groundwater in the vicinity of the MKC property was initially identified during an investigation of a leaking underground storage tank on the Madison Brass Works Property at 206-214 Waubesa Street. Based on indications that the PCE found at the Brass Works site was migrating from an up-gradient source located in the direction of MKC, the WDNR issued a letter on July 18, 1994, requesting that MKC investigate the horizontal and vertical extent of contamination. Reports documenting the various stages of investigation at the MKC site are listed on the WDNR BRRTS website under case number 02-13-558625.

Arcadis submitted an extensive report titled "Site Investigation and Interim Actions Report, February 2012 – January 2013, Madison-Kipp Corporation, 201 Waubesa Street, Madison, Wisconsin" (SI Report) to the WDNR on March 15, 2013. This site history is condensed from the Arcadis SI Report and other documents available on the WDNR website for the MKC property.

MKC purchased the property at the Waubesa Street site around 1900 and the facility has been primarily engaged in aluminum die-casting operations since the plant was constructed.

MKC started the site investigation in 1994. Potential PCE sources identified on the MKC property included a former PCE aboveground storage tank (AST) and two former vapor degreasers. The investigation of PCE expanded off site in 2001, and additional contaminants including polynuclear aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs) were detected on the MKC property as the investigation activities continued. The extent of the groundwater monitoring network is show on TRC Figure 2 (**Appendix A**).

MKC's investigation identified several areas of PCE contamination in soil and soil vapor. PCE contamination in shallow groundwater is largely localized to the MKC property; however, PCE contamination in bedrock extends off site as shown in TRC's Figures 8 through 11 (**Appendix A**). The groundwater monitoring network includes 41 single or nested monitoring wells and four multi-level monitoring wells with 20 discrete screen intervals for a total of 61 sampling points. Bedrock is present at a depth of approximately 35 feet and is overlain by fill, silty and sandy clay, and silty sand. The depth to the water table ranges from 15 to 35 feet below the ground surface.

TRC took over the groundwater monitoring duties from Arcadis around 2016. The most recent comprehensive report available is TRC's March 2017 "Operations, Monitoring and Maintenance Semi-Annual Report." The recent TRC report documents ongoing groundwater monitoring as well as operation of a groundwater extraction system that removes approximately 45 gallons of groundwater per minute from extraction well GWE-1, located on the MKC property north of the main plant building.

2.2 MKC PLUME STABILITY EVALUATION

Arcadis prepared a report evaluating the stability of the PCE plume and the potential of the plume to impact water quality at UW8 titled " Evaluation of Plume Stability and Fate and Transport Modeling for PCE in Bedrock Groundwater, Madison Kipp Corporation, Madison, Wisconsin," dated April 14, 2014. Arcadis' evaluation primarily focused on analysis of PCE concentration trends observed in groundwater monitoring wells located in and around the PCE plume and calibration of a discrete-fracture groundwater fate and transport model known as CRAFLUSH. The CRAFLUSH model incorporates "groundwater flow in a bedrock fracture network, dispersion, molecular diffusion and storage in bedrock matrix blocks, hydrophobic sorption, and chemical degradation due to both biotic and abiotic degradation processes" (Arcadis, 2014, p. 1).

The conclusions of Arcadis' plume stability report (Arcadis, 2014, p. 10-11) are as follows:

- The vertical extent of PCE has been delineated at the site and is limited to a depth of approximately 170 feet below ground surface.
- The intake portion of UW8 starts at approximately 280 feet below ground surface and, therefore, there are at least 110 feet of vertical separation between the bottom of the PCE plume and the top of the intake screen of UW8, as well as approximately 800 feet of horizontal separation.
- The intake portion of UW8 is screened below the Eau Claire Shale which is regional in extent, has a very low vertical hydraulic conductivity (0.0006 feet/day), and strongly restricts vertical groundwater flow and transport above the confining layer from migrating vertically downward and into the deeper aquifer in which UW8 is screened.
- Pumping at UW8 for water supply purposes will result in radial flow of groundwater from all directions toward UW8 to the extent that the vast majority (e.g., ≈90% of groundwater entering UW8 will be from other areas not associated with the MKC site).
- The PCE source area at the site (i.e., the zone with the highest PCE concentrations) will be hydraulically contained by MKC's proposed groundwater extraction system.
- The PCE plume at the MKC site has stabilized and is no longer expanding. The key controlling factors on plume stabilization are matrix diffusion and biodegradation (Arcadis, 2014, p. 10-11).

2.3 MEYER EVALUATION OF ARCADIS REPORT

MWU retained Dr. Jessica Meyer to independently evaluate MKC's findings with respect to potential contaminant impacts to UW8. Dr. Meyer has substantial experience in the characterization of chlorinated solvent plumes in fractured bedrock, including the Hydrite site in Cottage Grove, WI. Her report titled "Technical Evaluation of Assessments of the Potential for PCE in Groundwater Associated with the Madison-Kipp Corporation site to Impact Unit Well #8" concluded that, "Although I generally agree that the MKC site PCE plume is strongly attenuated and is not moving rapidly forward, I do not think the potential of PCE to impact UW8 has been assessed to an acceptable level of certainty based on the current monitoring network, data and analysis methods, key assumptions, and numerical modeling effort" (Meyer 2015, 27 p.).

Ms. Meyer's 2015 report presented a list of five options for future work aimed at reducing the uncertainty regarding the potential for PCE contamination to impact UW8. These options included:

1. <u>Additional Characterization and Temporal/Monitoring Data</u> – Addition of monitoring intervals downgradient of the inferred source area to improve three-dimensional

characterization of the PCE plume, provide additional information for further assessment of potential impact to UW8, and monitor any further migration of the PCE plume toward UW8 in the future

2. Assessment of the Site Concept Model – Utilize the site-specific data to refine the hydrogeologic unit model for the site

3. Revised Analysis of Data
    - Re-evaluating specific data (hydraulic conductivity, fracture network parameters, rock matrix, parameters, hydraulic gradients, etc.) within the context of the hydrogeologic unit conceptual model to better inform conceptual and numerical models
    - Analysis of time concentration data within the context of the site specific hydrogeologic unit conceptual model (i.e., analysis of concentration trends in each aquifer unit using only wells screened in that unit) to improve the evaluation of potential plume stability
    - Re-analysis of time concentration data when monitoring records extend at least 2 years with at least eight separate monitoring events to improve the evaluation of potential plume stability (including any new monitoring intervals installed at the site)

4. Additional Evaluation of the Flow System in Three Dimensions for the Current and Future Conditions
    - Evaluation and presentation of the vertical influence of the source zone extraction well
    - Delineation of the three-dimensional capture zone for the extraction well in order to characterize the percentage of the source zone flux captured by the extraction well
    - Analysis of the three-dimensional capture zone for UW8 under the range of pumping conditions observed at the site and under expected future conditions
    - Reiteration of the recommendation from Arcadis to seal the test hole adjacent to UW8 to minimize potential cross-contamination

5. Revision of CRAFLUSH Modeling
    - Development of clear definition for ‘impact to UW8’
    - Consider using a refined hydrogeologic unit conceptual model to guide revised Craflush modeling
    - Assess the impact of the specified constant source concentration on Craflush simulation results
    - Avoid ‘fitting’ the model to current observed data using unknown or unmeasured parameters. Rather conduct site-specific sensitivity analyses for field and literature derived parameters that address the observed range and/or estimated uncertainty in these parameters.
    - Assess how changes in the three-dimensional flow system (e.g., full time pumping of UW8) will influence plume behavior (Meyer, 2015).

2.4 SCOPE OF SCS's WORK

MWU retained SCS in November 2015 to further investigate the potential for the PCE contamination to impact UW8 as a follow-up to the evaluation performed by Ms. Meyer. SCS prioritized Dr. Meyer's recommendations for further analysis in the context of the available resources and the MWU's need for practical guidance regarding future use of UW8.

SCS's avenues of investigation in response to Ms. Meyer's specific options/recommendations enumerated in **Section 2.3** are described below with reference to the section in this report where that analysis is presented.

1. <u>Additional Characterization and Temporal/Monitoring Data</u>
   This study identifies potential locations for one or more "sentinel" monitoring wells in the primary aquifer that supplies water to UW8 (**Section 5.0**). SCS understands that the MWU does not have the resources to substantially expand the MKC groundwater monitoring network; however, the existing MKC investigation has not directly evaluated water quality in the lower sandstone aquifer.

2. <u>Assessment of the Site Concept Model</u>
   SCS examined the vertical distribution of sample locations relative to reported field observations and geophysical logs from the well bore holes to look for trends and evidence of preferential contaminant transport through fractures (**Section 3.2**). Detailed refinement of the site conceptual model is beyond the scope of this study.

3. <u>Revised Analysis of Data</u>
   SCS evaluated additional temporal PCE data collected through the end of 2016 and considered trends within apparent hydro-stratigraphic units (**Section 3.1**). SCS did not attempt to substantially refine the conceptual model and did not reevaluate site-specific data in detail.

4. <u>Additional Evaluation of the Flow System in Three Dimensions for the Current and Future Conditions</u>
   SCS used the Dane County groundwater model to focus on travel times to UW8 without specific consideration of the potential effects of the source zone extraction well (**Section 4.0**). SCS also used the groundwater model to evaluate the potential effects of an open test well at UW8. In addition, SCS reviewed the capture zone of the extraction well based on monitoring data reported by MKC (**Section 3.3**).

5. <u>Revision of CRAFLUSH Modeling</u>
   SCS did not attempt to reproduce or refine the previous CRAFLUSH modeling efforts (**Section 3.4**). It appeared that a significant amount of additional data and analysis would be necessary, and there was no guarantee that the results would produce a more accurate, verifiable prediction of contaminant transport.

Finally, SCS also reviewed the contaminant concentration data for UW8 itself (**Section 3.5**).

3.0 GROUNDWATER MONITORING REVIEW

The MKC groundwater monitoring network for the PCE plume includes 61 individual monitoring points. Well locations are shown on TRC Figure 2 included in **Appendix A**. The 61 individual sample points are grouped at 25 locations that include individual wells, nested wells consisting of multiple conventional wells, and four multi-level wells with multiple screen intervals in a single bore hole. The monitoring point names, sample depth intervals, number of samples collected since 2009, average PCE, concentrations and additional summary information are listed in **Table 1**.

3.1 PCE CONCENTRATION TRENDS

The temporal trends observed at the individual sampling points in the groundwater monitoring network generally show that PCE concentrations are stable or decreasing. The sampling points with increasing PCE trends suggest that fingers of contamination are continuing to migrate outward from the source area.

SCS re-tabulated PCE results for samples collected from 61 "permanent" MKC monitoring points starting December 2009 and continuing through October 2016, plotted the PCE concentration versus time for each monitoring point, and added a linear trend line. Trend plots for all monitoring points are included in **Appendix B**. The charts show the detection limit rather than 0 values for dates where PCE was not detected. SCS then applied what we believe are the same quantitative statistical analyses used by Arcadis in their 2014 plume stability evaluation, p-value and coefficient of determination (R^2), to the expanded set of PCE results. Average PCE concentrations, concentration trend over time, and statistical parameters are summarized in **Table 1**.

SCS did not plot contamination trends for contaminants other than PCE. PCE appears to be the contaminant on the leading edge of the plume. With few exceptions, other associated contaminants such as trichloroethylene (TCE) and cis-1,2- DCE, when detected, are present at lower concentrations than PCE.

3.1.1 Arcadis' Trend Data

Arcadis' contamination trend analysis (Arcadis, 2014, Table 1 - see **Appendix C**) included data from 22 monitoring points, of which 12 had sufficient data for quantitative statistical analysis. Among the 12 quantitative analyses, seven showed statistically significant decreasing trends (p-values less than 0.1), and five had p-values greater than 0.1 indicating that the trends were not statistically significant.

3.1.2 SCS Trend Data

The more extensive data set available to SCS during the preparation of this report included additional samples collected from most of the monitoring points that were previously sampled for PCE. Fifty of the monitoring points were sampled eight or more times, and 23 had p-values less than 0.1. Five of these 23 sample points showed statistically significant increasing trends and 18 showed decreasing trends. Qualitative analysis of the dataset identified 10 additional sampling points with increasing trend lines.

The trend analysis showed statistically significant increasing trends in MW-9D2, MP-14D, MP-15B, MP-15C, and MP-15D. These five monitoring points are clustered at two geographic locations: MP-14 is located about 400 feet west of the source area, and MW-9 and MP-15 are located together approximately 700 feet north of the source area. The impacted sample interval depths correspond to the lower Lone Rock and the upper and lower Wonewoc Formations. The rate of increase at MP-14D and MP-15B appears to be decreasing and the PCE concentrations in these wells appear to be approaching a plateau. Conversely, the rises in concentrations in MW-9D2, MP-15C, and MP-15D do not appear to be slowing.

The other sampling points with increasing, but less significant, trend lines include: MW5D, MP-13D, MP-13E, MP-13F, MP-16C, MW-20D, MW-20D2, MW-21D, MW-23D, and MW-27D2. These wells are open to the Lone Rock and the Wonewoc Formations and located in various directions within a distance of about 450 feet of the source area, with the exception of MW-27D2. MW-27D2 is located more than 1,400 feet north of the source area. The evidence of increasing PCE concentration at these wells is generally not very convincing. The last data point at MW-27D2, if confirmed by subsequent sampling, could indicate that PCE is starting to increase again after declining in 2014 and 2015.

As indicated above, the five sample points showing statistically significant increases of PCE over time are outnumbered more than 3:1 by the wells showing statistically significant PCE decreases over time. These wells with significant increasing or decreasing trends are further outnumbered by the 38 wells that either have no quantifiably consistent trend or no consistently detected PCE. Taken as a whole, these data suggest that the contaminant plume is relatively stable.

The wells showing statistically significant increases in PCE concentrations are located in directions away from UW8; however, the distribution and movement of PCE, and related contaminants, over time could change in the future under the influence of increased groundwater withdrawals from UW8 or decreased withdrawals from other city wells in the area. The increasing concentration trends are located in the deeper parts of the bedrock aquifer above the Eau Claire aquitard where PCE likely poses the greatest risk of encountering faster migration pathways toward pumping wells such as UW8.

3.2 CONTAMINANT DISTRIBUTION AND MONITORING NETWORK

SCS prepared a schematic north-south cross section (**Figure 1**) to summarize the vertical distribution of PCE sampling data in relation to the bedrock stratigraphy and flow and fracture data collected during MKC investigation activities. The location of the cross section follows cross section line A-A[1] shown on TRC Figure 2 (**Appendix A**). A standard geologic cross section along the same line is shown on TRC Figure 11 (**Appendix A**). The schematic cross section on **Figure 1** provides additional data as described below, but does not show the distances between borings in proportion to their actual location.

SCS developed the cross section shown on **Figure 1** to summarize the vertical distribution of data from MKC's site investigation activities. The cross section includes 12 well (or well nest) locations located along a section extending from the MW-27 monitoring well nest located north of the MKC site to UW8 located south of the MKC site near Lake Monona. For each location, the section shows the sampling points listed from shallowest to deepest, sample screen (open) interval, the ground surface elevation, and the lithology interpreted from boring logs and well construction reports. Average PCE concentrations (or detection limits) analyzed from 2009 through 2016 appear adjacent to their corresponding sample intervals. Where available, the section also shows PCE concentrations relative to regulatory standards obtained from profile samples collected during testing of open boreholes as well as a qualitative representation of fractures, fracture zones, and apparent zones of flow in or out of the borehole gleaned from geophysical studies and interpretations presented in Arcadis 2013 SI Report.

The contamination source area on the cross section is located near the groundwater extraction well identified as GWE-1. The cross section shows that the greatest levels of PCE contamination near the source area are generally located in the lower portion of Lone Rock Formation and the upper to middle portions of the Wonewoc Formation. Moving away from the source area, at the MW-27 and MW-6/17 nests, the greatest levels of contamination appear to be located deeper in the Wonewoc Formation. At the MW-27 and MW-25 well nests, the greatest PCE concentrations appear to be located in the monitoring intervals located across or near identified fracture zones.

As shown on **Figure 1**, the bedrock groundwater monitoring intervals at each location (well, well nest or multi-level well) are generally open across or near apparent fractures identified in the boreholes, although all apparent fracture zones in each borehole are not intersected by a sampling interval. Similarly, there are a few apparent groundwater flow zones identified in the open boreholes that are not intersected by sampling screen intervals. There are no monitoring points in the Mount Simon aquifer that is providing water to UW8. Section 4.5.1.3 of Arcadis' 2013 SI Report summarizes the geophysical data for monitoring wells installed in 2012 (MW-3 nest, MW-5 nest, MP-13, MP-14, MP-15, and MP-16). Review of the well screen depths for the 2012 wells indicates that, of the 28 screen intervals represented by these sample points, eight were located in the identified zones of highest fracture intensity.

3.3 EXTRACTION WELL

The influence of the groundwater extraction and treatment system (GETS) appears to be limited primarily to the portion of the contaminated zone within the Lone Rock Formation, based on drawings prepared by TRC (Figures 3 through 6 in **Appendix A**). The GETS commenced full-time operation in January 2016 after a startup and testing period in the last 6 months of 2015 (TRC, 2017, p. 2). The extraction well is open to the entire thickness of the lower Lone Rock Formation and the upper Wonewoc Formation, as well as approximately the upper half of the lower Wonewoc Formation.

The monitoring wells shown as influenced by the GETS on TRC Figure 3 (**Appendix A**) are all screened in the Lone Rock Formation. The radius of the apparent capture zone shown on Figure 3 is approximately 100 to 300 feet, and the zone extends further to the north of the GETS well than to the south. The potentiometric contours for the upper Wonewoc Formation shown on TRC Figure 6 do not indicate a capture zone for the GETS well in this formation, and show an apparent flow direction primarily toward the east-southeast.

While the treatment system data indicate that recovery well is removing contaminant mass from the source area, the PCE iso-concentration contours suggest that most of the contaminant mass is beyond the reach of the recovery well. A substantial portion of the contamination identified on the southern portion of the site in the Lone Rock Formation and most, or all, of the contamination plume in the Wonewoc Formation are outside the capture zone of the recovery well.

3.4 CRAFLUSH MODEL

Arcadis' predictive modeling using the CRAFLUSH model indicated that: "the PCE plume is stable and no longer migrating. Results indicate that the primary mechanism controlling the PCE plume length is matrix diffusion and the primary mechanism controlling plume stability is the PCE degradation rate" (Arcadis, 2014, p. 10).

SCS did not attempt to reproduce or refine the CRAFLUSH mathematical fate and transport modeling described by Arcadis in their 2014 evaluation of plume stability. The 23 calibration targets used by Arcadis were "…selected as those monitoring wells screened in the Upper Wonewoc Formation (Figure 3) because the extent of PCE is larger in this formation compared to other geologic formation at the site" (Arcadis, 2014, p. 9). Review of the CRAFLUSH targets listed in Table 3 of the 2014 Arcadis report indicated that only six discrete sample locations, and what may have been an averaged concentration from multiple intervals in MP-13, were within the Upper Wonewoc Formation. Other sample points included among the calibration targets included those screened in soil (4), the upper (5), and lower (6) Lone Rock Formations, and lower Wonewoc Formation (1). Based on the uncertainty regarding some of the model parameters identified by Dr. Meyer and the relatively small number of calibration targets in the modeled formations, SCS believes that additional CRAFLUSH modeling efforts will not provide greater certainty regarding the stability of the PCE plume.

3.5 CONTAMINATION IN UW8

PCE has not been detected in UW8 in samples collected from 1988 through the most recent reported sampling in August 2017. VOCs detected in UW8 during this period include bromodichloromethane, bromoform (tribromomethane), dibromochloromethane, chloroform (trichloromethane), 1,2-dichloroethane (DCA), and cis-1,2-dichloroethylene (DCE). Bromodichloromethane, bromoform, dibromochloromethane, and chloroform are all trihalomethanes which result from treatment of water with chlorine. 1,2-DCA was detected only twice in UW8 and is not related to the degradation of PCE. Cis-1,2-DCE often occurs as the result of the breakdown or degradation of either TCE or PCE.

The history of cis-1,2-DCE concentrations in UW8 is summarized on the chart shown on **Figure 2**. Cis-1,2-DCE has been detected in 17 of the 31 samples analyzed, at concentrations ranging from 0.1 to 0.26 micrograms per liter (µg/L). When cis-1,2-DCE has been detected, the concentrations are slightly greater than the detection limit and less than the limit at which the laboratory can reliably quantify the amount of detected contamination. The detected concentrations are also well below the preventive action limit of 7 µg/L and the enforcement standard of 70 µg/L. The trend line on **Figure 2** appears to show that the detected concentrations of cis-1,2-DCE have increased over time; however, given the variability of the data and the fact that the reported concentrations are below the limit of quantitation, the trend line is not very significant.

Examination of the groundwater monitoring data from the MKC investigation shows that cis-1,2-DCE is present in the plume, but it does not appear to be on the leading edge of the plume. At most locations, the concentrations of cis-1,2-DCE are much less than those of PCE. For example, at MW-25D, located about three-quarters of the distance from MKC to UW8, cis-1,2-DCE first appeared in the October 2016 sample, while PCE has been detected since the well was first sampled in 2013. Closer to the source, at the edge of the Kipp property, concentrations of PCE are about 200 times greater than those of cis-1,2-DCE. Similarly, near the northern edge of the plume, at the MW-27 nest, the concentrations of PCE are higher than those of cis-1,2-DCE.

The presence cis-1,2-DCE in UW8 is difficult to directly attribute to migration of contaminants from the MKC site using the currently available data. Based on the relative proportions of cis-1,2-DCE and PCE outer reaches of the MKC contamination plume in the upper bedrock aquifer, the first contaminant to arrive at UW8 might be expected to be PCE rather than cis-1,2-DCE. However, if the plume has penetrated the Eau Claire aquitard and different geochemical/ degradation conditions prevail in the lower bedrock aquifer, the relative proportions of cis-1,2-DCE and PCE could vary from what has been observed in the upper bedrock aquifer.

4.0 GROUNDWATER FLOW MODEL

SCS used the 2016 groundwater flow model for Dane County developed by the Wisconsin Geological and Natural History Survey and the United States Geological Survey to evaluate advective groundwater transport pathways and travel times between the MKC site and UW8. Documentation of the model is provided by Parsen and others (2016). SCS referenced the user guide prepared by Bradbury and others (2016) when modifying the model to simulate different pumping rates and add particles for groundwater flow pathway tracking.

4.1 SITE-SPECIFIC CONSIDERATIONS

The conceptual model, design, and underlying assumptions incorporated into the groundwater model are described in detail in the model documentation report. Considerations specific to the subject of this study include:

- The finite difference grid spacing of the model is 360 feet. The distance between UW8 and the apparent source area on the MKC property is about 2,000 feet. Furthermore, the distance from the downgradient edge of the MKC property to UW8 is about 1,300 feet. With only about three to six grid cells along the flow path, the model provides relatively coarse horizontal resolution of the potential flow paths between MKC and UW8.

- The flow model represents full thickness of the unconsolidated sediments and bedrock aquifers down to the underling relatively impermeable Precambrian “basement” rock using 12 layers. The entire thickness of the Mount Simon aquifer, roughly 490 feet, is represented by a single model layer, and several model layers in the study area have only a nominal thickness of about 0.2 feet because the hydro-stratigraphic units they represent are not present in this area. The shaly portion of the Eau Claire Formation, which forms the “confining unit” or aquitard above the underlying Mt. Simon aquifer, is represented in the model as a layer about 5 feet thick.

- While the model is capable of representing changing conditions over time, all simulations in this study were run under steady state conditions. Under steady state conditions, the model simulates the head distribution results in the aquifer after pumping a well for an infinite period of time. The model assumes that the pumping rate is constant over time. Based on SCS’s experience, the head in the confined Mt. Simon aquifer appears to respond relatively quickly to changes in pumping rates in the vicinity of a pumping well. In this scenario, use of steady state conditions is probably a reasonable approximation of reality within a few years of the resumption of normal pumping rates in UW8.

- Particle travel times are calculated using an assumption of advective flow. This means that a discrete “particle” of contamination moves through an average path through the pore spaces of the aquifer without being retarded by sticking to the aquifer materials, breaking down during transport, dispersing away from the primary travel direction, or getting stuck in dead end pores.

UW8 is represented in the calibrated model with an average pumping rate of 53,183 cubic feet per day or 276 gallons per minute (gpm). This rate is based on limited usage of the well. Under conditions corresponding to “normal” use for the well for water supply, the average flow is anticipated to be 211,765 cubic feet per day or about 1,100 gpm.

4.2 MODELED SCENARIOS

4.2.1 Normal Pumping

SCS first simulated the conditions resulting from pumping UW8 under anticipated normal conditions with an annual average flow rate of 1,100 gpm. Simulated particle traces are shown in plan view on **Figure 3** and in cross-section view on **Figure 4**. This scenario resulted in approximately 16 feet of drawdown in the Mt. Simon aquifer in adjacent model grid cells (within 360 feet horizontally from the pumping well). Under these conditions the calculated travel time of a particle introduced at the MKC source area in the unconsolidated aquifer, near the water table, to UW8 is about 46 years. The corresponding travel time for a particle starting at the base of the upper bedrock aquifer, just above the Eau Claire aquitard, is about 12 years. The calculated transit times for upper and lower particles starting at the downgradient edge of the MKC property near the intersection of South Marquette Street and Atwood Avenue are 38 and 6 years, respectively.

4.2.2 Open Test Well at UW8

SCS looked at the potential effects of an open borehole or test well extending from the upper bedrock, across the Eau Claire aquitard into the full thickness of the Mt. Simon, by adding a new well to the model in the same grid cell as UW8, open to model layers 7 through 12 with a pumping rate of zero. Particle traces simulated in this scenario are shown on **Figure 5**. This open borehole had a negligible effect on the transport time of particles introduced at the MKC site.

The vertical contribution of flow from the overlying bedrock aquifer across the Eau Claire aquitard through the open borehole is about 17 gpm or 1.5 percent of the total volume withdrawn from UW8 under modeled normal withdrawals of 1,100 gpm.

The negligible impact of the open test well on modeled transit times is explained by the fact that the model shows particles crossing the confining unit relatively close to the source area and then travelling laterally in the underlying Mt. Simon. Stated another way, particles are shown to travel primarily downward to and through the confining unit before travelling horizontally most of the distance to UW8 in the lower sandstone aquifer.

4.2.3 Reduced Pumping Rate

For the purpose of comparison, SCS ran the model using the current 276 gpm annual average pumping rate for UW8, with no open test well near UW8. Particle traces simulated in this scenario are shown on **Figure 6**. Under these conditions the calculated travel time of a particle introduced at the MKC source area in the unconsolidated aquifer, near the water table, to UW8 is about 79 years. The corresponding travel time for a particle starting at the base of the upper bedrock aquifer, just above the Eau Claire aquitard, is about 32 years. The calculated transit times for upper and lower particles starting at the downgradient edge of the MKC property near the intersection of South Marquette Street and Atwood Avenue are 56 and 17 years, respectively.

5.0 SENTINEL WELL LOCATION CONSIDERATIONS

The groundwater flow modeling results suggest that the best location for a sentinel well is in the lower bedrock aquifer, because most of the horizontal travel is expected to occur in this unit. A sentinel well situated in the upper bedrock aquifer at a distance from the MKC source area would be likely to miss the primary migration pathway. A second reason for placing a sentinel well in the lower bedrock aquifer is the fact that none of the existing MKC monitoring wells are screened below the confining unit. If the particle transport below the source area is primarily vertical as indicated by the model, it is conceivable that contamination from the source area may have moved downward to and through the confining unit, perhaps through system of (sub)vertical fractures, without being encountered by the monitoring wells in the upper bedrock.

The particle flow paths produced by groundwater model suggest that the sentinel well should be screened in the uppermost part of the Mt. Simon aquifer. SCS recommends that the screened interval(s) should be selected based on geophysical and flow logging of an open borehole drilled through approximately the upper third of the anticipated thickness of the Mt. Simon at the selected well location.

As stated previously, the horizontal distance between the downgradient edge of the MKC property and UW8 is only slightly more than 1,300 feet. Given model-calibrated values of horizontal hydraulic conductivity in the Mt. Simon of 16 feet per day, a horizontal gradient from MKC to UW8 of 0.007 and an effective porosity of 0.15, and a resulting advective velocity of 270 feet per year, un-attenuated contaminants would cover this distance in less than 5 years.

Potential monitoring locations within the City of Madison public right-of-way (ROW) or adjoining Madison Metropolitan School District (MMSD) property are shown in blue on **Figure 7**. The potential well locations shown on **Figure 7** are along the particle flow paths between various contaminated portions of the MKC property and UW8, and are clear of overhead utilities. SCS did not evaluate the presence of underground utilities in the ROW that could further limit the available options for well locations. Drilling work on MMSD property or on streets adjacent to the school might need to be limited to times when school is not in session to minimize potential student safety concerns.

Placing a sentinel well slightly closer to the MKC site than the MW25 nest provides two main advantages. It maximizes the time available to plan corrective actions in the event contamination is encountered, and it may reduce the uncertainty regarding whether the well is in the correct location to encounter potential contaminants as they migrate away from the source area.

6.0 CONCLUSIONS

- Although most of the 61 groundwater monitoring points installed for the MKC investigation where PCE has been detected appear to show stable or declining PCE concentrations, five monitoring points show increasing PCE concentration trends. The PCE plume appears to be continuing to expand to the north in the direction of the MW-9/MP-15 well nest.

- Based on the limited data available it is difficult to evaluate the extent to which fractures in the bedrock are controlling the migration of the PCE contamination plume in groundwater. Detailed geophysical logging has not been performed in all of the monitoring wells. SCS did not see evidence of a laterally continuous fracture zone across the north-south extent of the plume. The highest observed concentrations in each well nest do not appear to be well correlated with identified fracture or flow zones. As shown on the TRC figures included in **Appendix A**, the horizontal extent of contamination is greatest in the Wonewoc Formation, and relatively few monitoring points are located at the base of the Wonewoc.

- The GETS is removing contaminant mass from the aquifer system; however, the influence of the system relative to the documented extent of contamination is relatively small. Contamination beyond the capture zone of the extraction well will likely remain subject to migration along head and concentration gradients that are not subject to the control of the GETS system.

- The value of CRAFLUSH model predictions is limited by both the amount of available calibration data in the targeted zones and site-specific values for model input parameters.

- It is unclear whether the cis-1,2-DCE detected in the samples from UW8 is related to the documented MKC contamination. In the MKC plume, PCE generally appears to be on the leading edge of the plume and is lagged by cis-1,2-DCE. Within the resolution of the analytical methods used, the trace concentrations of cis-1,2-DCE detected in UW8 appear to be relatively consistent over the last 29 years.

- Simulations performed using the Dane County groundwater flow model suggest that the un-retarded travel times to UW8 from various locations within the MKC contamination plume range from 6 to 46 years. Based on the monitoring data from UW8, it does not appear that breakthrough of the PCE plume at this well has occurred. The model does not account for retardation or attenuation of dissolved contaminants along the flow path, although these processes very likely are occurring.

- The particle flow paths simulated by the groundwater model suggest that the movement of contamination below the MKC site is primarily vertical and that rapid horizontal transport would not occur until the contaminants penetrate the Eau Claire into the underlying Mt. Simon aquifer. Perhaps contrary to the common perception of the Eau Claire as a relatively impermeable confining unit, the calibrated flow model suggests that un-attenuated particles would move down across the Eau Claire aquitard in a few years. The model simulations suggest that if the plume were to penetrate the Eau Claire, un-attenuated contaminants could migrate toward UW8 within as few as 5 years.

- Because the groundwater model suggests that the primary pathway for horizontal movement of contamination is through the Mt. Simon aquifer, model simulations of an open test well penetrating the Eau Claire aquitard near UW8 show little if any impact of such a well on anticipated particle (contamination) arrival times at UW8.

- Based on the current understanding PCE distribution in groundwater and the results of groundwater flow model particle tracking scenarios, the issue of greatest concern to MWU likely is PCE penetration through the Eau Claire aquitard at points closer to MKC than to UW8.

- In addition to ongoing review of the monitoring data that MKC is reporting to WDNR, SCS recommends that MWU consider installing a new groundwater monitoring well, open to the Mt. Simon Formation, at a location no closer to UW8 than the existing MW-25 well nest, but at least 500 feet downgradient from MW-17. The relatively low detected PCE concentrations at MW-25 pose little threat of cross contaminating the Mt. Simon during the brief period a borehole would be open for the construction of a monitoring well.

7.0 REFERENCES

Arcadis, U.S., Inc. (Arcadis) 2013, Site Investigation and Interim Actions Report, February 2012- January 2013, Madison-Kipp Corporation, 201 Waubesa Street, Madison, Wisconsin: March 15, 2013, 118 p.

Arcadis, 2014, Evaluation of Plume Stability and Fate and Transport Modeling for PCE in Bedrock Groundwater, Madison Kipp Corporation, Madison, Wisconsin: April 16, 2014, 45 p.

Bradbury, K.R., Parsen, M.J., and Fehling, A.C., 2016, The 2016 Groundwater Flow Model for Dane County, Wisconsin - User's Manual: Wisconsin Geological and Natural History Survey Bulleting 110 - supplement, 32 p.

Meyer, J., 2014, Technical Evaluation of Assessments of the Potential for PCE in Groundwater Associated with the MKC Site to Impact Unit Well #8: Madison, Wisconsin, January 21, 2015, 27 p.

Parsen, M.J., Bradbury, K.R., Hunt, R.J., and Feinstein, D.T., 2016, The 2016 Groundwater Flow Model for Dane County, Wisconsin: Wisconsin Geological and Natural History Survey Bulletin 110, 56 p.

TRC, 2017, Operations, Monitoring, and Maintenance Semi-Annual Report, July 1, 2016 – December 31, 2016, Madison-Kipp Corporation: March 7, 2017, 584 p.

[This page left blank intentionally.]

TABLE 1

MKC Monitoring Well Summary

Table 1. MKC Monitoring Well Summary

PCE Plume Evaluation - Unit Well 8

SCS Project 25215167.00

Well ID	Date Installed	Ground Surface Elevation (ft. amsl)	Depth to Top of Well Screen (feet)	Depth to Bottom of Well Screen (feet)	Screen Length (feet)	Unit Open to Screen	Fracture Flow?[1]	Arcadis CRA-FLUSH Target	Number of Samples through 2016	Average PCE Concentration[2] (ug/L)	PCE Trend[3]	PCE Trend Line Fit (R^2)	PCE Trend P-value	Trend Significant?[4]
MW-1	1/10/95	861.71	14	24	10	Soil	NA		12	**16**	declining	0.39	2.93E-02	Yes
MW-2S	7/31/95	866.34	19	29	10	Soil	NA		9	1.2	declining	0.45	4.77E-02	Yes
MW-2D	7/31/95	866.50	39	44	5	ULR	--		16	**556**	declining	0.90	1.60E-08	Yes
MW-3S	8/1/95	867.87	19	29	10	Soil	NA	Yes	15	**1,017**	unclear	0.07	3.38E-01	-
MW-3D	unknown	867.68	48	53	5	ULR	Yes	Yes	19	**737**	declining	0.65	2.83E-05	Yes
MW-3D2	4/2/01	867.58	76	81	5	LLR	Possibly	Yes	21	**1,857**	declining	0.70	2.04E-06	Yes
MW-3D3	7/13/12	867.61	214	224	10	LW/EC	No		13	1.0	asymptotic	0.22	1.06E-01	-
MW-4S	unknown	880.81	35	50	15	Soil/ULR	--		9	1.4	stable	0.00	9.15E-01	-
MW-4D	6/6/96	881.18	65	70	5	LLR	--		8	0.4	declining	0.46	4.32E-02	Yes
MW-4D2	unknown	880.36	91	96	5	LLR	--		13	1.0	declining	0.49	7.63E-03	Yes
MW-5S	4/4/01	872.56	34	44	10	ULR	Possibly	Yes	14	**190**	declining	0.31	3.97E-02	Yes
MW-5D	5/3/01	872.58	75	80	5	LLR	No	Yes	16	**1,001**	increasing?	0.04	4.40E-01	-
MW-5D2	2/11/03	872.59	165.8	170.8	5	LW	Yes	Yes	13	**518**	unclear	0.00	9.37E-01	-
MW-5D3	7/12/12	872.64	225	235	10	LW/EC	No		14	1.9	asymptotic	0.18	1.29E-01	-
MW-6S	2/4/03	877.20	31.4	41.4	10	Soil/ULR	--		15	0.4	<1	0.06	3.94E-01	-
MW-6D	2/4/03	877.11	65.5	70.5	5	LLR	--	Yes	19	**17**	declining	0.86	1.19E-08	Yes
MW-7	7/25/11	870.91	24	35	11	Soil	NA		6	0.2	asymptotic	0.73	3.26E-02	-
MW-8	7/25/11	867.69	24	34	10	Soil	NA		6	0.2	asymptotic	0.73	3.25E-02	-
MW-9D	7/26/11	855.80	44	49	5	ULR	No		11	0.2	asymptotic	0.07	4.37E-01	-
MW-9D2	7/27/11	855.89	64	69	5	LLR	No		14	**34.0**	**increasing**	0.38	1.88E-02	Yes
MW-10S	4/4/12	864.88	11	21	10	Soil	NA		6	0.3	<1	0.00	9.26E-01	-
MW-11S	4/10/12	874.10	24	34	10	Soil	NA		6	0.2	<1	0.37	1.98E-01	-
MW-12S	4/10/12	859.78	3	13	10	Soil	NA		6	1.1	<2	0.00	9.87E-01	-
MP-13A	9/30/12	864.49	44	48	4	ULR	Possibly	combin-ed as one target?	11	**682**	declining	0.60	4.92E-03	Yes
MP-13B	9/30/12	864.49	67	71	4	LLR	Possibly		11	**2,295**	declining	0.85	5.51E-05	Yes
MP-13C	9/30/12	864.49	81	85	4	LLR	No		11	**6,937**	stable	0.00	8.70E-01	-
MP-13D	9/30/12	864.49	102	106	4	UW	No		11	**1,776**	increasing	0.14	2.53E-01	-
MP-13E	9/30/12	864.49	121	125	4	UW	No		10	**5,480**	increasing?	0.06	4.80E-01	-
MP-13F	9/30/12	864.49	135	139	4	LW	No		10	**4,340**	increasing?	0.03	6.26E-01	-
MP-13G	9/30/12	864.49	163	167	4	LW	No		10	**746**	declining	0.51	1.98E-02	Yes
MP-14A	10/22/12	866.88	70	75	5	LLR	Possibly		7	0.2	asymptotic	0.26	2.37E-01	-
MP-14B	10/22/12	866.88	100	105	5	UW	Possibly		10	0.6	<2	0.04	5.73E-01	-
MP-14C	10/22/12	866.88	135	140	5	LW	No		13	**399**	declining	0.19	1.36E-01	-
MP-14D	10/22/12	866.88	170	178	8	LW	No		10	**527**	**increasing**	0.45	3.48E-02	Yes
MP-15A	12/11/12	855.98	88	92	4	UW	Yes		9	**168**	stable	0.00	8.86E-01	-
MP-15B	12/11/12	855.98	100	105	5	UW	No		9	**710**	**increasing**	0.57	1.83E-02	Yes
MP-15C	12/11/12	855.98	120	125	5	LW	No		9	**2,000**	**increasing**	0.55	2.19E-02	Yes
MP-15D	12/11/12	855.98	142	146	4	LW	No		9	**841**	**increasing**	0.79	1.45E-03	Yes
MP-15E	12/11/12	855.98	177	187	10	LW	No		9	**103**	declining	0.61	1.25E-02	Yes

Table 1. MKC Monitoring Well Summary

PCE Plume Evaluation - Unit Well 8

SCS Project 25215167.00

Well ID	Date Installed	Ground Surface Elevation (ft. amsl)	Depth to Top of Well Screen (feet)	Depth to Bottom of Well Screen (feet)	Screen Length (feet)	Unit Open to Screen	Fracture Flow?[1]	Arcadis CRA-FLUSH Target	Number of Samples through 2016	Average PCE Concentration[2] (ug/L)	PCE Trend[3]	PCE Trend Line Fit (R^2)	PCE Trend P-value	Trend Significant?[4]
MP-16A	11/30/12	870.68	80	84	4	LLR	No		6	0.4	<1	0.07	6.14E-01	-
MP-16B	11/30/12	870.68	106	116	10	UW	Yes		9	**139**	declining	0.06	5.23E-01	-
MP-16C	11/30/12	870.68	140	144	4	LW	No		12	**28.3**	increasing?	0.24	1.07E-01	-
MP-16D	11/30/12	870.68	175	179	4	LW	Possibly		9	4.9	declining	0.29	1.38E-01	-
MW-17	11/8/12	877.26	160	170	10	UW	--	Yes	8	**943**	increasing?	0.08	3.27E-01	-
MW-18S	11/2/12	869.89	20	30	10	Soil	NA	Yes	9	**1,870**	declining	0.42	6.22E-02	Yes
MW-19D	10/24/12	867.44	60	90	30	LLR	--	Yes	9	**2,022**	declining	0.41	6.22E-02	Yes
MW-19D2	10/24/12	867.44	110	140	30	UW	--	Yes	9	**1,139**	unclear	0.00	9.85E-01	-
MW-20D	10/25/12	867.36	60	90	30	LLR	--	Yes	9	**923**	increasing	0.02	7.34E-01	-
MW-20D2	10/25/12	867.36	110	140	30	UW	--	Yes	9	**728**	increasing	0.03	6.32E-01	-
MW-21D	10/26/12	867.77	60	90	30	LLR	--	Yes	9	**1,378**	increasing	0.09	4.45E-01	-
MW-21D2	10/26/12	867.77	110	170	60	UW	--	Yes	9	**2,248**	declining	0.30	1.23E-01	-
MW-22S	1/4/13	874.45	24	35	11	Soil	NA	Yes	9	**79.1**	declining	0.49	3.53E-02	Yes
MW-22D	1/4/13	874.75	45	50	5	ULR	--	Yes	12	**250**	declining	0.66	1.33E-03	Yes
MW-23S	1/3/13	874.55	24	35	11	Soil	NA	Yes	10	**268**	declining	0.26	1.31E-01	-
MW-23D	1/3/13	874.55	45	50	5	ULR	--	Yes	12	**152**	increasing?	0.04	5.45E-01	-
MW-24	3/28/13	876.55	30	40	10	Soil/ULR	--	Yes	5	2.6	declining	0.68	8.54E-02	-
MW-25D	5/2/13	886.97	120	130	10	UW	Yes	Yes	12	1.1	declining	0.04	2.64E-02	Yes
MW-25D2	5/2/13	886.97	160	170	10	UW	No	Yes	15	0.2	<1	0.10	2.63E-01	-
MW-26S	8/21/13	857.51	6.8	16.8	10	Soil	NA		5	0.4	asymptotic	0.42	2.40E-01	-
MW-27D	12/19/13	862.96	130	140	10	LW	No		12	4.3	unclear	0.00	9.47E-01	-
MW-27D2	12/19/13	862.96	170	180	10	LW	Yes		9	**31.3**	increasing	0.09	4.44E-01	-
GWE-1	1/9/14	867.62	60	175	115	bedrock	Yes							-

Abbreviations:

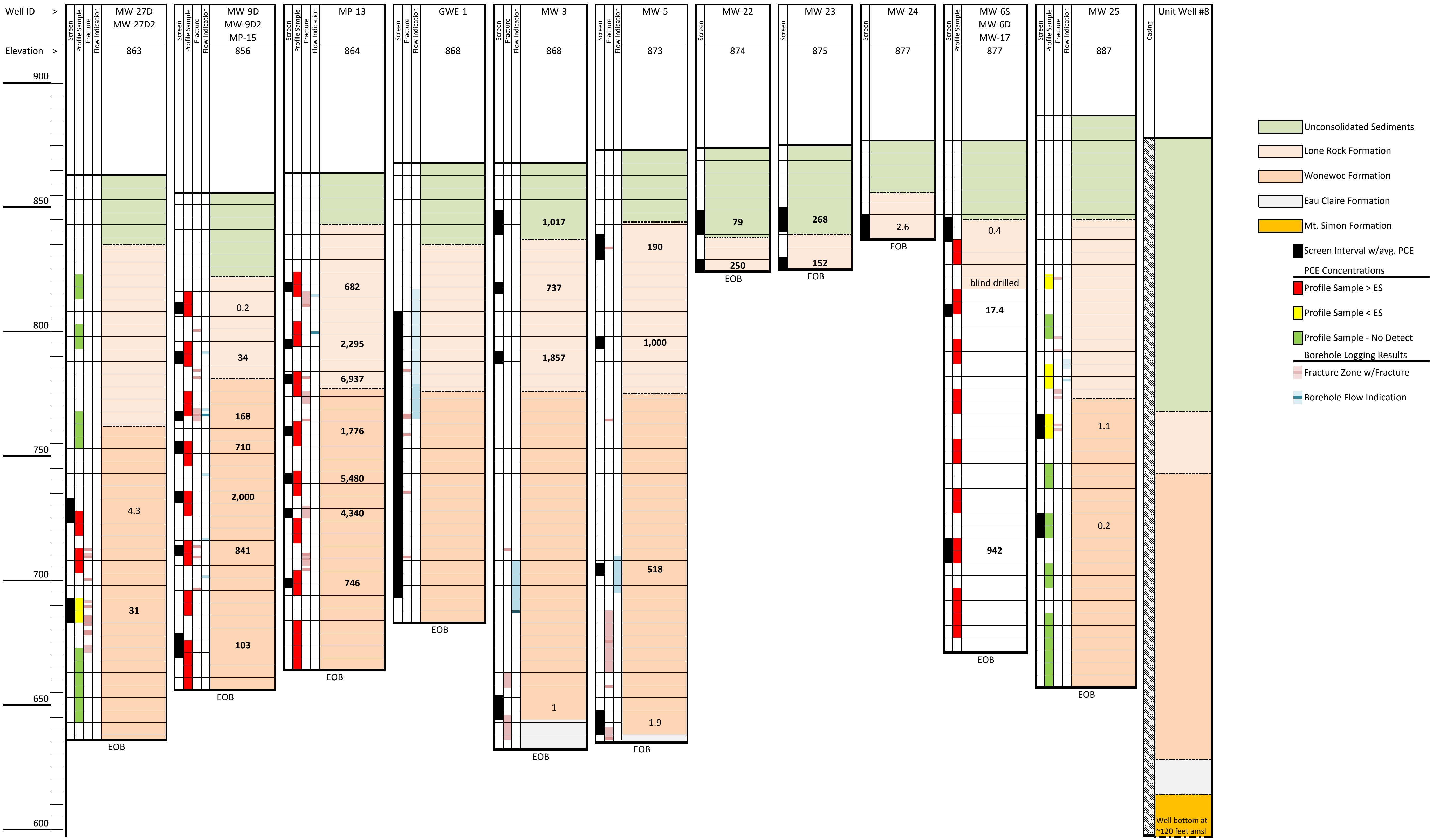
amsl = above mean sea level
ULR = Upper Lone Rock Formation
LLR = Lower Lone Rock Formation
UW = Upper Wonewoc Formation
LW = Lower Wonewoc Formation
PCE = Tetrachloroethylene

Notes:

1) Evidence water moving in or out of the borehole over a short vertical interval as indicated by an inflection of the continuous borehole fluid temperature or conductivity logs as interpreted by SCS
2) **Bold** font indicates PCE concentration exceeds the NR 140 groundwater enforcement standard
3) **Bold** font indicates increasing trend is statistically significant; "Asymptotic" indicates that reported PCE concentrations or detected limits declined to trace or demimimus concentrations after initially elevated levels
4) The calculated p-value for the relationship between time and concentration is less than 0.1, which is taken as an indication that the slope relationship between the two is statistically significant (not random).

FIGURES

Figure 1 - Well Summary/North-South Cross Section
PCE Plume Evaluation - Unit Well 8
SCS Project #25215167.00



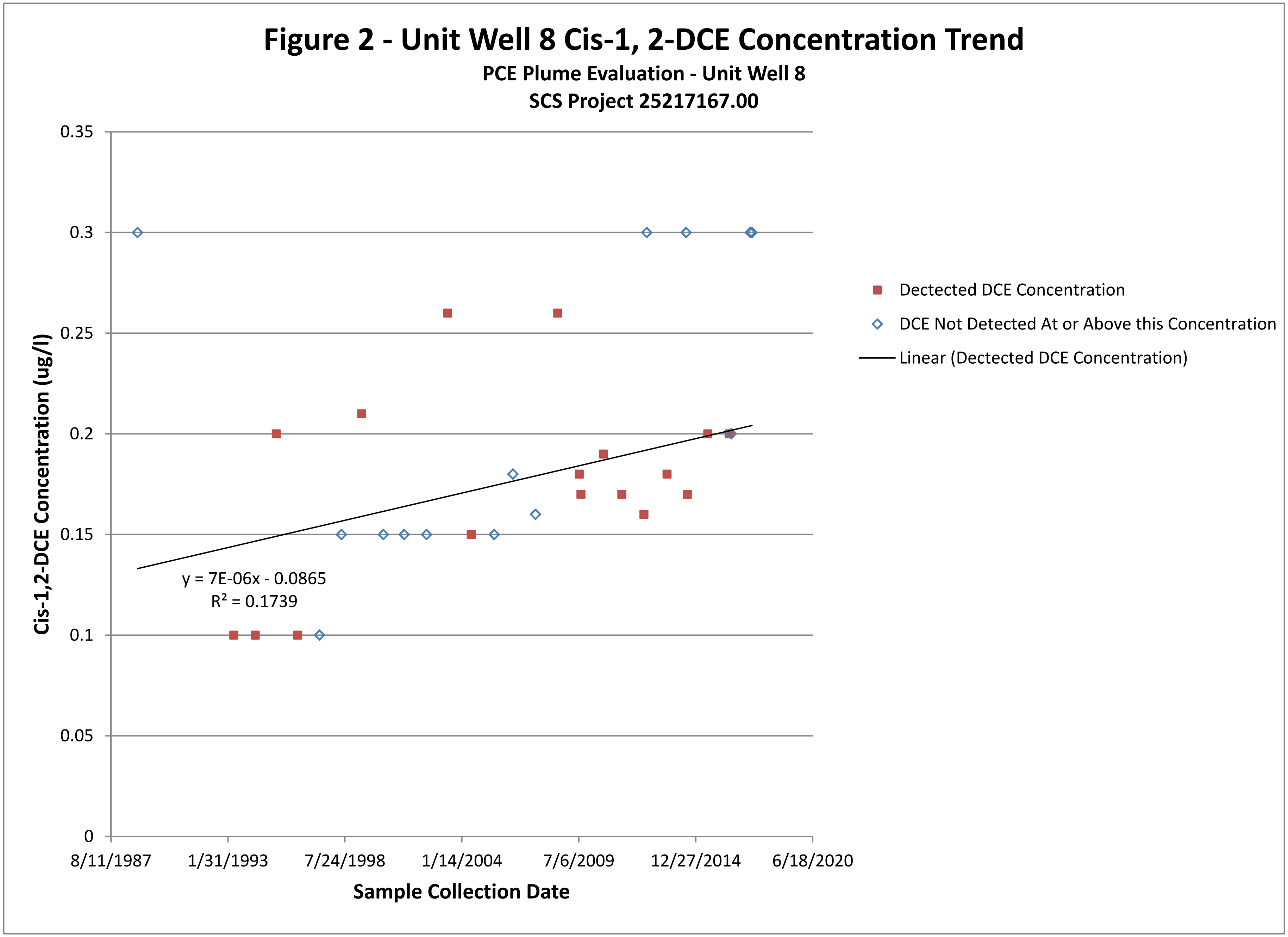


Figure 2 - Unit Well 8 Cis-1, 2-DCE Concentration Trend
PCE Plume Evaluation - Unit Well 8
SCS Project 25217167.00
Cis-1,2-DCE Concentration (ug/l)
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
8/11/1987
1/31/1993
7/24/1998
1/14/2004
7/6/2009
12/27/2014
6/18/2020
Sample Collection Date
y = 7E-06x - 0.0865
R² = 0.1739
Dectected DCE Concentration
DCE Not Detected At or Above this Concentration
Linear (Dectected DCE Concentration)

Figure 3 - Particle Tracking and Head Contours in the Mt. Simon Formation - UW8 Pumping at 1,100 gpm
PCE Plume Evaluation - Unit Well 8
SCS Project 25215167.00

Notes: 1) Particles tracks start at the water table and the base of the Wonewoc Formation - the longer travel times are associated with particles starting at the water table
2) Particle tracking times are shown in years from starting point
3) Heads in the Mt. Simon Formation are contoured at a 2-foot interval

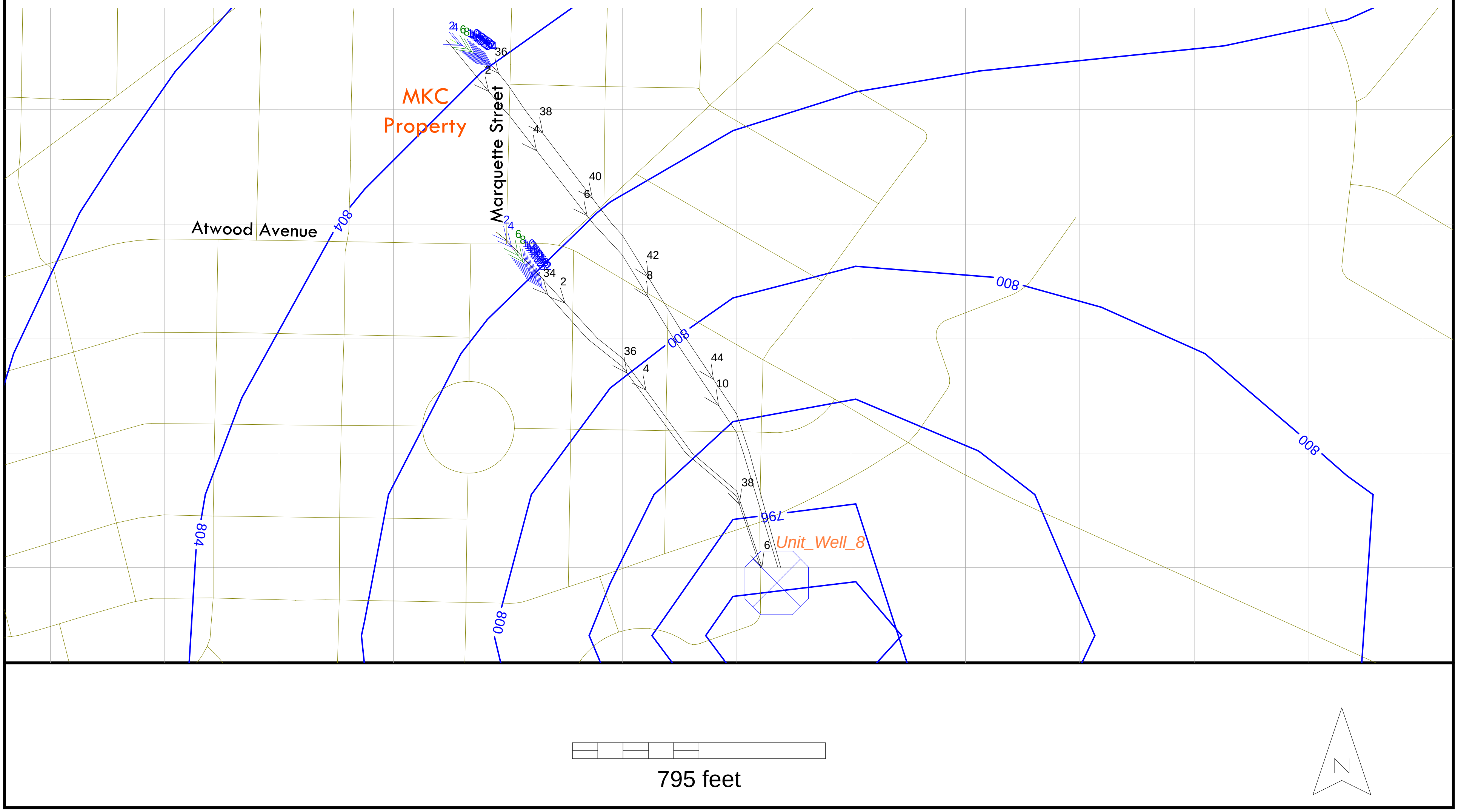


Figure 4 - North-South Cross Section With Particle Trace and Model Layers - UW8 Pumping at 1,100 gpm
PCE Plume Evaluation - Unit Well 8
SCS Project 25215167.00

Notes: 1) Particle track starts at the water table
2) Particle tracking times are shown in years from starting point
3) The cross section is oriented north-south while the actual partical trace is northwwest to southeast so horizontal distances along the pearticle path are forshortened

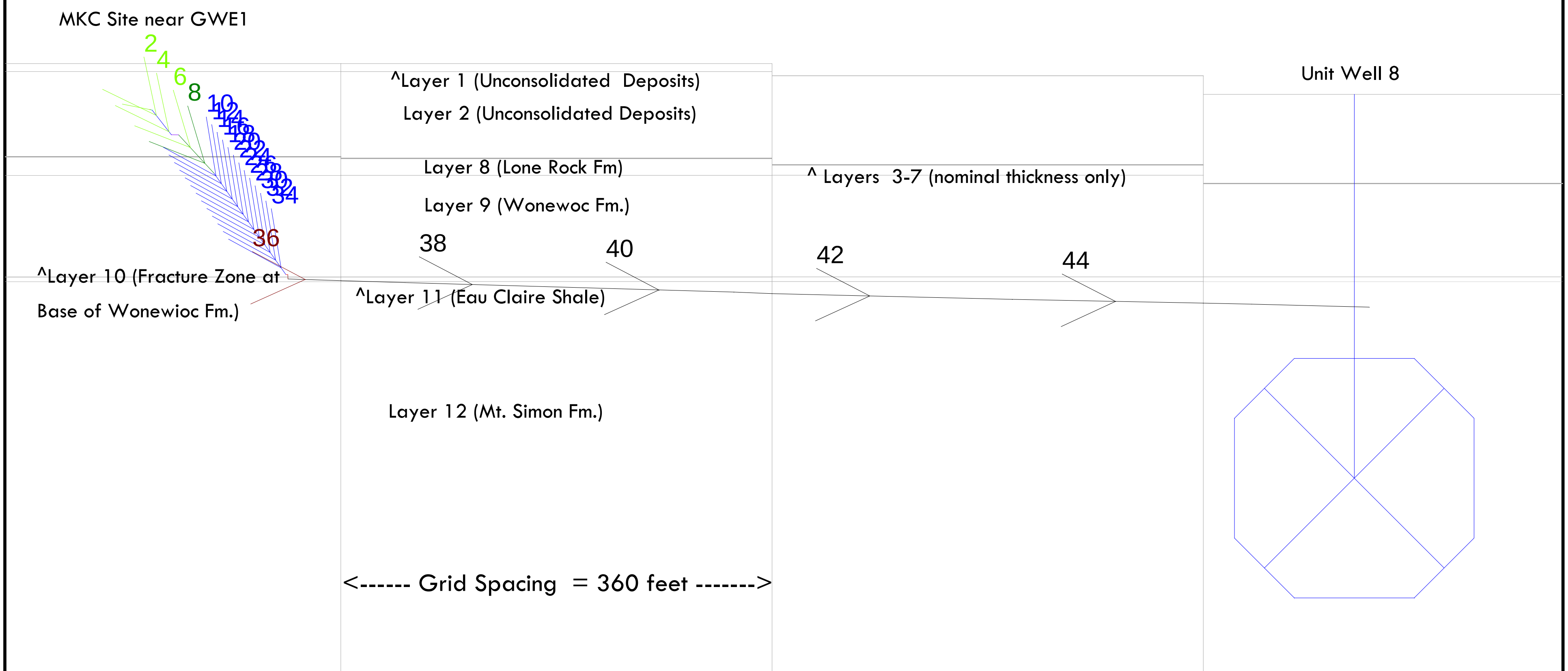


Figure 5 - Particle Tracking and Head Contours in the Mt. Simon Formation - UW8 Pumping at 1,100 gpm with Open Test Well Near UW8

PCE Plume Evaluation - Unit Well 8

SCS Project 25215167.00

Notes:
1) Particles tracks start at the water table and the base of the Wonewoc Formation - the longer travel times are associated with particles starting at the water table
2) Particle tracking times are shown in years from starting point
3) Heads in the Mt. Simon Formation are contoured at a 2-foot interval

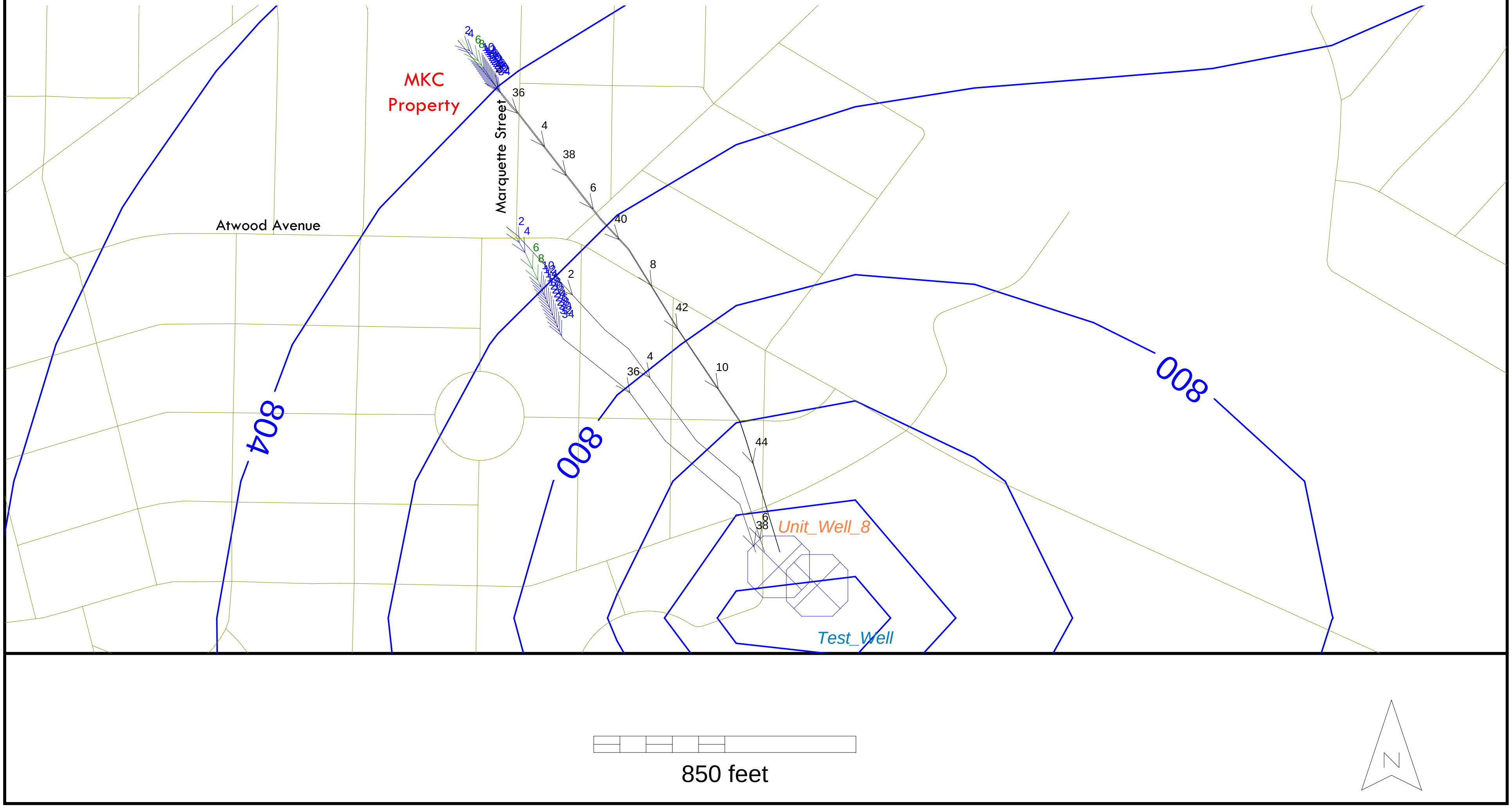
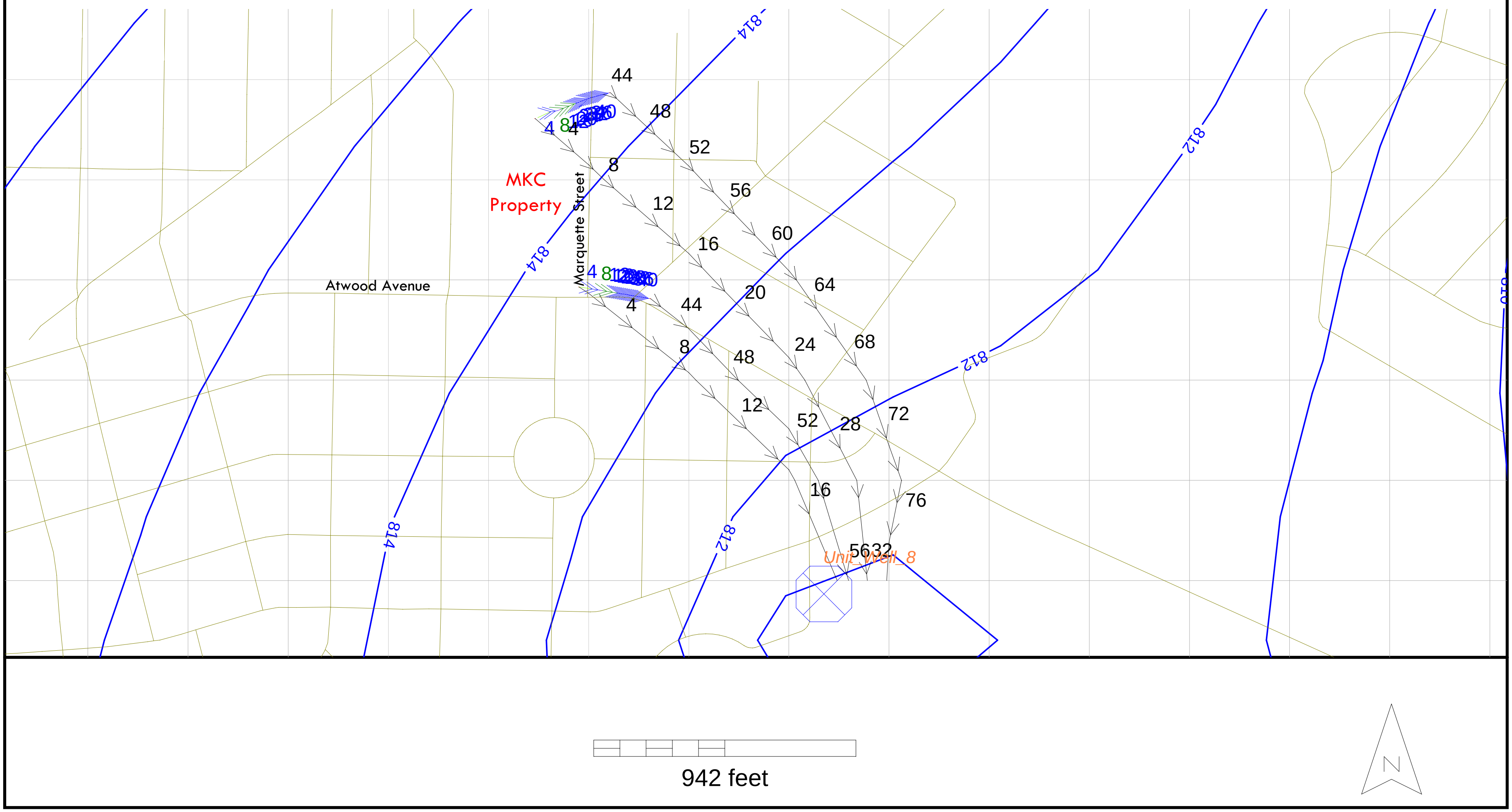


Figure 6 - Particle Tracking and Head Contours in the Mt. Simon Formation - UW8 Pumping at 276 gpm
PCE Plume Evaluation - Unit Well 8
SCS Project 25215167.00

Notes: 1) Particles tracks start at the water table and the base of the Wonewoc Formation - the longer travel times are associated with particles starting at the water table
2) Particle tracking times are shown in years from starting point
3) Heads in the Mt. Simon Formation are contoured at a 1-foot interval



August 16, 2017

Tax Parcels

1:2,400

0 0.0175 0.035 0.07 mi

0 0.0225 0.045 0.09 km

Figure 7 - Potential Monitoring Well Locations
PCE Plume Evaluation - Unit Well 8
SCS Project 2521516.00

Potential Well Locations Along Likely Contaminant Flow Paths That Are Not Obstructed by Terrace Trees or Overhead Utilities are Shown in Blue

Dane County

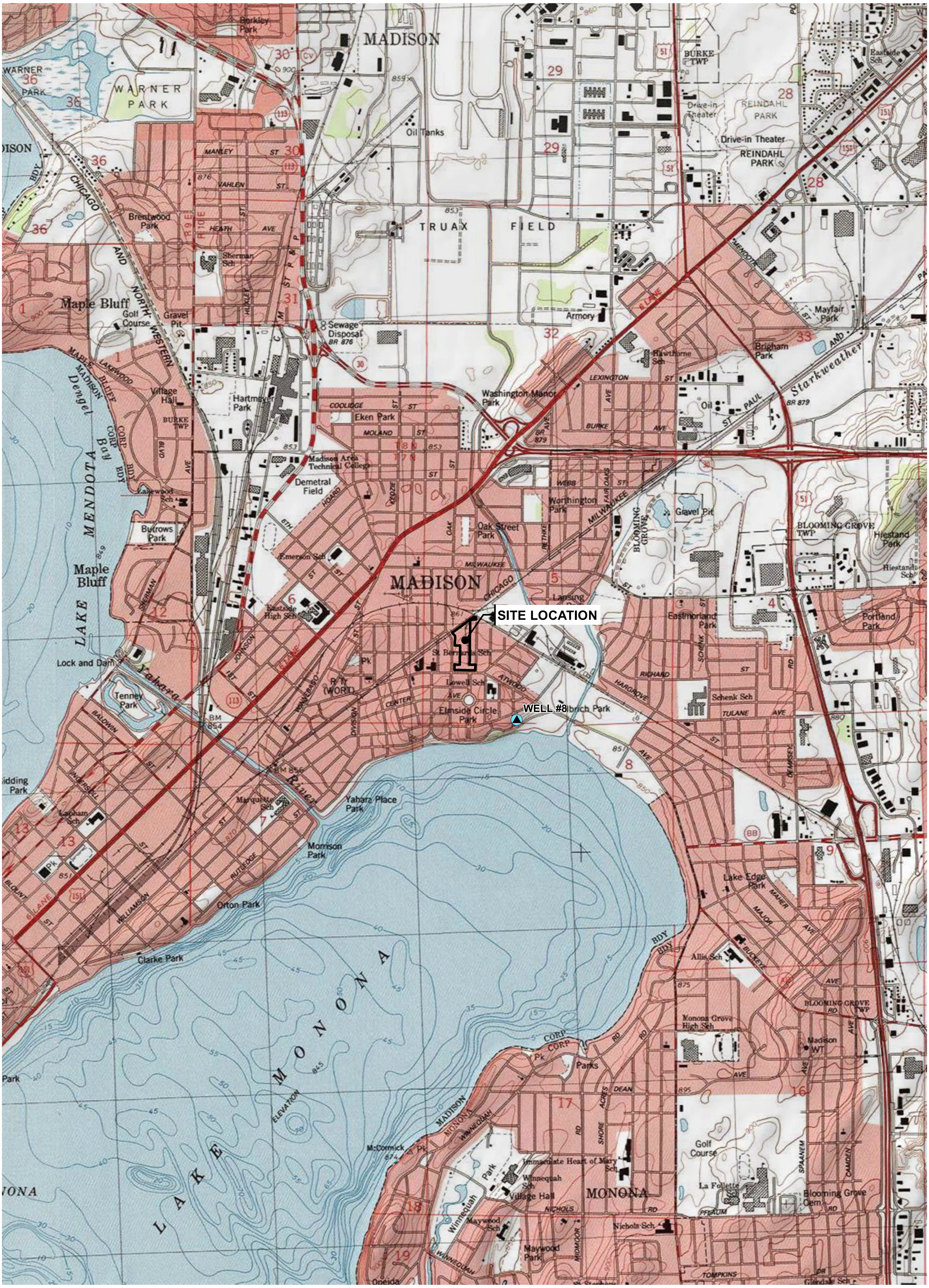
APPENDIX A

TRC Report Figures

Plot Date: 3/7/2017, 14:47:38 PM by BDEEGAN -- LAYOUT: ANSI B (11"x17")
Path: E:\MadisonKIPPCorp\2016_243950\243950-2016S2-001.mxd

Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet (Foot US)
Map Rotation: 0

TRC - GIS



LEGEND

SITE PROPERTY BOUNDARY

MUNICIPAL SUPPLY WELL

BASE MAP FROM USGS 7.5 MINUTE TOPOGRAPHIC QUADRANGLE SERIES, "USA TOPO MAPS" WEB BASEMAP SERVICE LAYER.

0 2,000 4,000 FEET

1 " = 2,000 '
1:24,000

N

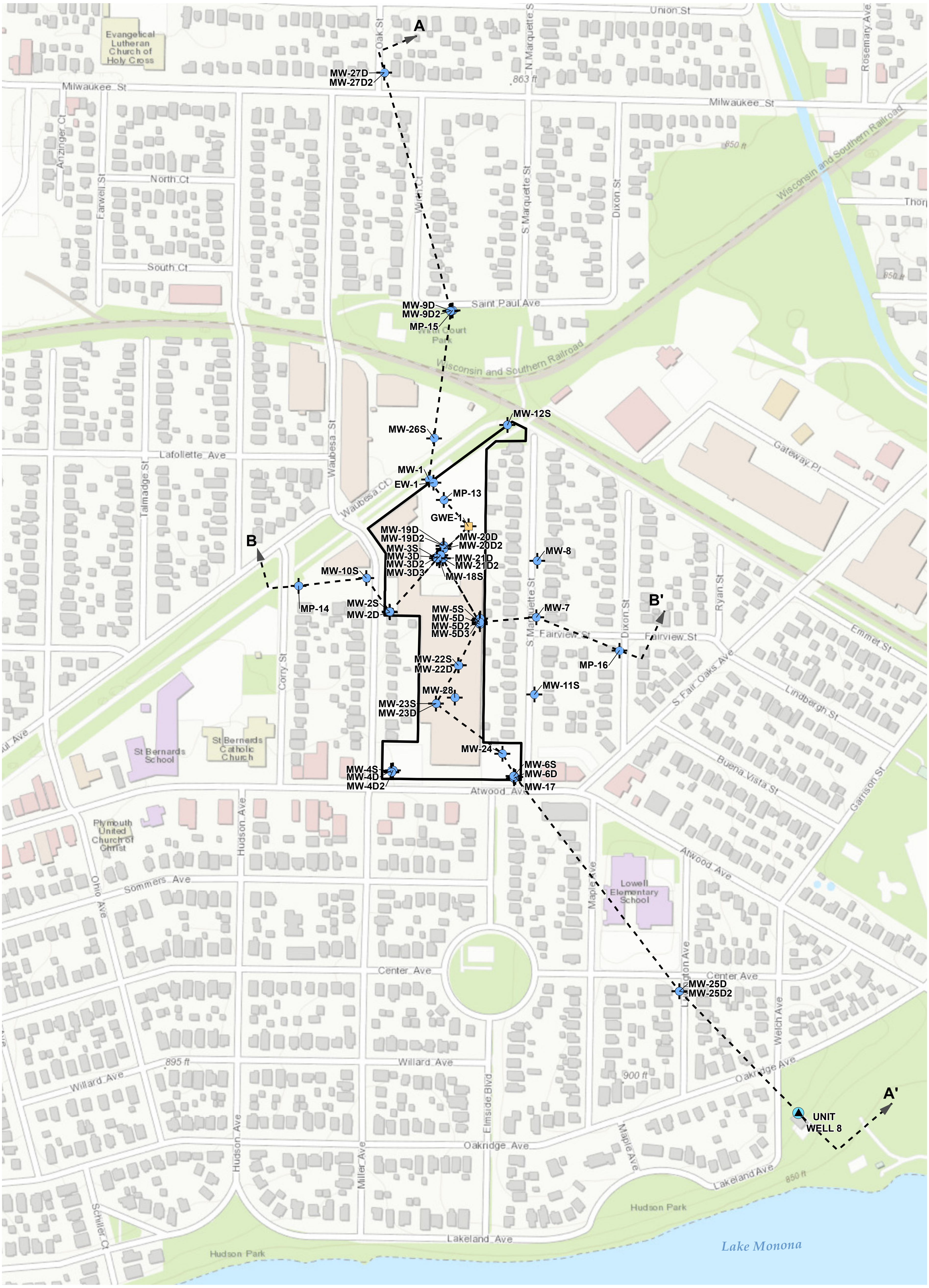
TRC
708 Heartland Trail
Suite 3000
Madison, WI 53717
Phone: 608.826.3600

PROJECT:
MADISON-KIPP CORPORATION
201 WAUBESA STREET
MADISON, WISCONSIN

TITLE:
SITE LOCATION MAP

DRAWN BY:	J PAPEZ
CHECKED BY:	LAUNER
APPROVED BY:	A STEHN
DATE:	MARCH 2017
PROJ. NO.:	243950
FILE:	243950-2016S2-001.mxd

FIGURE 1



LEGEND

- SITE PROPERTY BOUNDARY
- CROSS SECTION
- GROUNDWATER EXTRACTION WELL
- MONITORING WELL
- MUNICIPAL SUPPLY WELL

BASE MAP FROM ESRI, "WORLD TOPOGRAPHIC MAP" WEB BASEMAP SERVICE LAYER.

0 300 600 FEET

1 " = 300 '

1:3,600

N

TRC
708 Heartland Trail
Suite 3000
Madison, WI 53717
Phone: 608.826.3600

PROJECT:

MADISON-KIPP CORPORATION
201 WAUBESA STREET
MADISON, WISCONSIN

TITLE:

WELL LOCATIONS MAP

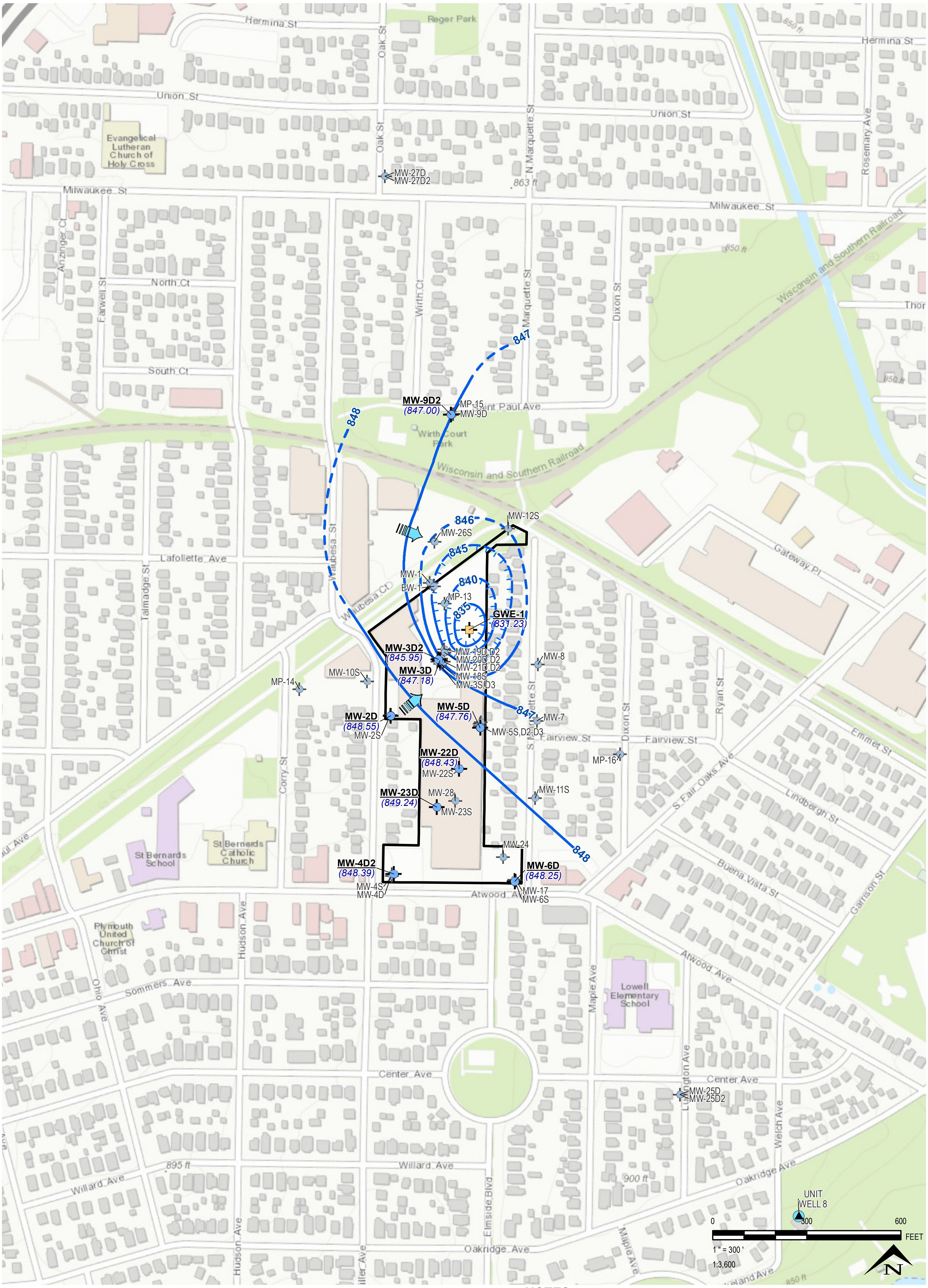
DRAWN BY:	J PAPEZ
CHECKED BY:	LAUNER
APPROVED BY:	A STEHN
DATE:	MARCH 2017
PROJ. NO.:	243950
FILE:	243950-2016S2-002.mxd

FIGURE 2

Plot Date: 3/7/2017, 13:53:57 PM by BDEEGAN -- LAYOUT: ANSI B (11"x17")
Path: E:\MadisonKIPPCorp\2016_243950\243950-2016S2-003.mxd

Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet (Foot US)
Map Rotation: 0

TRC - GIS



LEGEND

- SITE PROPERTY BOUNDARY
- GROUNDWATER EXTRACTION WELL
- MONITORING WELL
- MUNICIPAL SUPPLY WELL
- GROUNDWATER ELEVATION CONTOUR (1' FT INTERVAL, DASHED WHERE INFERRED)
- INWARD GRADIENT CONTOUR (5' INTERVAL)
- GROUNDWATER FLOW DIRECTION

NOTES

1. BASE MAP FROM ESRI, "WORLD TOPOGRAPHIC MAP", WEB BASEMAP SERVICE LAYER.
2. GROUNDWATER ELEVATIONS MEASURED OCT.10, 2016. WELLS SHOWN IN GRAY ARE EITHER NOT USED FOR CONTOURING OR NOT INFLUENCED BY THE EXTRACTION WELL.
3. MW-23D WAS NOT USE FOR CONTOURING.

TRC
708 Heartland Trail
Suite 3000
Madison, WI 53717
Phone: 608.826.3600

PROJECT:

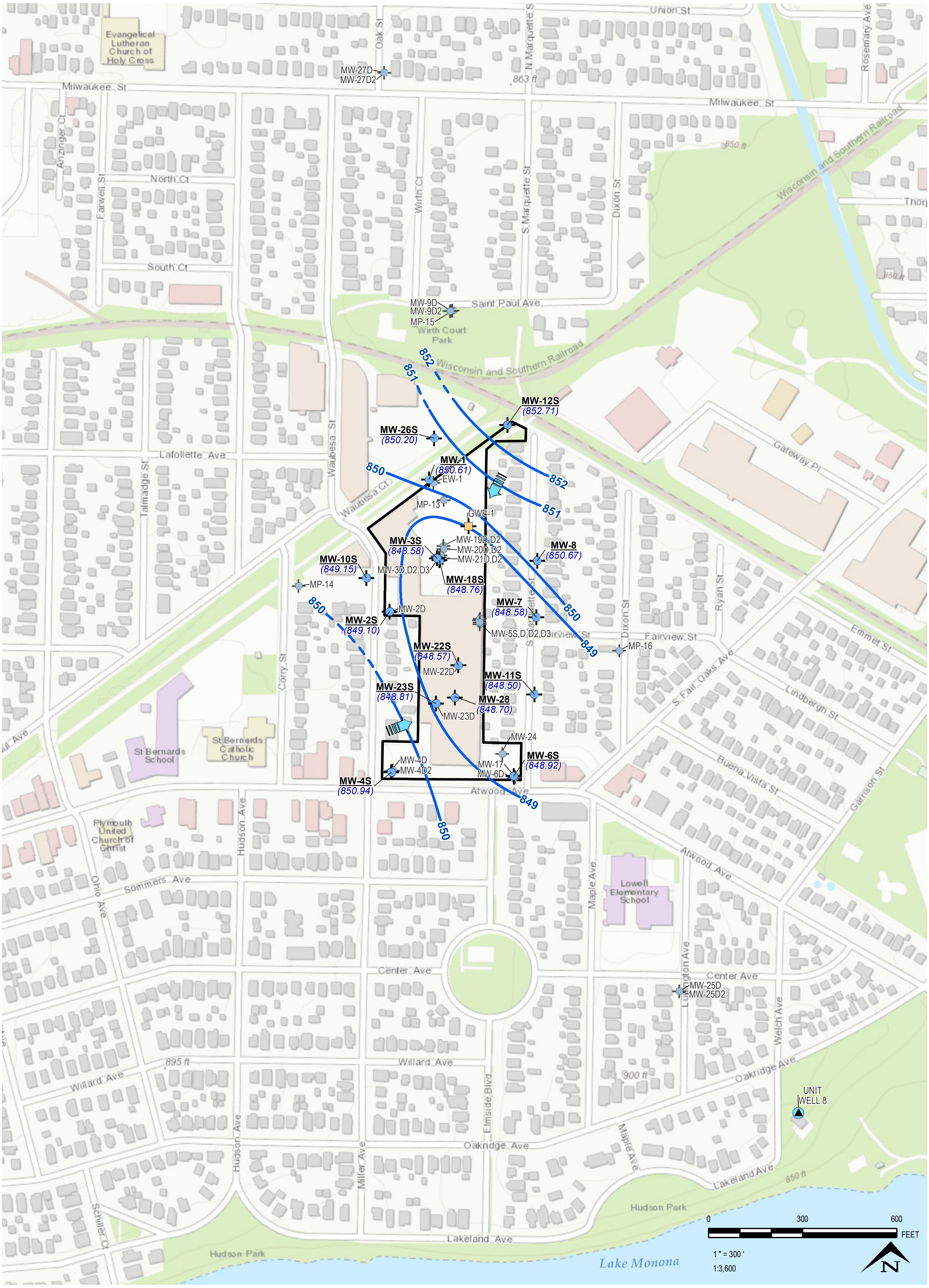
MADISON-KIPP CORPORATION
201 WAUBESA STREET
MADISON, WISCONSIN

TITLE:

EXTRACTION WELL INFLUENCE
OCTOBER 2016

DRAWN BY:	J PAPEZ
CHECKED BY:	LAUNER
APPROVED BY:	T OCONNELL
DATE:	MARCH 2017
PROJ. NO.:	243950
FILE:	243950-2016S2-003.mxd

FIGURE 3



LEGEND

- SITE PROPERTY BOUNDARY
- GROUNDWATER EXTRACTION
- MONITORING WELL
- MUNICIPAL SUPPLY WELL
- GROUNDWATER ELEVATION CONTOUR (0.5' INTERVAL, DASHED WHERE INFERRED)
- GROUNDWATER FLOW DIRECTION

NOTES

1. BASE MAP FROM ESRI, "WORLD TOPOGRAPHIC MAP", WEB BASEMAP SERVICE LAYER.
2. GROUNDWATER ELEVATIONS MEASURED ON OCT. 10, 2016. WELLS SHOWN IN GRAY ARE NOT PART OF THIS GROUNDWATER UNIT.
3. WATER TABLE ENCOUNTERED BETWEEN APPROXIMATELY 6-30 FT BELOW GROUND SURFACE, WITH SCREEN ELEVATIONS RANGING FROM 857 - 830 FT ABOVE MEAN SEA LEVEL.

TRC
708 Heartland Trail
Suite 3000
Madison, WI 53717
Phone: 608.826.3600

PROJECT:
**MADISON-KIPP CORPORATION
201 WAUBESA STREET
MADISON, WISCONSIN**

TITLE:
**WATER TABLE ELEVATIONS
OCTOBER 2016**

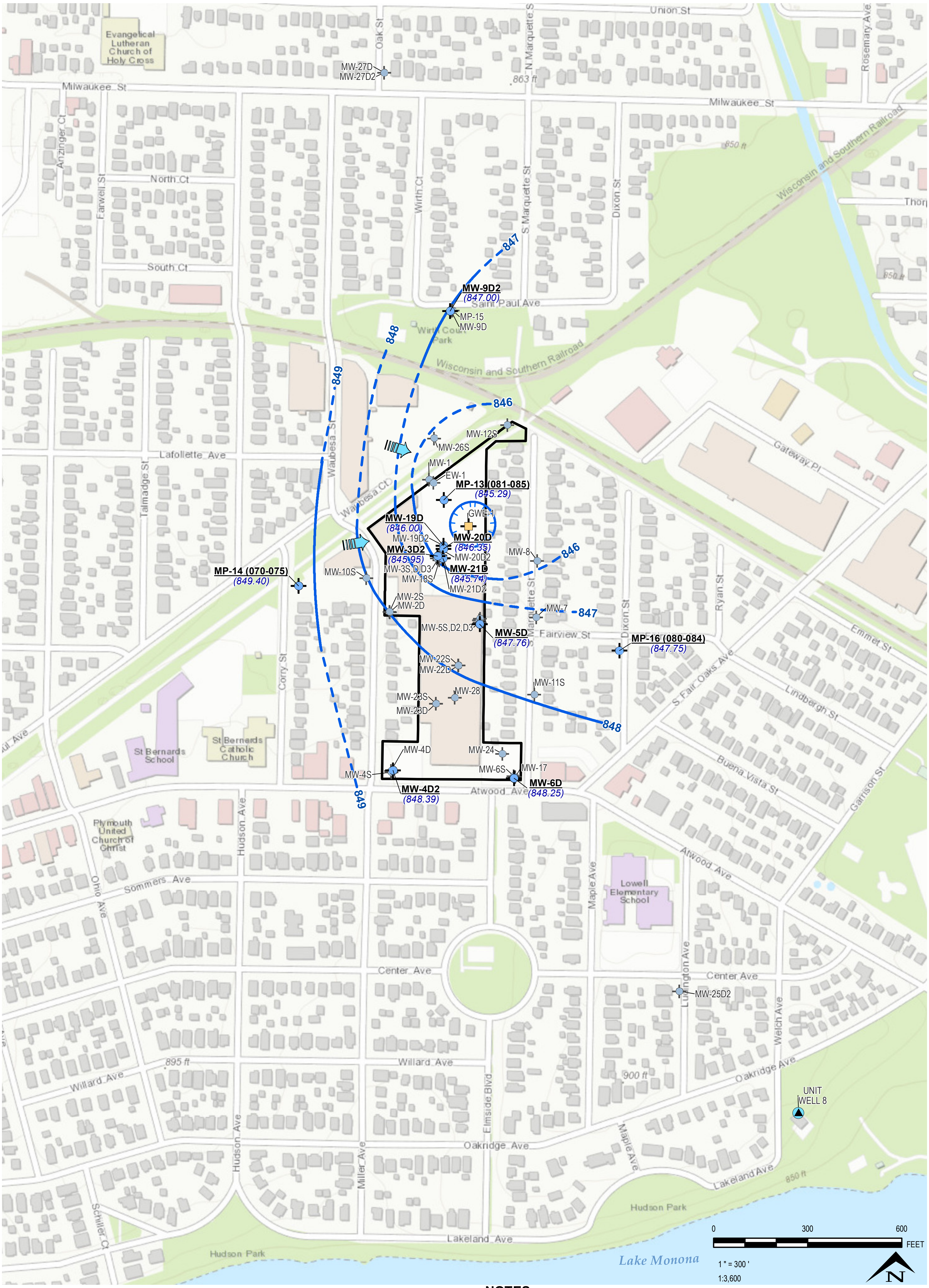
DRAWN BY:	J PAPEZ
CHECKED BY:	LAUNER
APPROVED BY:	T OCONNELL
DATE:	MARCH 2017
PROJ. NO.:	243950
FILE:	243950-2016S2-004.mxd

FIGURE 4

Plot Date: 3/7/2017, 14:25:24 PM by BDEEGAN -- LAYOUT: ANSI B (11"x17")
Path: E:\MadisonKIPPCorp\2016_243950\243950-2016S2-005.mxd

Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet (Foot US)
Map Rotation: 0

TRC - GIS



LEGEND

- SITE PROPERTY BOUNDARY
- GROUNDWATER EXTRACTION WELL
- MONITORING WELL
- MUNICIPAL SUPPLY WELL
- INWARD GRADIENT CONTOUR
- GROUNDWATER ELEVATION CONTOUR (1' FT INTERVAL, DASHED WHERE INFERRED)
- GROUNDWATER FLOW DIRECTION

NOTES

1. BASE MAP FROM ESRI, "WORLD TOPOGRAPHIC MAP", WEB BASEMAP SERVICE LAYER.
2. GROUNDWATER ELEVATIONS MEASURED OCT. 10, 2016. WELLS SHOWN IN GRAY ARE NOT PART OF THIS GROUNDWATER UNIT.
3. * MW-19D, MW-20D, & MW-21D NOT USED FOR CONTOURING.
4. LOWER LONE ROCK WATER LEVELS ENCOUNTERED BETWEEN APPROXIMATELY 8 - 32 FT BELOW GROUND SURFACE, WITH SCREEN ELEVATIONS RANGING FROM 812 - 777 FT ABOVE MEAN SEA LEVEL.

TRC
708 Heartland Trail
Suite 3000
Madison, WI 53717
Phone: 608.826.3600

PROJECT:
MADISON-KIPP CORPORATION
201 WAUBESA STREET
MADISON, WISCONSIN

TITLE:
LOWER LONE ROCK FORMATION
POTENTIOMETRIC SURFACE
OCTOBER 2016

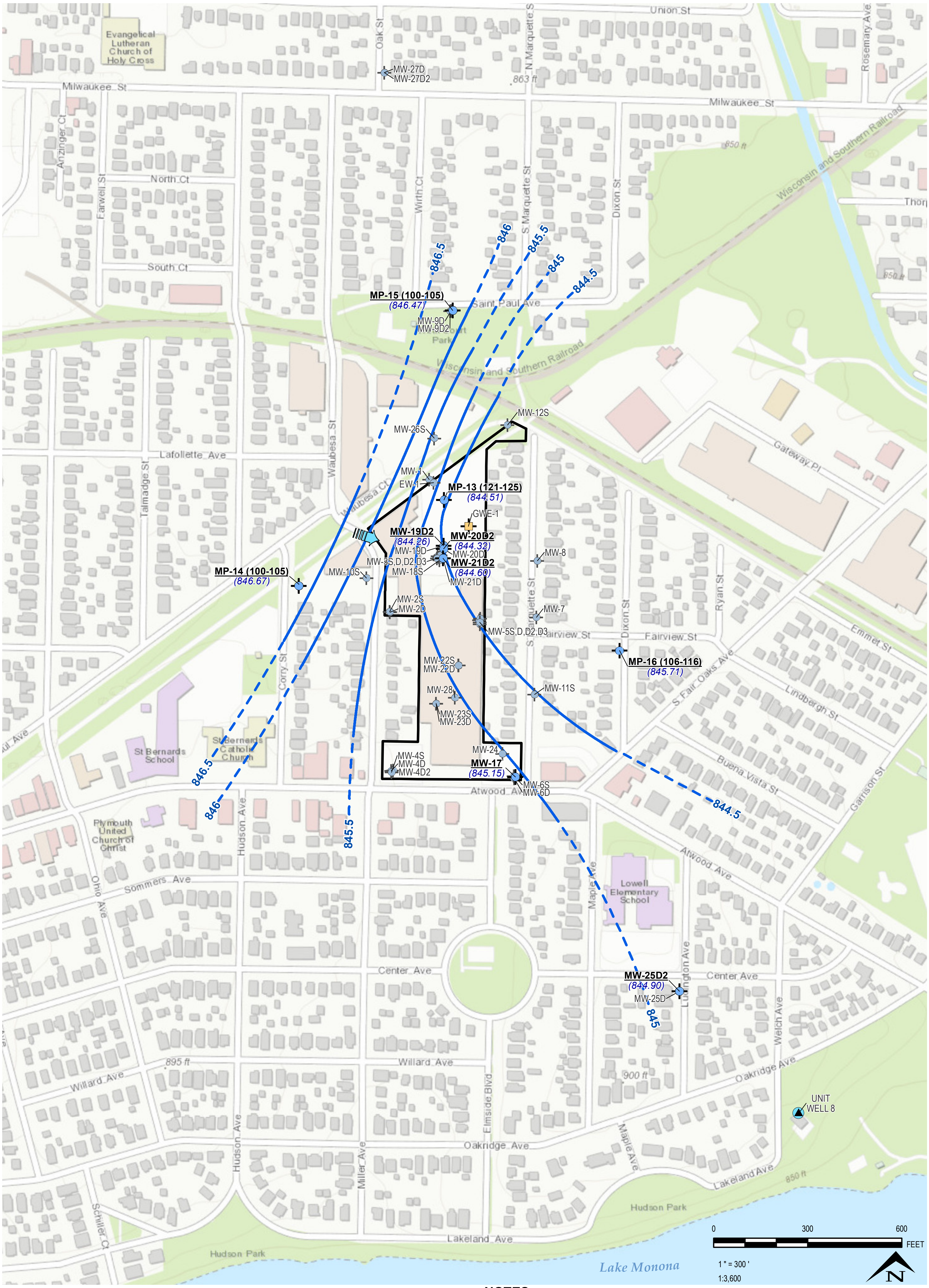
DRAWN BY:	J PAPEZ
CHECKED BY:	LAUNER
APPROVED BY:	T O'CONNELL
DATE:	MARCH 2017
PROJ. NO.:	243950
FILE:	243950-2016S2-005.mxd

FIGURE 5

Plot Date: 3/7/2017, 13:56:01 PM by BDEEGAN -- LAYOUT: ANSI B (11"x17")
Path: E:\MadisonKIPPCorp\2016_243950\243950-2016S2-006.mxd

Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet (Foot US)
Map Rotation: 0

TRC - GIS



LEGEND

- SITE PROPERTY BOUNDARY
- GROUNDWATER EXTRACTION WELL
- MONITORING WELL
- MUNICIPAL SUPPLY WELL
- GROUNDWATER ELEVATION CONTOUR (0.5' FT INTERVAL, DASHED WHERE INFERRED)
- GROUNDWATER FLOW DIRECTION

NOTES

1. BASE MAP FROM ESRI, "WORLD TOPOGRAPHIC MAP", WEB BASEMAP SERVICE LAYER.
2. GROUNDWATER ELEVATIONS MEASURED OCT. 10, 2016. WELLS SHOWN IN GRAY ARE NOT PART OF THIS GROUNDWATER UNIT.
3. MP-16 NOT USED FOR CONTOURING.
4. UPPER WONEWOC WATER LEVELS ENCOUNTERED BETWEEN APPROXIMATELY 9 - 42 FT BELOW GROUND SURFACE, WITH SCREEN ELEVATIONS RANGING FROM 767 - 698 FT ABOVE MEAN SEA LEVEL.

TRC
708 Heartland Trail
Suite 3000
Madison, WI 53717
Phone: 608.826.3600

PROJECT:
MADISON-KIPP CORPORATION
201 WAUBESA STREET
MADISON, WISCONSIN

TITLE:
UPPER WONEWOC FORMATION POTENTIOMETRIC SURFACE OCTOBER 2016

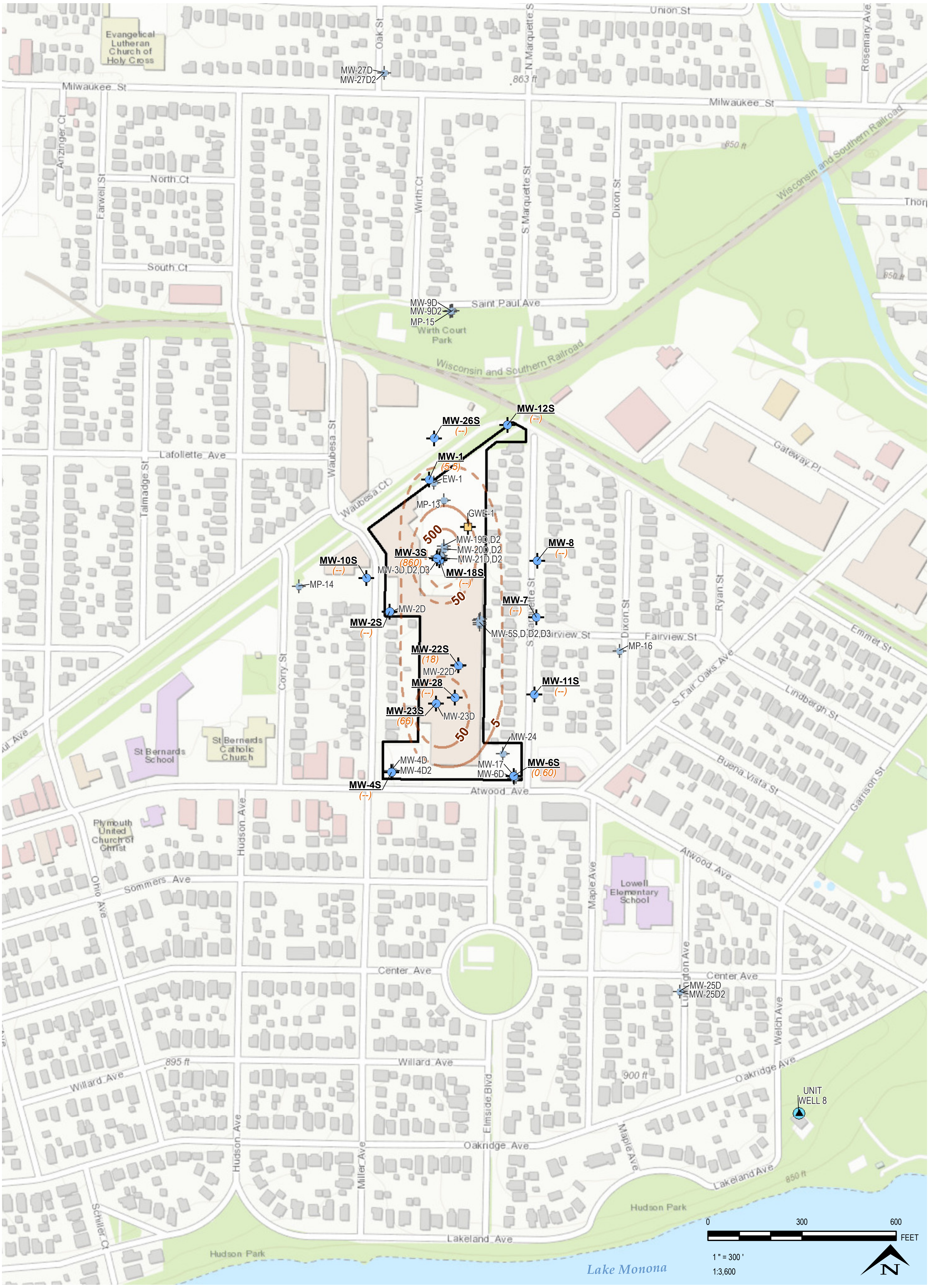
DRAWN BY:	J PAPEZ
CHECKED BY:	LAUNER
APPROVED BY:	T OCONNELL
DATE:	MARCH 2017
PROJ. NO.:	243950
FILE:	243950-2016S2-006.mxd

FIGURE 6

Plot Date: 3/7/2017, 14:12:41 PM by BDEEGAN -- LAYOUT: ANSI B (11"x17")
Path: E:\MadisonKIPPCorp\2016_243950\243950-2016S2-008.mxd

Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet (Foot US)
Map Rotation: 0

TRC - GIS



LEGEND

- SITE PROPERTY BOUNDARY
- GROUNDWATER EXTRACTION WELL
- MONITORING WELL
- MUNICIPAL SUPPLY WELL
- (7.5) PCE CONCENTRATION [µg/L]
- (--) NOT SAMPLED
- PCE ISOCONCENTRATION CONTOUR (µg/L, DASHED WHERE INFERRED)

NOTES

1. BASE MAP FROM ESRI, "WORLD TOPOGRAPHIC MAP", WEB BASEMAP SERVICE LAYER.
2. WELLS SAMPLED BETWEEN OCT.10-14, 2016. WELLS SHOWN IN GRAY ARE NOT PART OF THIS GROUNDWATER UNIT.WELLS IN UNIT BUT NOT SAMPLED WERE NOT PART OF 2016 MONITORING PLAN.
3. WATER TABLE ENCOUNTERED APPROXIMATELY 6 -30 FT BGS, WITH SCREEN ELEVATIONS RANGING FROM 857 -834 FT ABOVE MEAN SEA LEVEL.
4. HISTORICAL DATA WAS USED IN CONJUNCTION WITH OCTOBER 2016 DATA FOR CONTOUR INTERPRETATION.

TRC
708 Heartland Trail
Suite 3000
Madison, WI 53717
Phone: 608.826.3600

PROJECT:
MADISON-KIPP CORPORATION
201 WAUBESA STREET
MADISON, WISCONSIN

TITLE:
WATER TABLE
TETRACHLOROETHENE (PCE) ISOCONCENTRATIONS
OCTOBER 2016

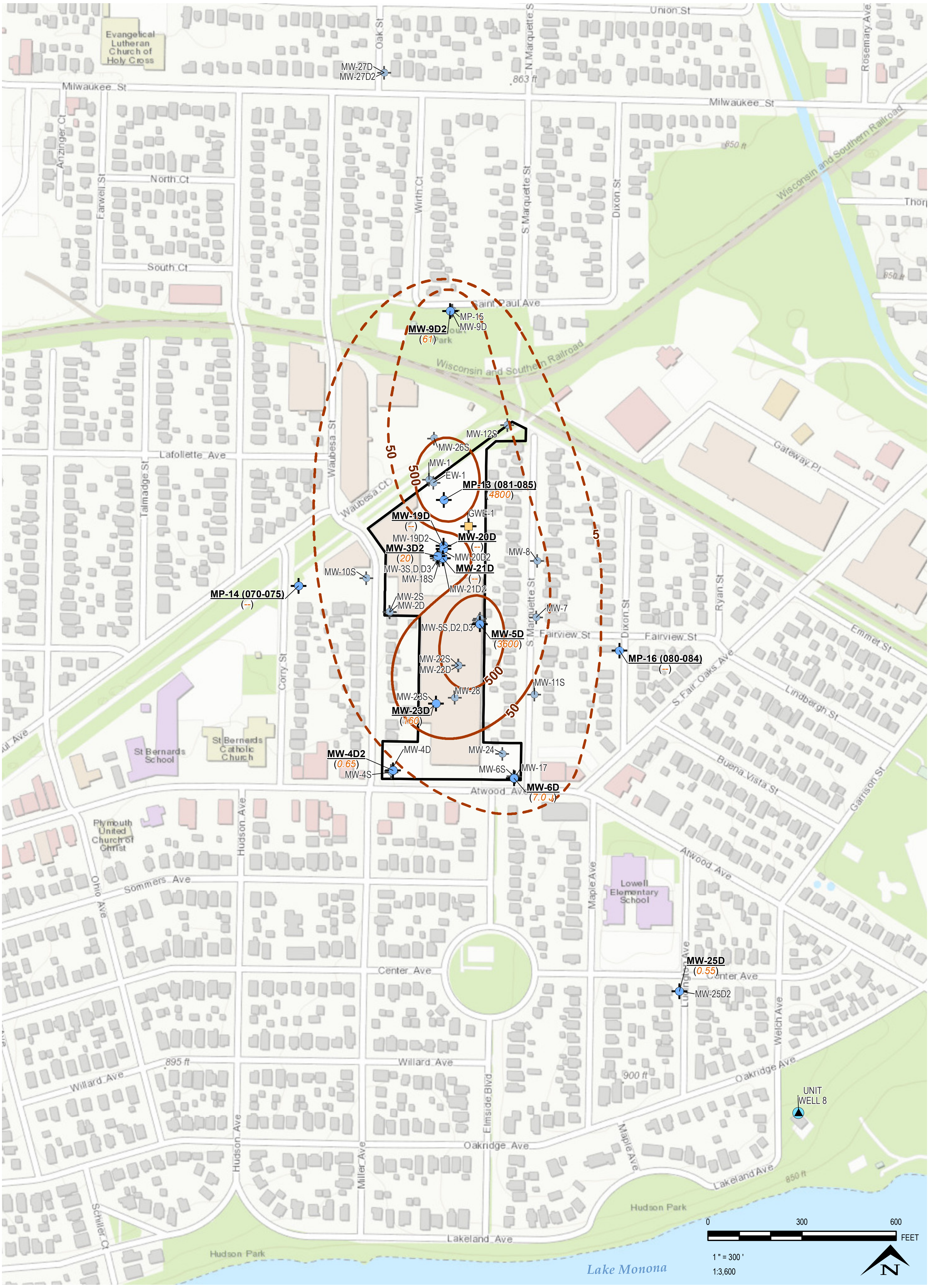
DRAWN BY:	J PAPEZ
CHECKED BY:	LAUNER
APPROVED BY:	T OCONNELL
DATE:	MARCH 2017
PROJ. NO.:	243950
FILE:	243950-2016S2-008.mxd

FIGURE 8

Plot Date: 3/7/2017, 14:15:42 PM by BDEEGAN -- LAYOUT: ANSI B (11"x17")
Path: E:\MadisonKIPPCorp\2016_243950\243950-2016S2-009.mxd

Coordinate System: NAD 1983 StatePlane Wisconsin South FIPS 4803 Feet (Foot US)
Map Rotation: 0

TRC - GIS



LEGEND

SITE PROPERTY BOUNDARY	(7.5) PCE CONCENTRATION [µg/L]
GROUNDWATER EXTRACTION WELL	J ESTIMATED VALUE (DETECTED BELOW REPORTING LIMIT)
MONITORING WELL	(--) NOT SAMPLED
MUNICIPAL SUPPLY WELL	PCE ISOCONCENTRATION CONTOUR (µg/L, DASHED WHERE INFERRED)

NOTES

1. BASE MAP FROM ESRI, "WORLD TOPOGRAPHIC MAP", WEB BASEMAP SERVICE LAYER.
2. WELLS SAMPLED BETWEEN OCT.10-14, 2016. WELLS SHOWN IN GRAY ARE NOT PART OF THIS GROUNDWATER UNIT. WELLS IN UNIT BUT NOT SAMPLED WERE NOT PART OF 2016 MONITORING PLAN.
3. THE LOWER LONE ROCK FORMATION IS INTERPRETED TO BE FROM APPROXIMATELY 65 -100 FEET BELOW GROUND SURFACE (818-781) FEET ABOVE MEAN SEA LEVEL).

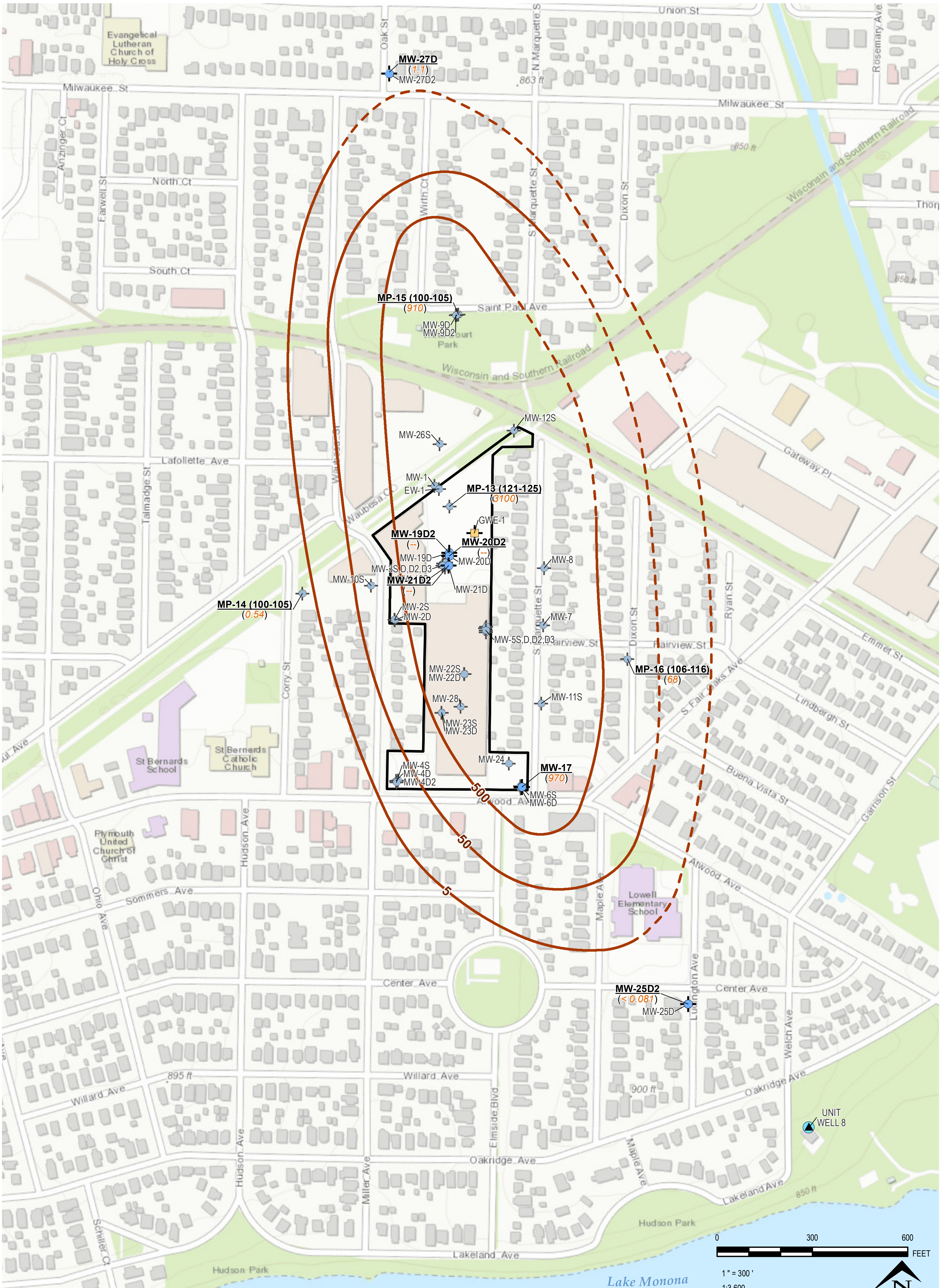
TRC
708 Heartland Trail
Suite 3000
Madison, WI 53717
Phone: 608.826.3600

PROJECT:
MADISON-KIPP CORPORATION
201 WAUBESA STREET
MADISON, WISCONSIN

TITLE:
LOWER LONE ROCK FORMATION
TETRACHLOROETHENE (PCE) ISOCONCENTRATIONS
OCTOBER 2016

DRAWN BY:	J PAPEZ
CHECKED BY:	LAUNER
APPROVED BY:	T OCONNELL
DATE:	MARCH 2017
PROJ. NO.:	243950
FILE:	243950-2016S2-009.mxd

FIGURE 9



LEGEND

- SITE PROPERTY BOUNDARY
- GROUNDWATER EXTRACTION WELL
- MONITORING WELL
- MUNICIPAL SUPPLY WELL
- (7.5) PCE CONCENTRATION [µg/L]
- (--) NOT SAMPLED
- PCE ISOCONCENTRATION CONTOUR (µg/L, DASHED WHERE INFERRED)

NOTES

1. BASE MAP FROM ESRI, "WORLD TOPOGRAPHIC MAP", WEB BASEMAP SERVICE LAYER.
2. WELLS SAMPLED BETWEEN OCT.10-14, 2016. WELLS SHOWN IN GRAY ARE NOT PART OF THIS GROUNDWATER UNIT. WELLS IN UNIT BUT NOT SAMPLED WERE NOT PART OF 2016 MONITORING PLAN.
3. THE UPPER WONEWOC FORMATION IS INTERPRETED TO BE FROM APPROXIMATELY 87 – 139 FEET BELOW GROUND SURFACE (767 – 690 FEET ABOVE MEAN SEA LEVEL).

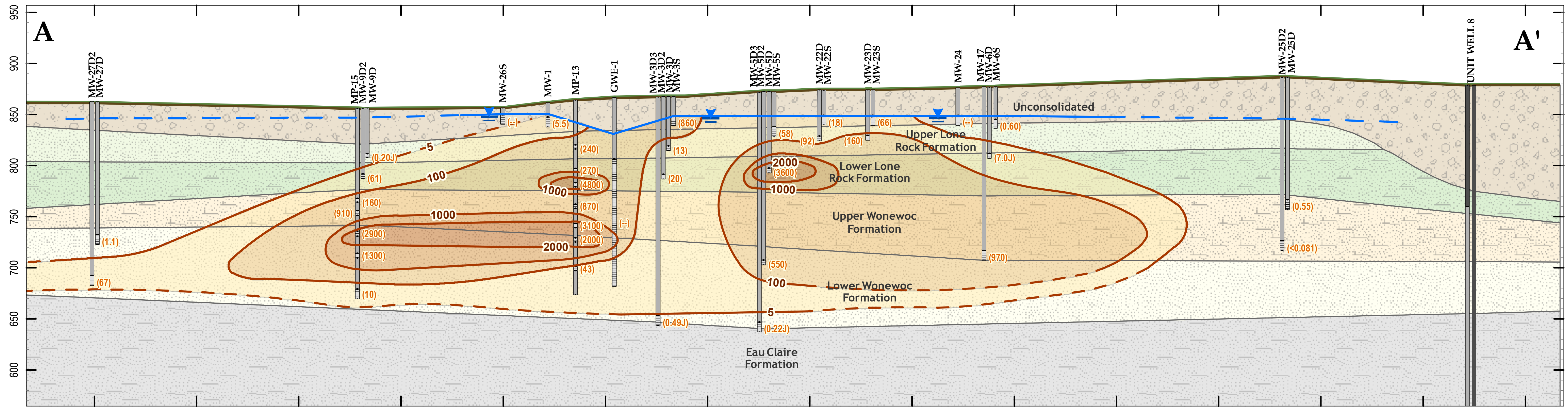
TRC
708 Heartland Trail
Suite 3000
Madison, WI 53717
Phone: 608.826.3600

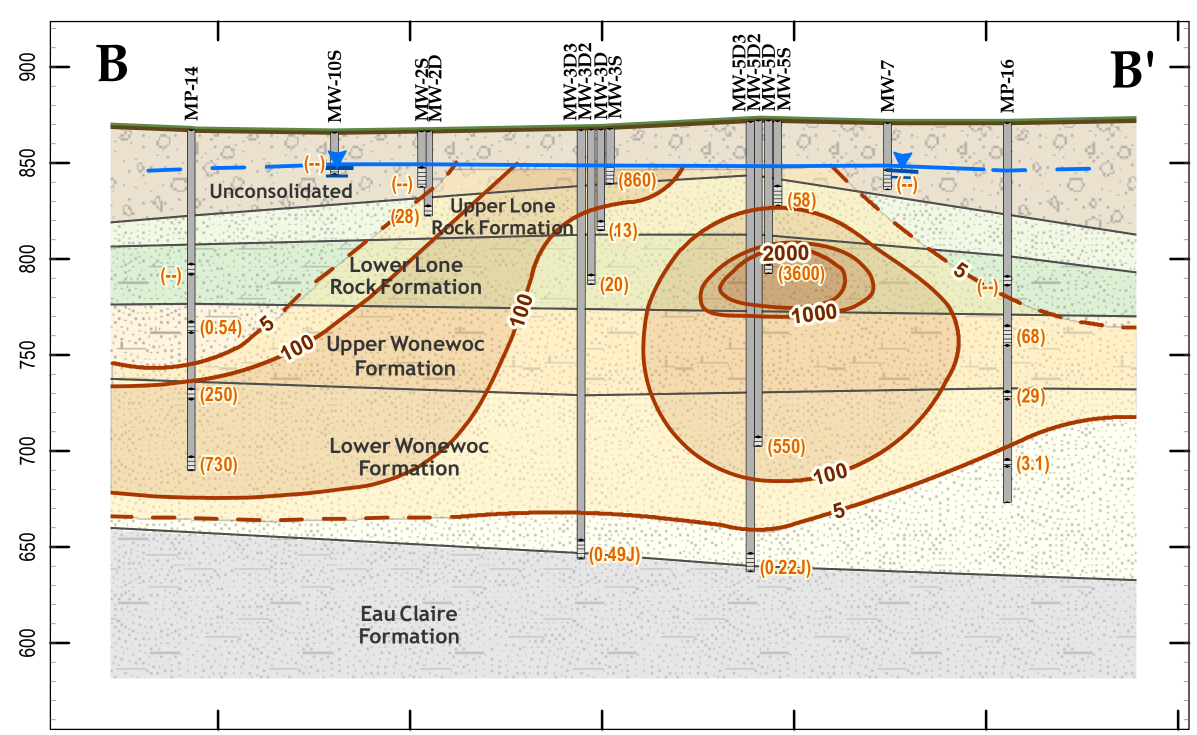
PROJECT:
MADISON-KIPP CORPORATION
201 WAUBESA STREET
MADISON, WISCONSIN

TITLE:
UPPER WONEWOC FORMATION
TETRACHLOROETHENE (PCE) ISOCONCENTRATIONS
OCTOBER 2016

DRAWN BY:	J PAPEZ
CHECKED BY:	LAUNER
APPROVED BY:	T OCONNELL
DATE:	MARCH 2017
PROJ. NO.:	243950
FILE:	243950-2016S2-010.mxd

FIGURE 10





LEGEND

WELL CONSTRUCTION

- WELL RISER
- WELL CASING
- WELL SCREEN
- WATER TABLE ELEVATION

(550) PCE CONCENTRATION [µg/L]

(--) NOT SAMPLED

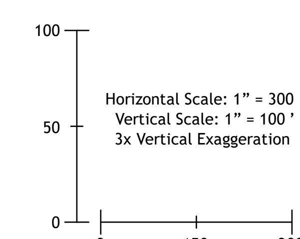
J ESTIMATED RESULT (LESS THAN QUANTITATION LIMIT)

PCE CONCENTRATIONS IN GROUNDWATER (DASHED WHERE INFERRED)

- < 5 µg/L
- 5 - <100 µg/L
- 100 - <1000 µg/L
- 1000 - <2000 µg/L
- 2000 - 5000 µg/L

NOTES

1. SEE FIGURE 2 FOR PLAN VIEW CROSS SECTION LOCATIONS.
2. WELLS SAMPLED BETWEEN OCT. 10-14, 2016.
3. FEATURES SHOWN ARE APPROXIMATE



PROJECT:
MADISON-KIPP CORPORATION
201 WAUBESA STREET
MADISON, WISCONSIN

TITLE:
GEOLOGIC CROSS SECTIONS A-A' AND B-B' TETRACHLOROETHENE (PCE) CONCENTRATIONS - OCTOBER 2016

DRAWN BY:	J PAPEZ	PROJ NO.:	243950
CHECKED BY:	L AUNER		
APPROVED BY:	T OCONNELL		**FIGURE 11**
DATE:	MARCH 2017		

TRC

708 Heartland Trail, Suite 3000
Madison, WI 53717
Phone: 608.826.3600
www.trcsolutions.com

FILE NO.: 243950-2016S2-011.mxd

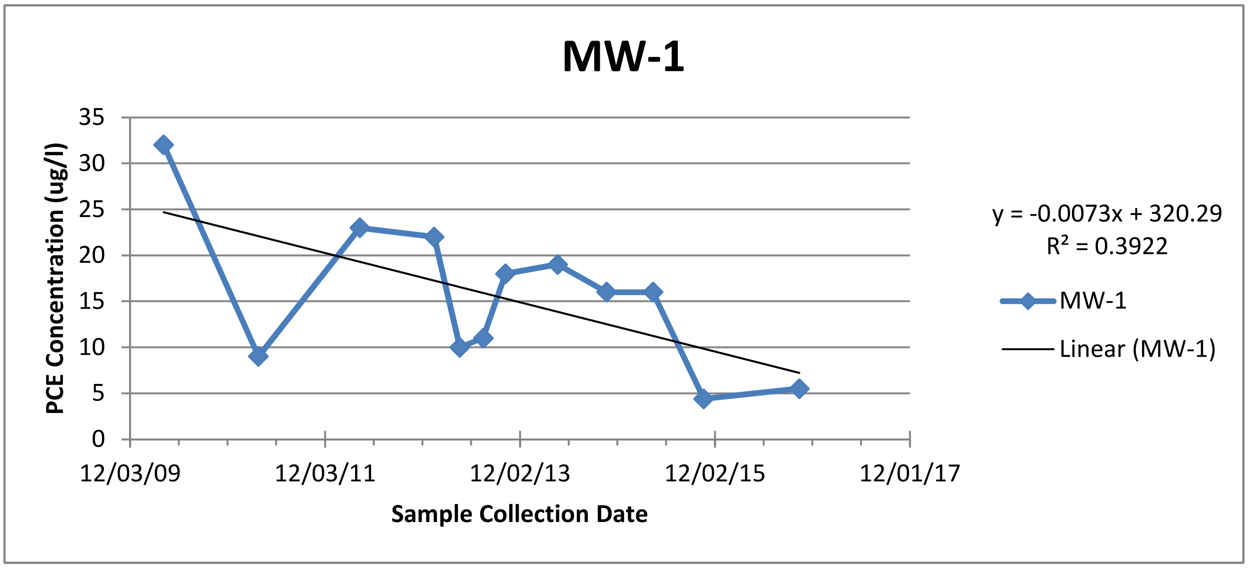
TRC - GIS

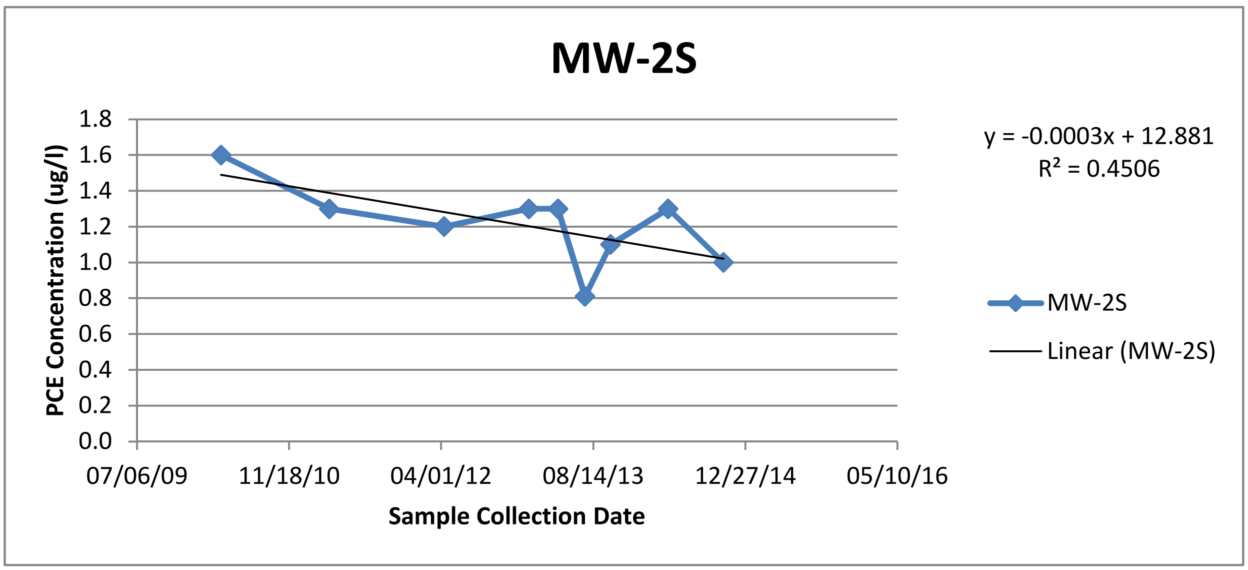
Coordinate System: (None Defined)
Map Rotation: 0

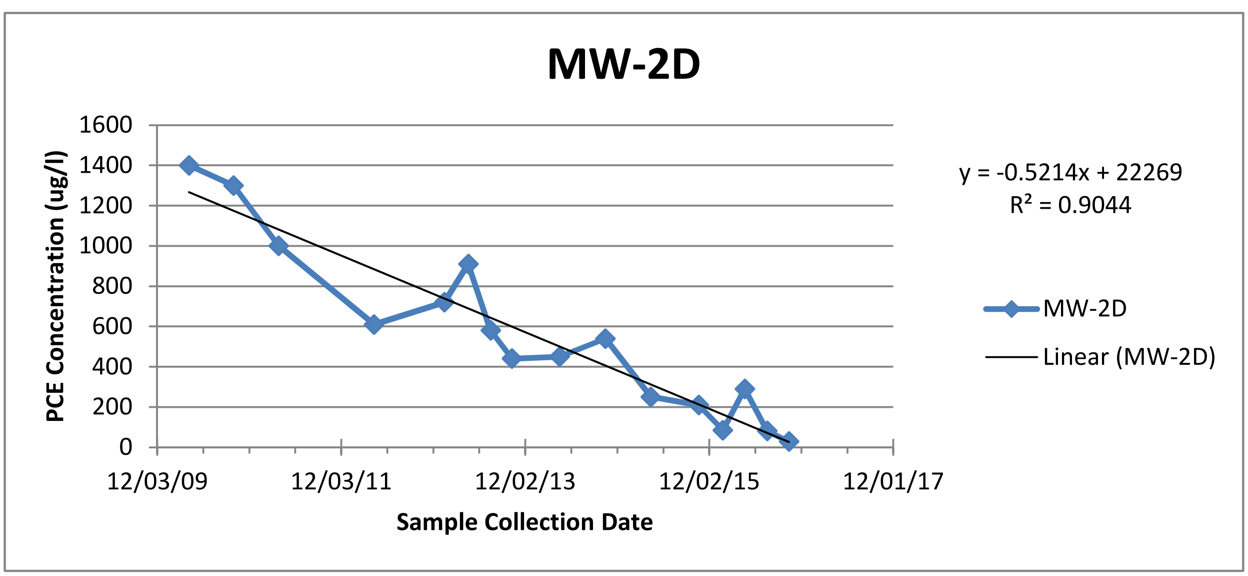
Plot Date: 3/7/2017, 14:18:47 PM by BDEEGAN -- LAYOUT: ANSI B(11"x17")
Path: E:\MadisonKIPPCorp\2016_243950\243950-2016S2-011.mxd

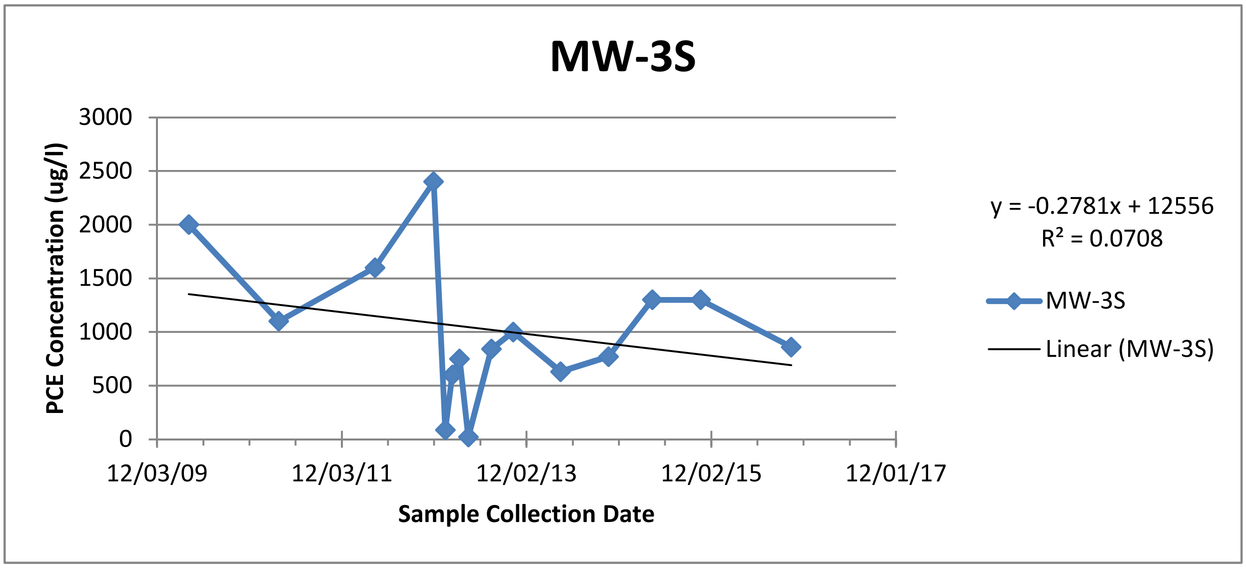
APPENDIX B

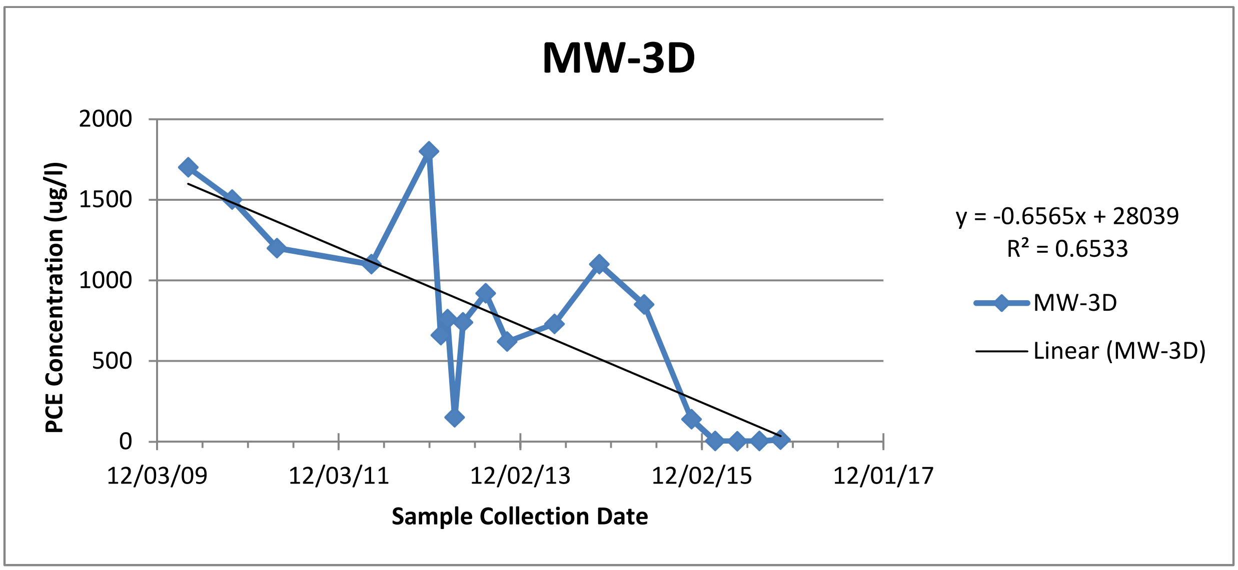
PCE Trend Plots

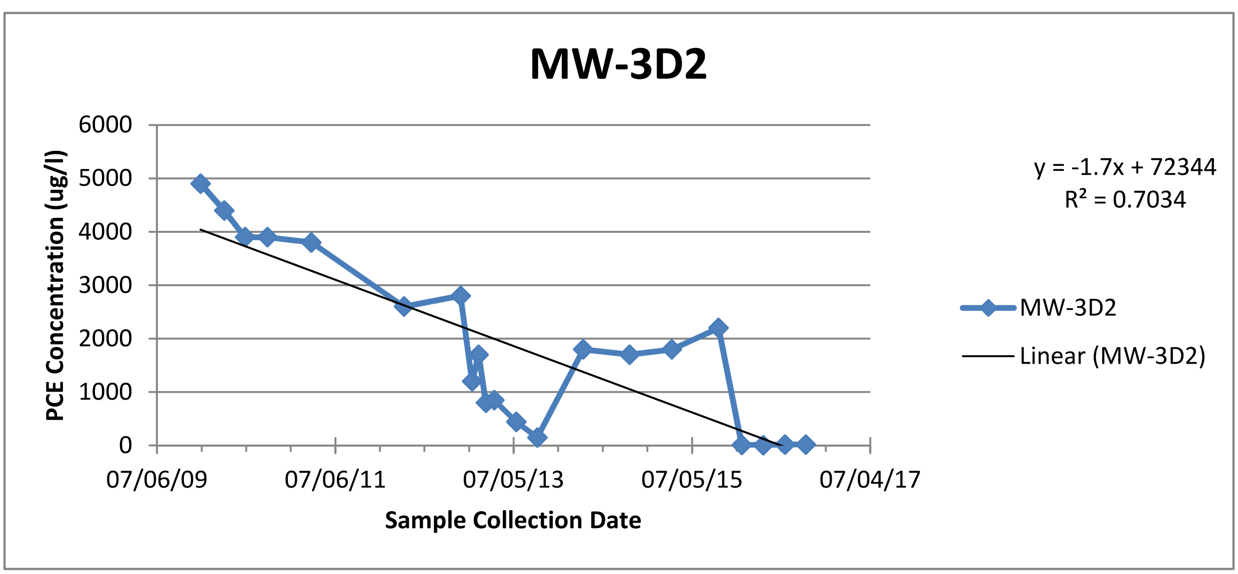

MW-1
PCE Concentration (ug/l)
35
30
25
20
15
10
5
0
12/03/09
12/03/11
12/02/13
12/02/15
12/01/17
Sample Collection Date
y = -0.0073x + 320.29
R² = 0.3922
MW-1
Linear (MW-1)

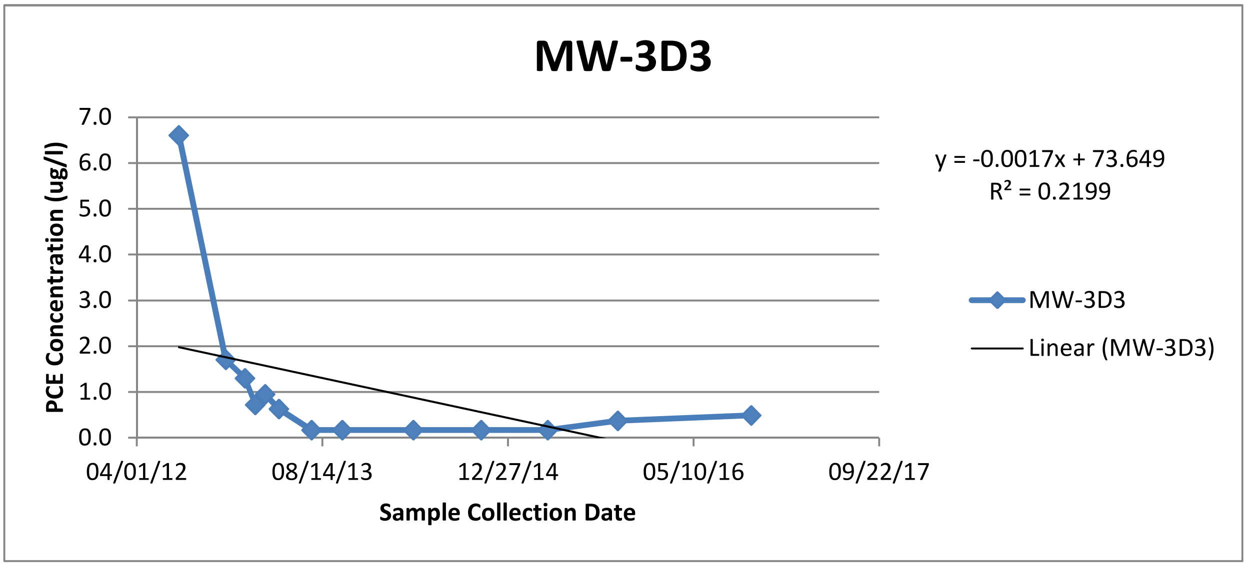

MW-2S
PCE Concentration (ug/l)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
Sample Collection Date
y = -0.0003x + 12.881
R² = 0.4506
MW-2S
Linear (MW-2S)

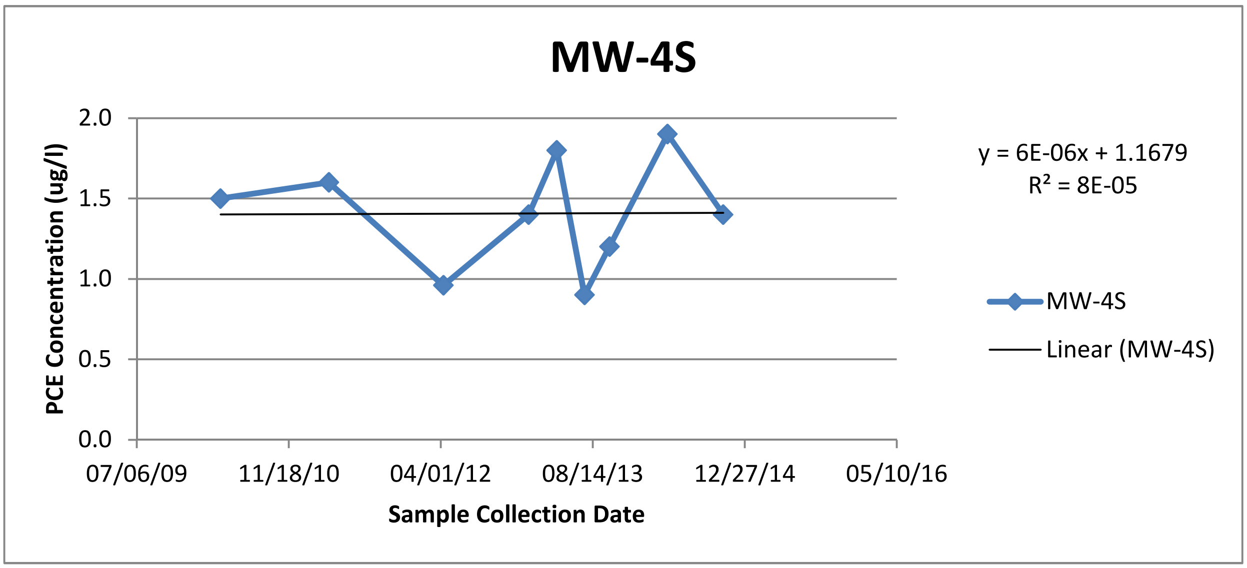

MW-2D
PCE Concentration (ug/l)
1600
1400
1200
1000
800
600
400
200
0
12/03/09
12/03/11
12/02/13
12/02/15
12/01/17
Sample Collection Date
y = -0.5214x + 22269
R² = 0.9044
MW-2D
Linear (MW-2D)

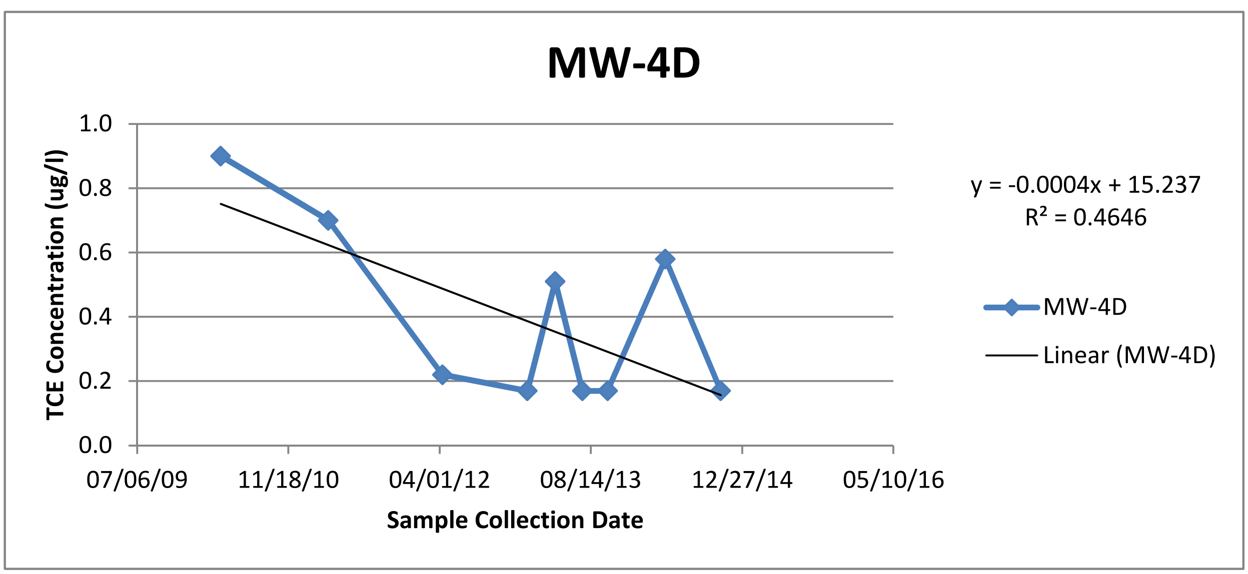

MW-3S
3000
2500
2000
1500
1000
500
0
PCE Concentration (ug/l)
12/03/09
12/03/11
12/02/13
12/02/15
12/01/17
Sample Collection Date
y = -0.2781x + 12556
R² = 0.0708
MW-3S
Linear (MW-3S)

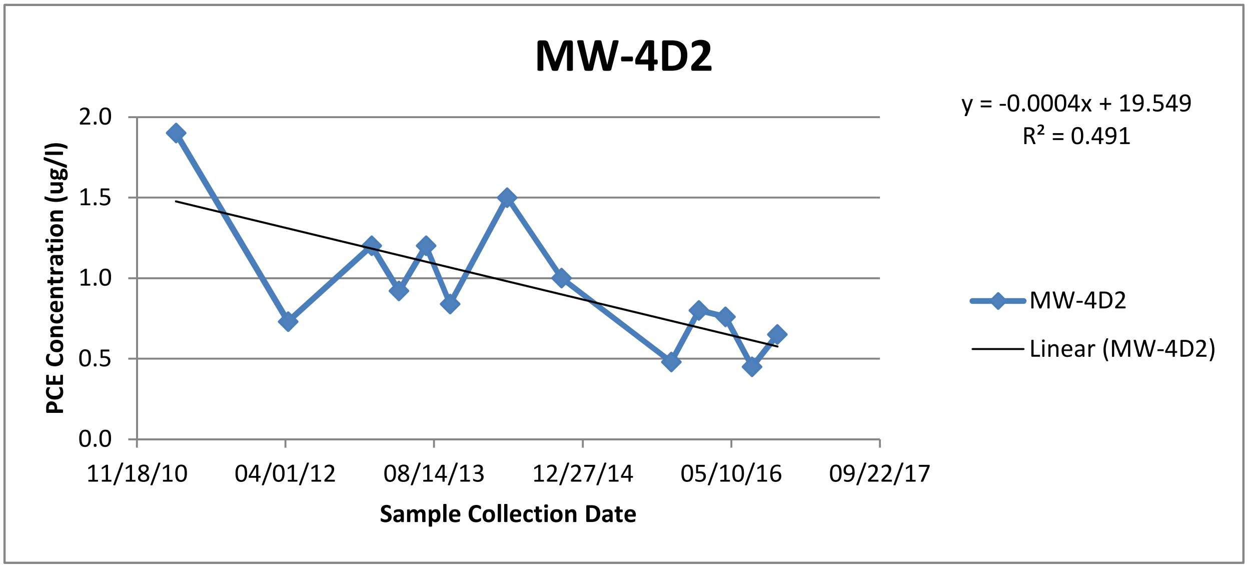

MW-3D
2000
1500
1000
500
0
PCE Concentration (ug/l)
12/03/09
12/03/11
12/02/13
12/02/15
12/01/17
Sample Collection Date
y = -0.6565x + 28039
R² = 0.6533
MW-3D
Linear (MW-3D)

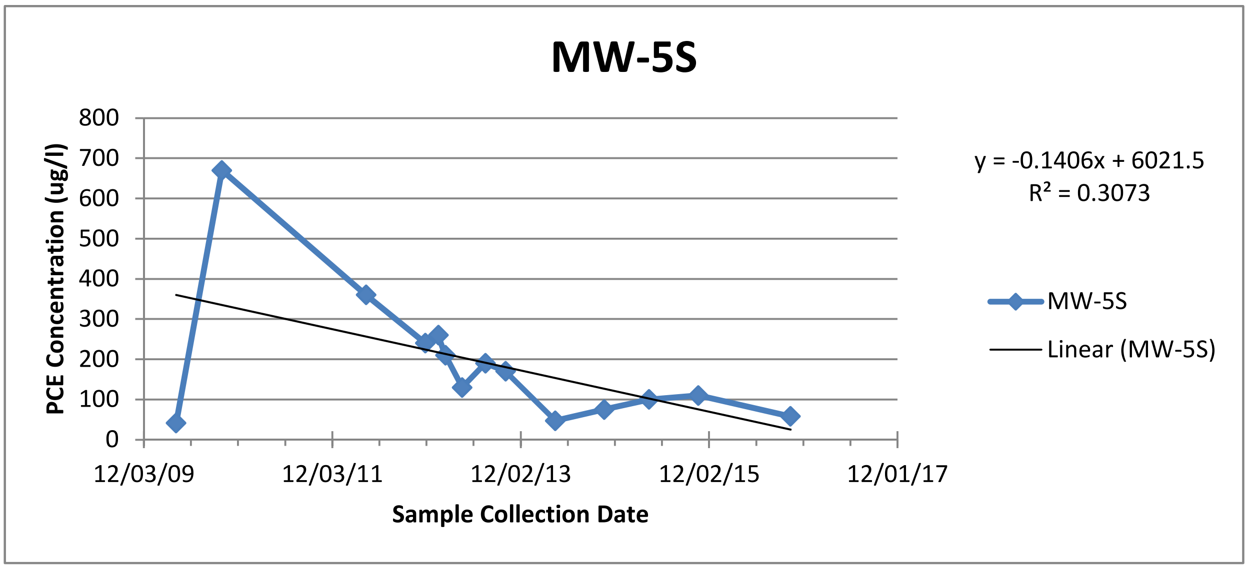

MW-3D2
6000
5000
4000
3000
2000
1000
0
PCE Concentration (ug/l)
07/06/09
07/06/11
07/05/13
07/05/15
07/04/17
Sample Collection Date
y = -1.7x + 72344
R² = 0.7034
MW-3D2
Linear (MW-3D2)

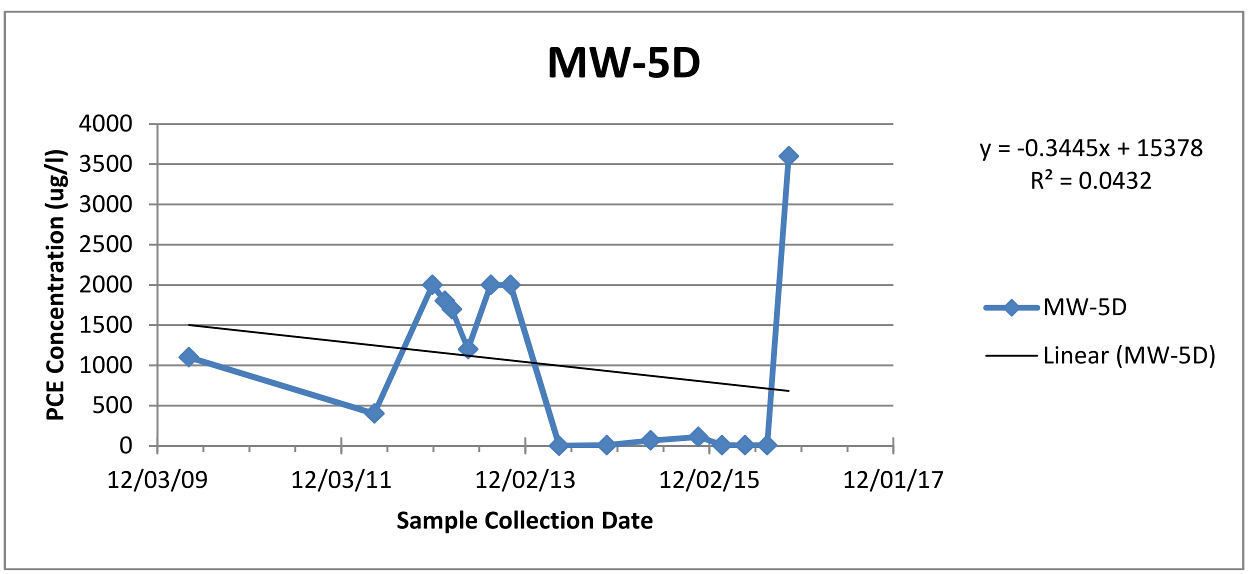

MW-3D3
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
PCE Concentration (ug/l)
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
Sample Collection Date
y = -0.0017x + 73.649
R² = 0.2199
MW-3D3
Linear (MW-3D3)

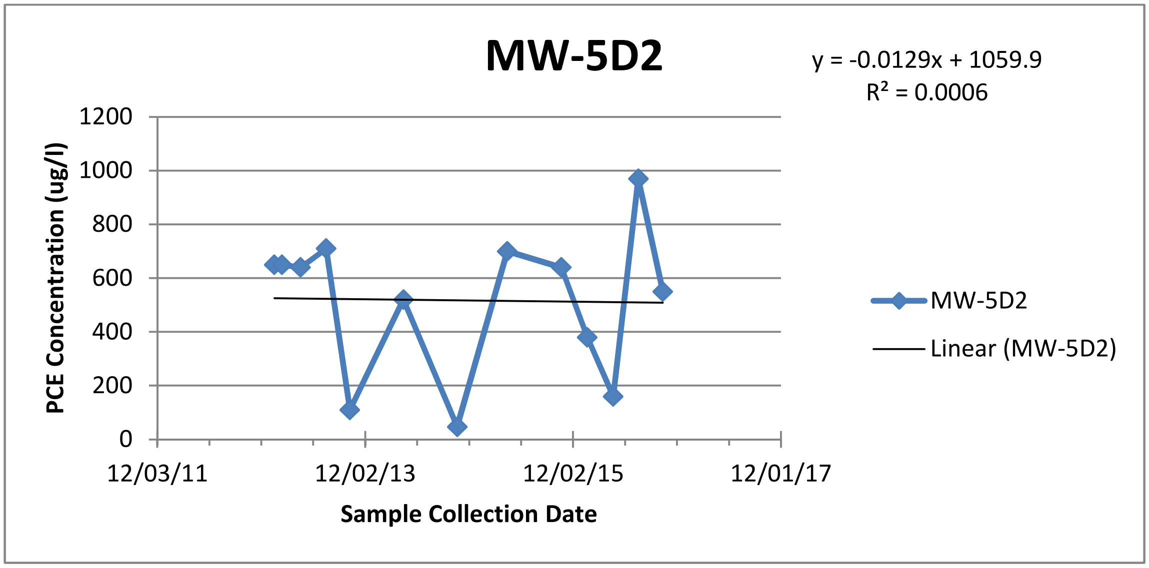

MW-4S
2.0
1.5
1.0
0.5
0.0
PCE Concentration (ug/l)
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
Sample Collection Date
y = 6E-06x + 1.1679
R² = 8E-05
MW-4S
Linear (MW-4S)

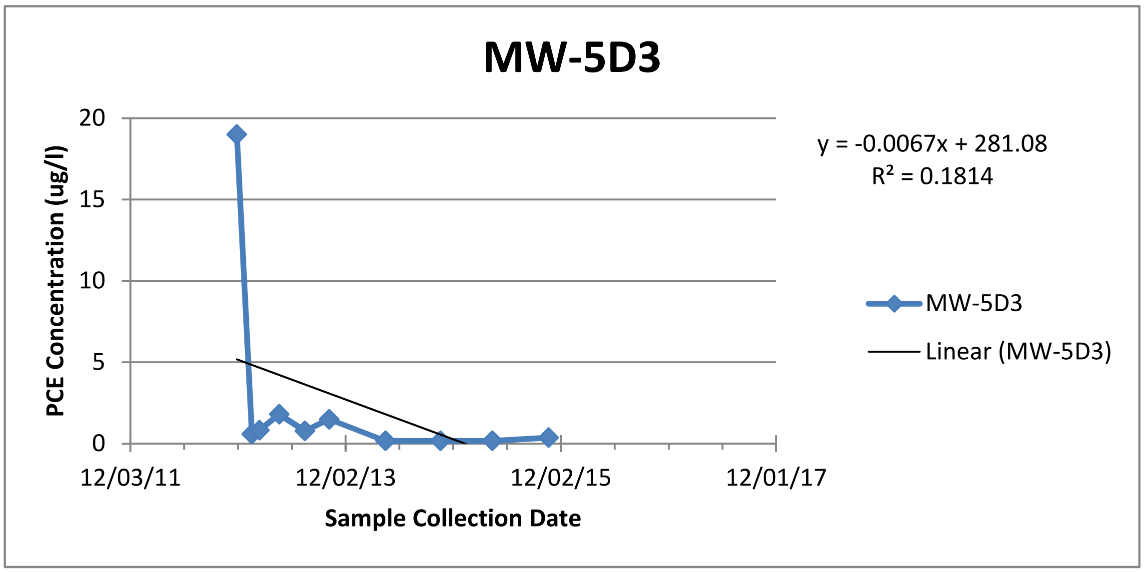

MW-4D
1.0
0.8
0.6
0.4
0.2
0.0
TCE Concentration (ug/l)
07/06/09
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
Sample Collection Date
y = -0.0004x + 15.237
R² = 0.4646
MW-4D
Linear (MW-4D)

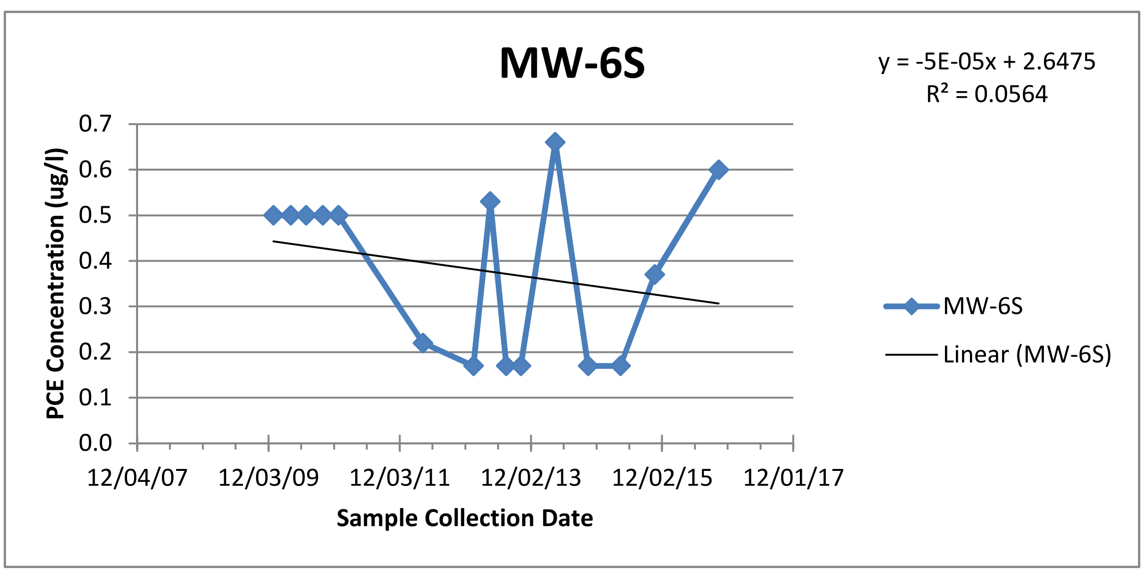

MW-4D2
y = -0.0004x + 19.549
R² = 0.491
PCE Concentration (ug/l)
2.0
1.5
1.0
0.5
0.0
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
Sample Collection Date
MW-4D2
Linear (MW-4D2)

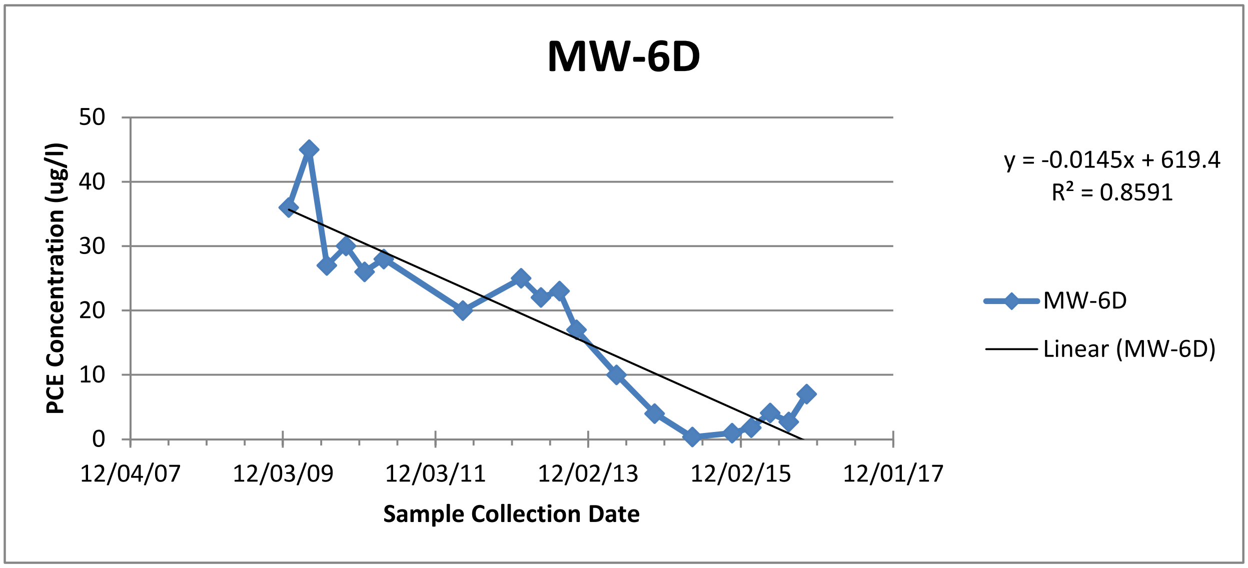

MW-5S
y = -0.1406x + 6021.5
R² = 0.3073
PCE Concentration (ug/l)
800
700
600
500
400
300
200
100
0
12/03/09
12/03/11
12/02/13
12/02/15
12/01/17
Sample Collection Date
MW-5S
Linear (MW-5S)

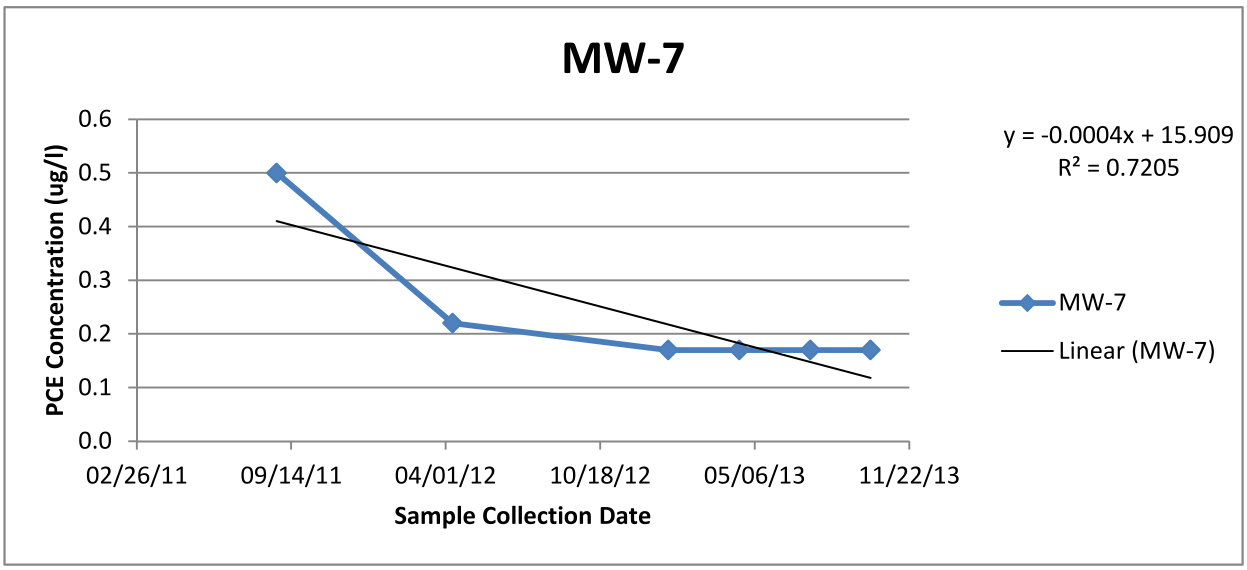

MW-5D
y = -0.3445x + 15378
R² = 0.0432
PCE Concentration (ug/l)
4000
3500
3000
2500
2000
1500
1000
500
0
12/03/09
12/03/11
12/02/13
12/02/15
12/01/17
Sample Collection Date
MW-5D
Linear (MW-5D)

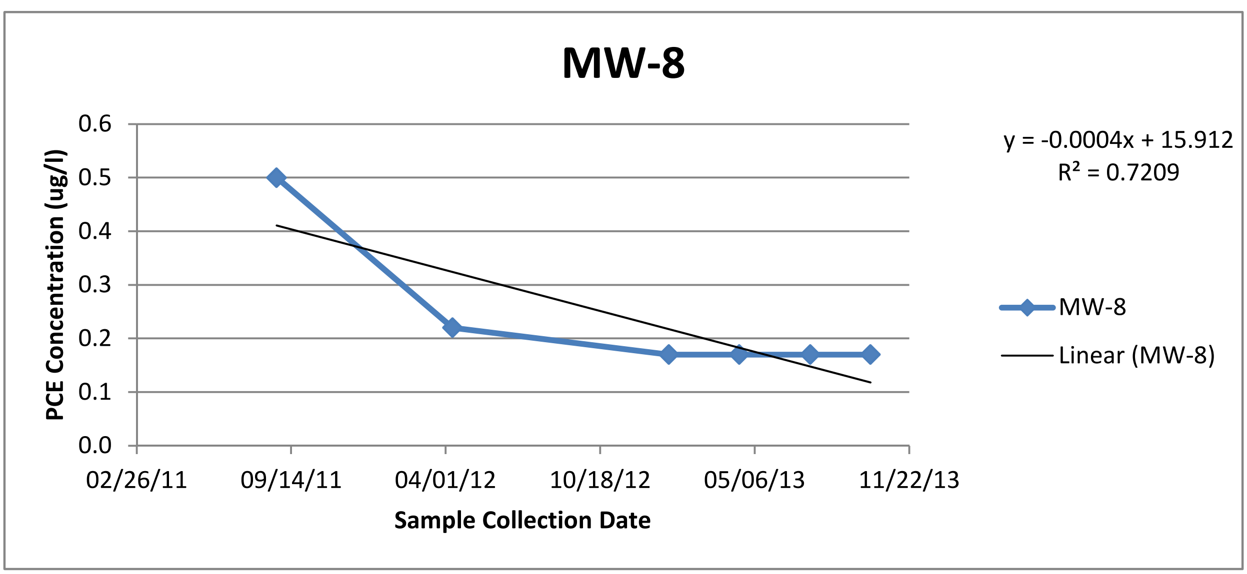

MW-5D2
y = -0.0129x + 1059.9
R² = 0.0006
1200
1000
800
600
400
200
0
PCE Concentration (ug/l)
12/03/11
12/02/13
12/02/15
12/01/17
Sample Collection Date
MW-5D2
Linear (MW-5D2)

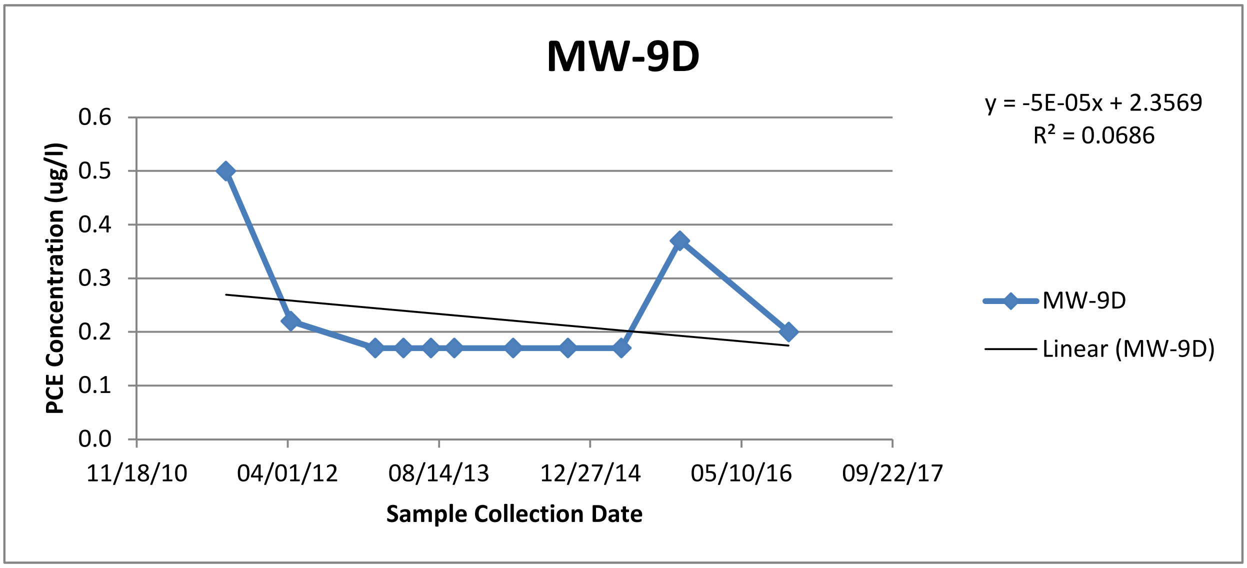

MW-5D3
y = -0.0067x + 281.08
R² = 0.1814
20
15
10
5
0
PCE Concentration (ug/l)
12/03/11
12/02/13
12/02/15
12/01/17
Sample Collection Date
MW-5D3
Linear (MW-5D3)

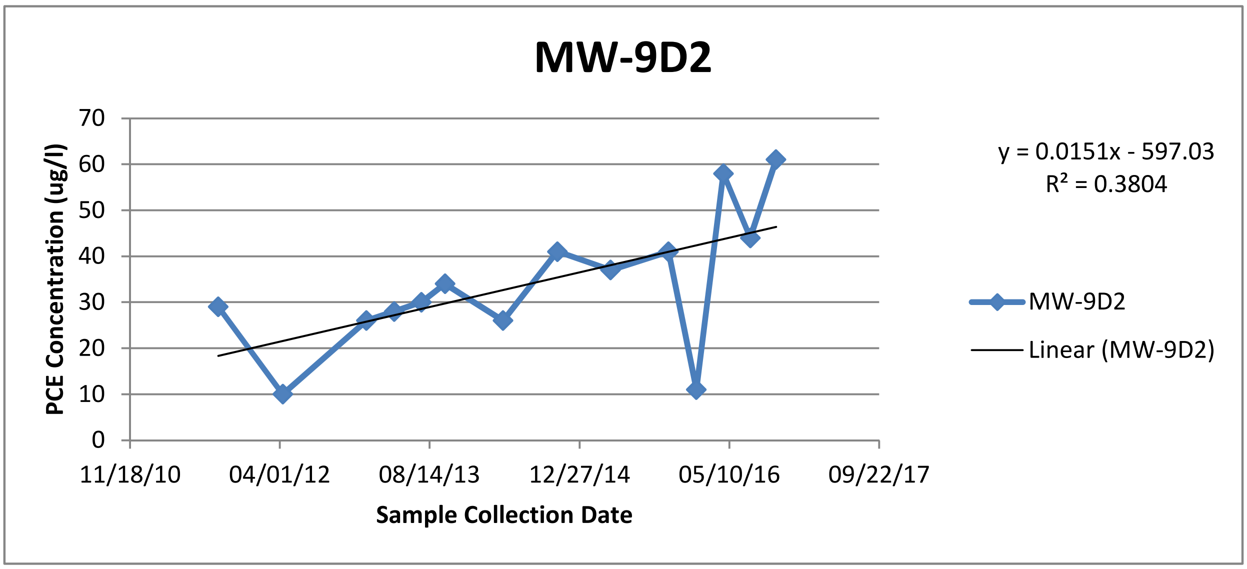

MW-6S
y = -5E-05x + 2.6475
R² = 0.0564
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
PCE Concentration (ug/l)
12/04/07
12/03/09
12/03/11
12/02/13
12/02/15
12/01/17
Sample Collection Date
MW-6S
Linear (MW-6S)

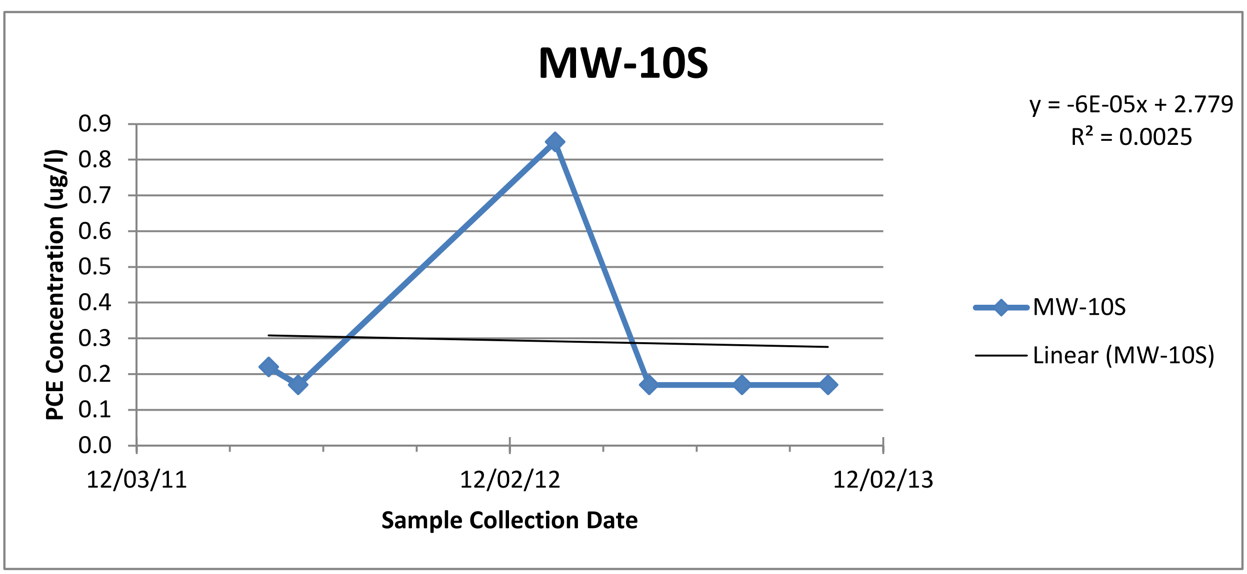

MW-6D
50
40
30
20
10
0
PCE Concentration (ug/l)
12/04/07
12/03/09
12/03/11
12/02/13
12/02/15
12/01/17
Sample Collection Date
y = -0.0145x + 619.4
R² = 0.8591
MW-6D
Linear (MW-6D)

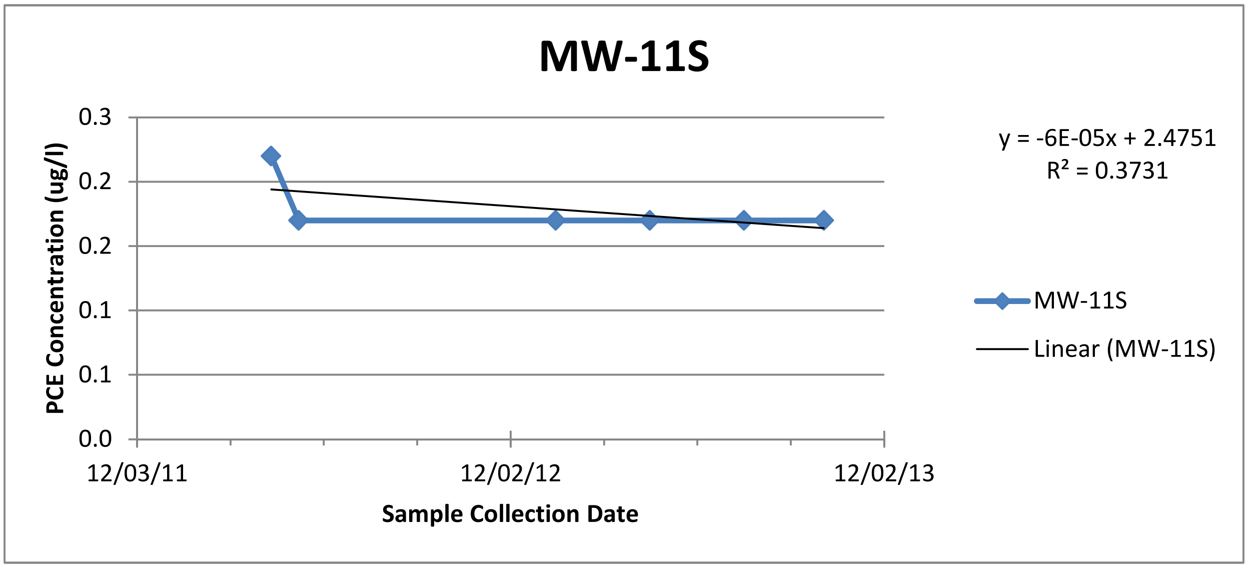

MW-7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
PCE Concentration (ug/l)
02/26/11
09/14/11
04/01/12
10/18/12
05/06/13
11/22/13
Sample Collection Date
y = -0.0004x + 15.909
R² = 0.7205
MW-7
Linear (MW-7)

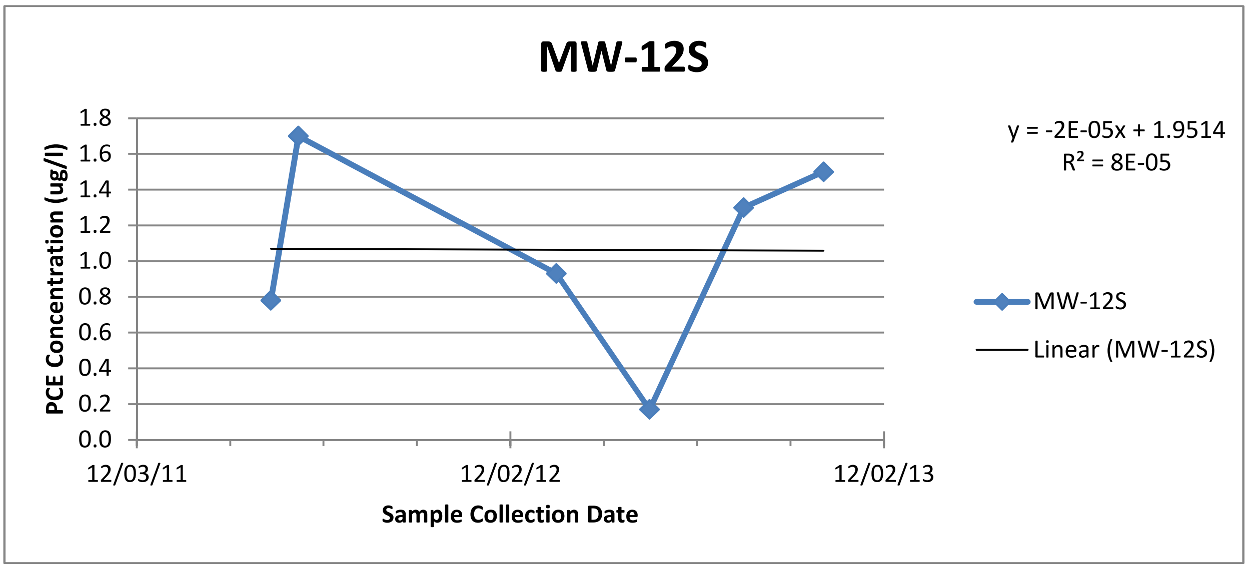

MW-8
0.6
0.5
0.4
0.3
0.2
0.1
0.0
PCE Concentration (ug/l)
02/26/11
09/14/11
04/01/12
10/18/12
05/06/13
11/22/13
Sample Collection Date
y = -0.0004x + 15.912
R² = 0.7209
MW-8
Linear (MW-8)

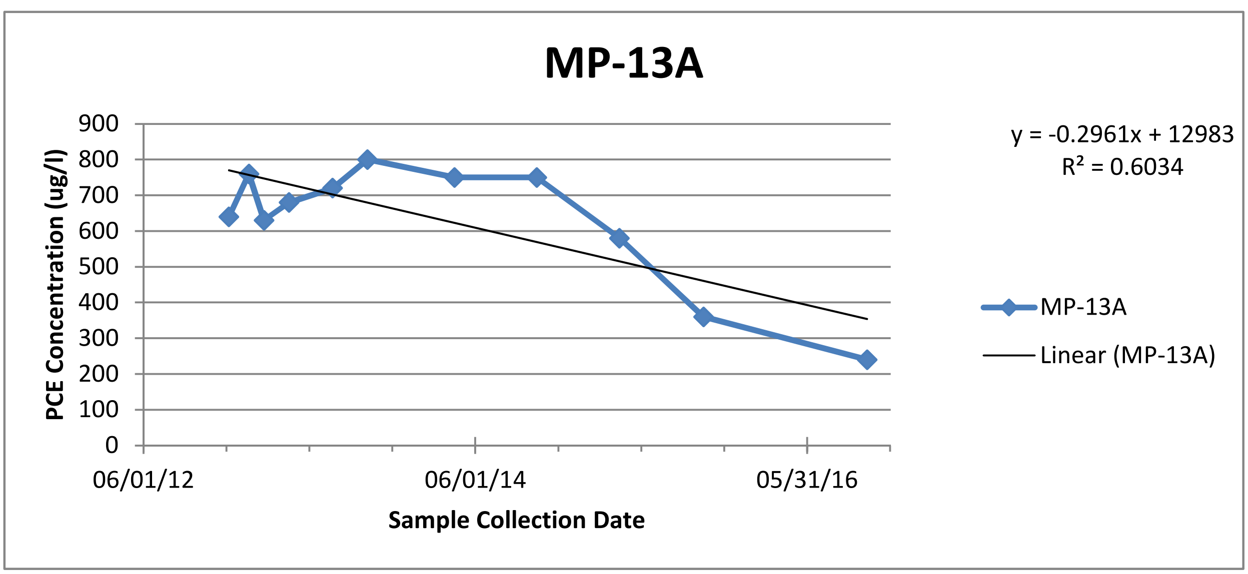

MW-9D
y = -5E-05x + 2.3569
R² = 0.0686
PCE Concentration (ug/l)
0.6
0.5
0.4
0.3
0.2
0.1
0.0
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
Sample Collection Date
MW-9D
Linear (MW-9D)

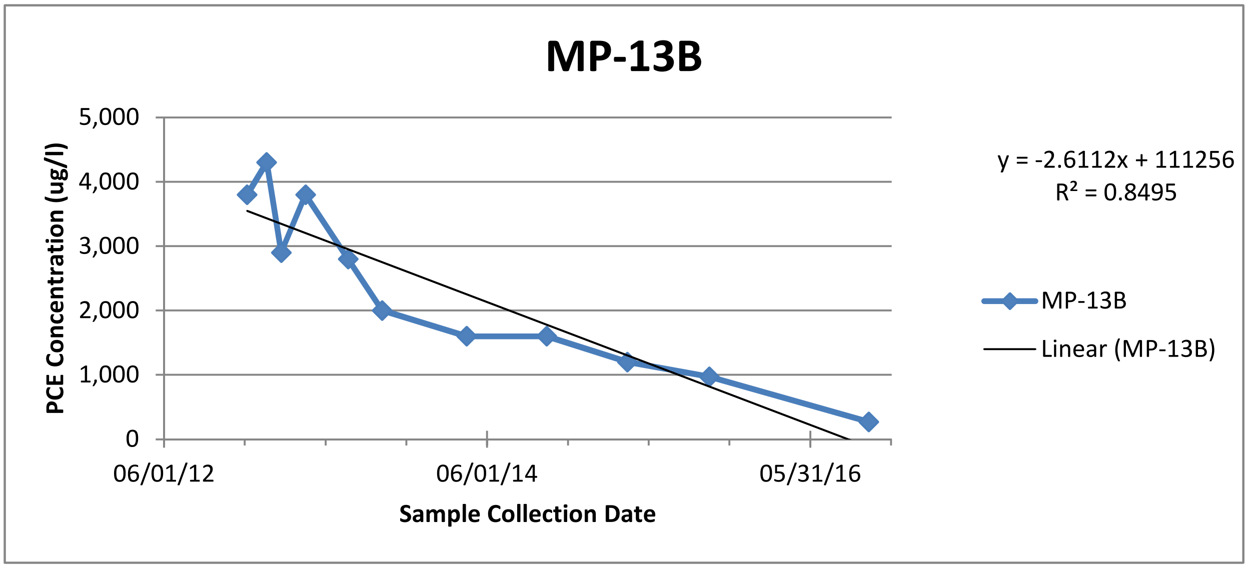

MW-9D2
y = 0.0151x - 597.03
R² = 0.3804
PCE Concentration (ug/l)
70
60
50
40
30
20
10
0
11/18/10
04/01/12
08/14/13
12/27/14
05/10/16
09/22/17
Sample Collection Date
MW-9D2
Linear (MW-9D2)

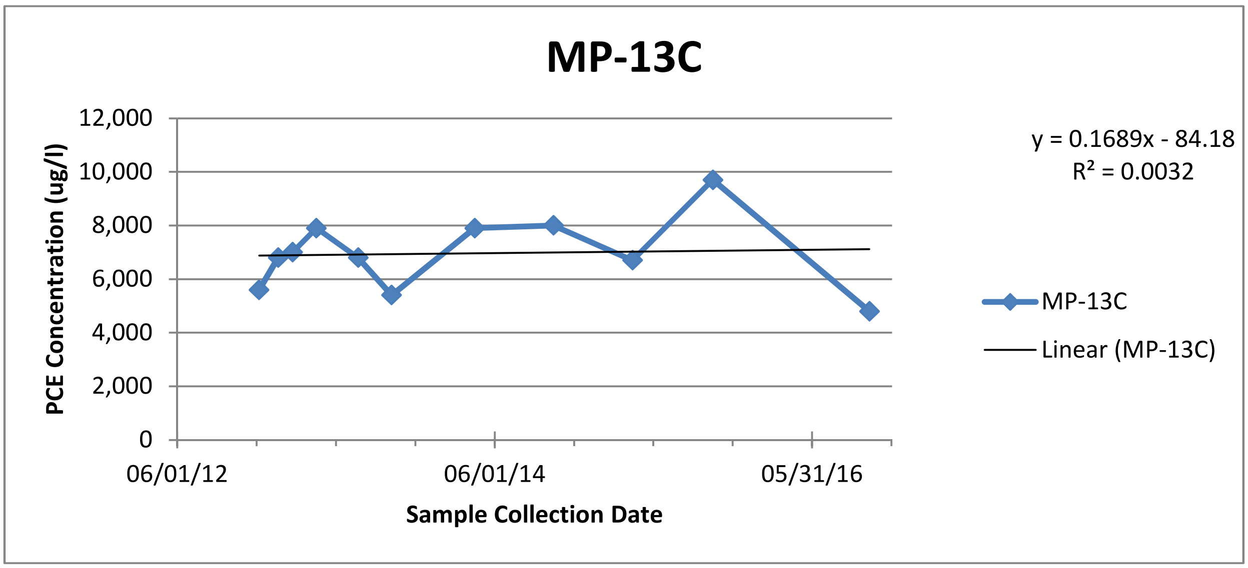

MW-10S
y = -6E-05x + 2.779
R² = 0.0025
PCE Concentration (ug/l)
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
12/03/11
12/02/12
12/02/13
Sample Collection Date
MW-10S
Linear (MW-10S)

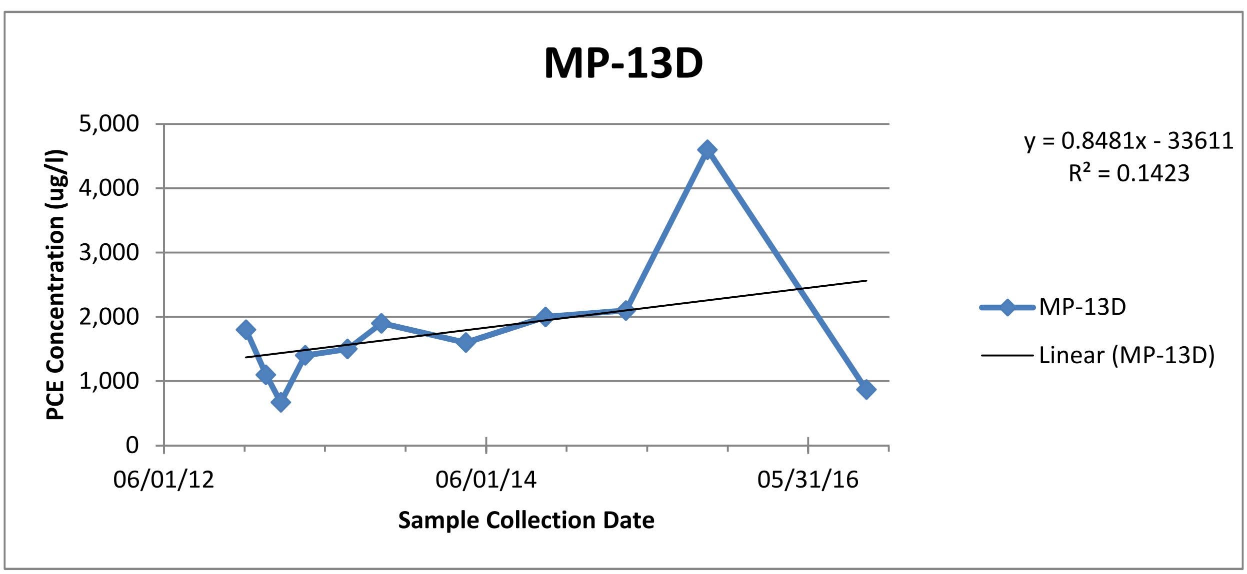

MW-11S
y = -6E-05x + 2.4751
R² = 0.3731
PCE Concentration (ug/l)
0.3
0.2
0.2
0.1
0.1
0.0
12/03/11
12/02/12
12/02/13
Sample Collection Date
MW-11S
Linear (MW-11S)

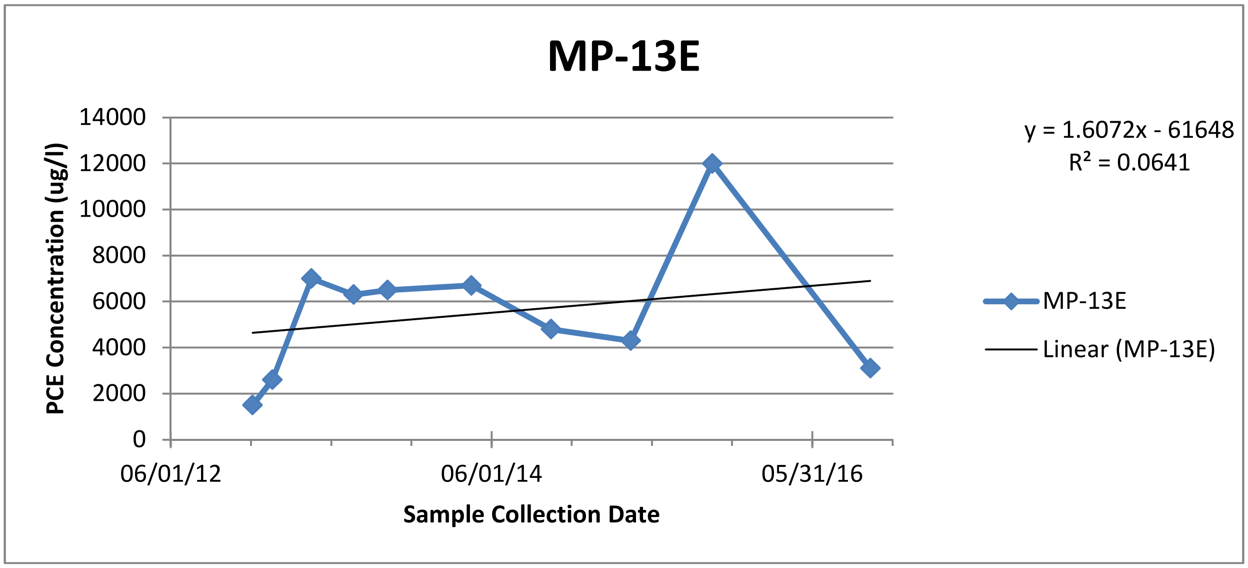

MW-12S
y = -2E-05x + 1.9514
R² = 8E-05
PCE Concentration (ug/l)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
12/03/11
12/02/12
12/02/13
Sample Collection Date
MW-12S
Linear (MW-12S)

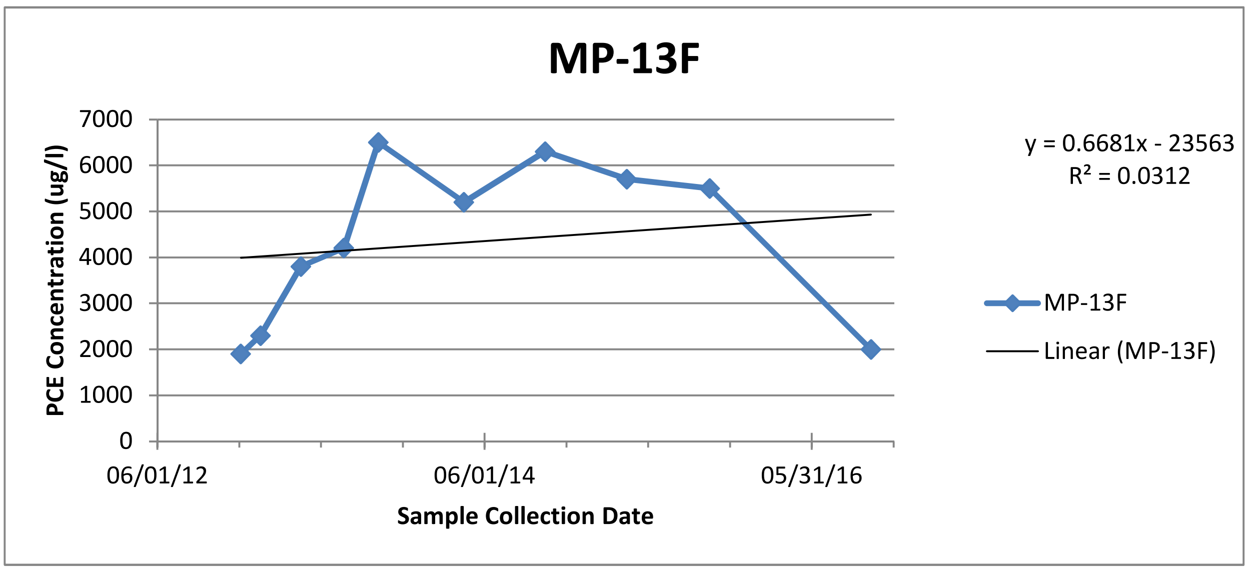

MP-13A
y = -0.2961x + 12983
R² = 0.6034
PCE Concentration (ug/l)
900
800
700
600
500
400
300
200
100
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
MP-13A
Linear (MP-13A)

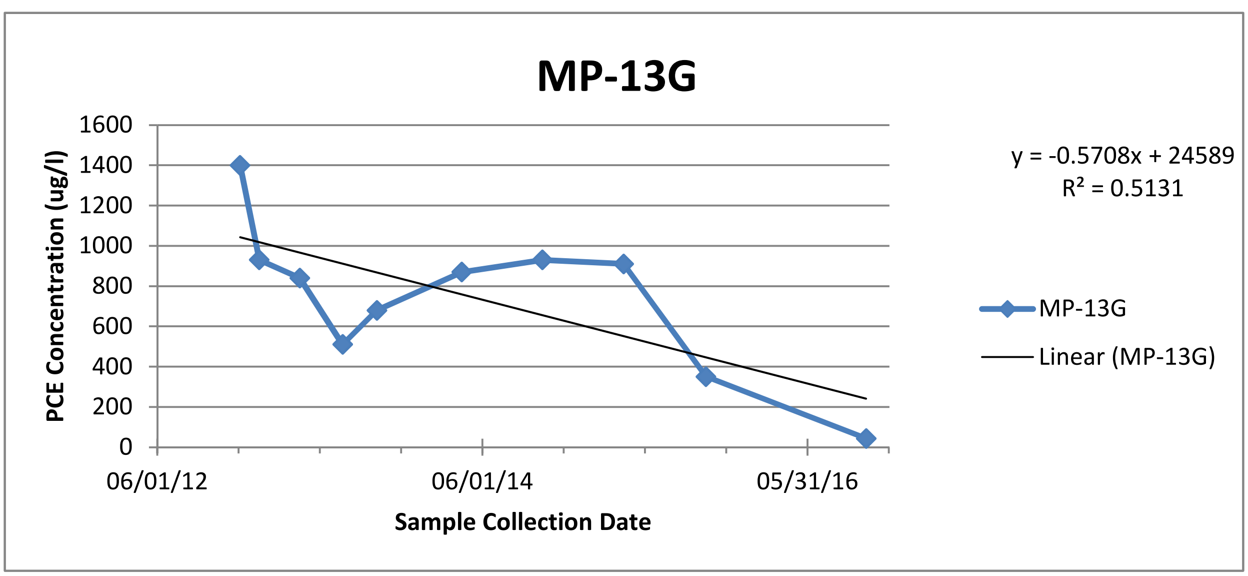

MP-13B
5,000
4,000
3,000
2,000
1,000
0
PCE Concentration (ug/l)
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = -2.6112x + 111256
R² = 0.8495
MP-13B
Linear (MP-13B)

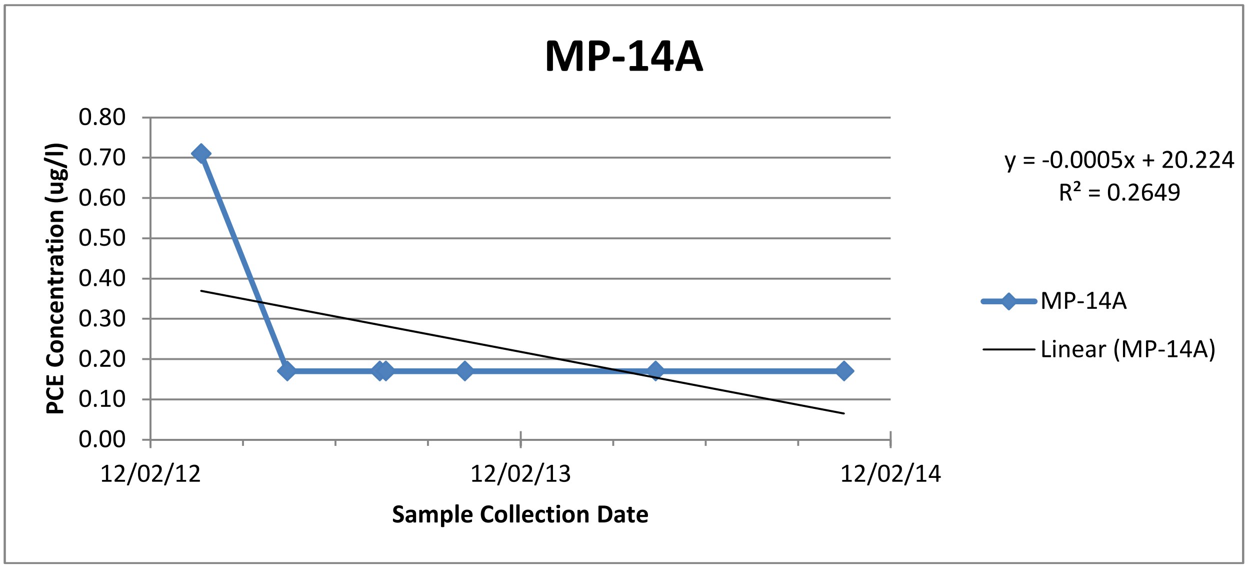

MP-13C
12,000
10,000
8,000
6,000
4,000
2,000
0
PCE Concentration (ug/l)
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = 0.1689x - 84.18
R² = 0.0032
MP-13C
Linear (MP-13C)

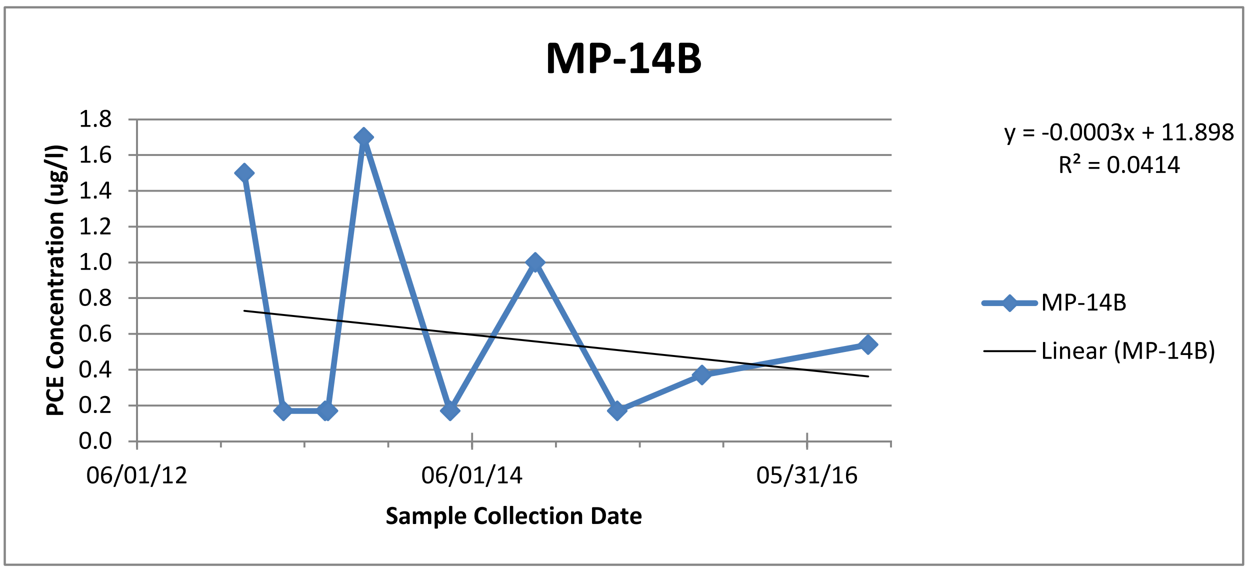

MP-13D
5,000
4,000
3,000
2,000
1,000
0
PCE Concentration (ug/l)
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = 0.8481x - 33611
R² = 0.1423
MP-13D
Linear (MP-13D)

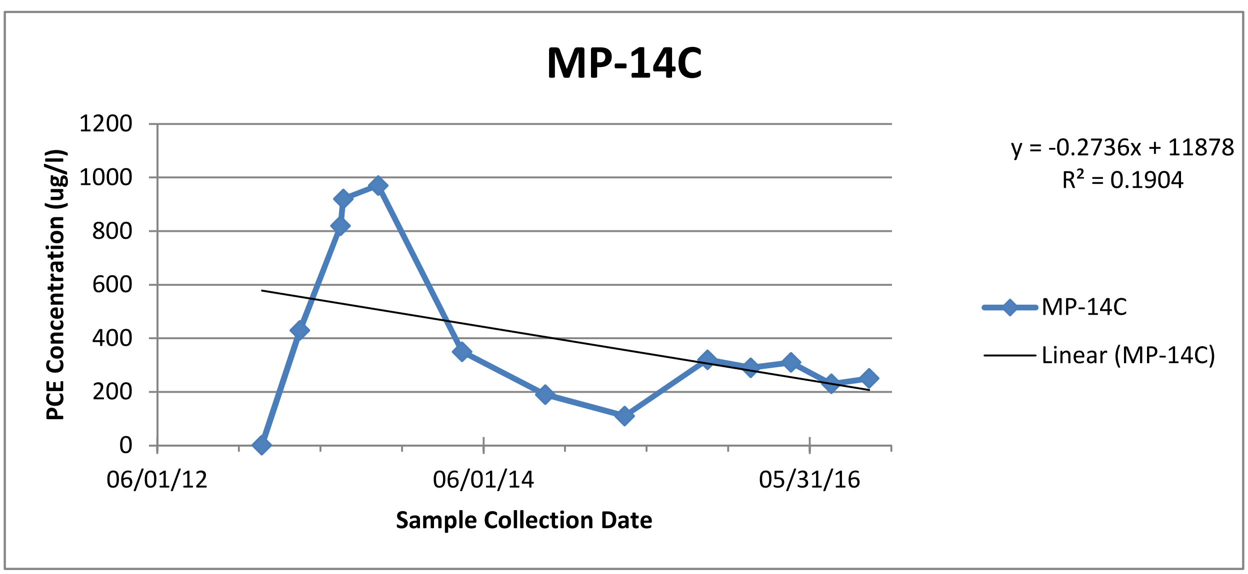

MP-13E
PCE Concentration (ug/l)
14000
12000
10000
8000
6000
4000
2000
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = 1.6072x - 61648
R² = 0.0641
MP-13E
Linear (MP-13E)

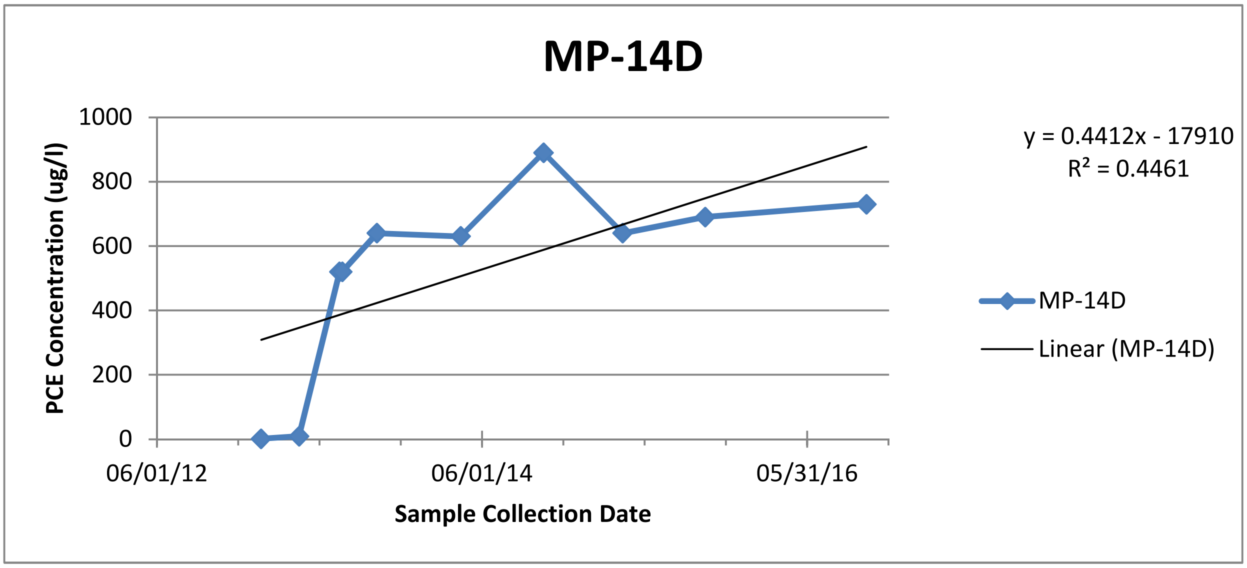

MP-13F
PCE Concentration (ug/l)
7000
6000
5000
4000
3000
2000
1000
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = 0.6681x - 23563
R² = 0.0312
MP-13F
Linear (MP-13F)

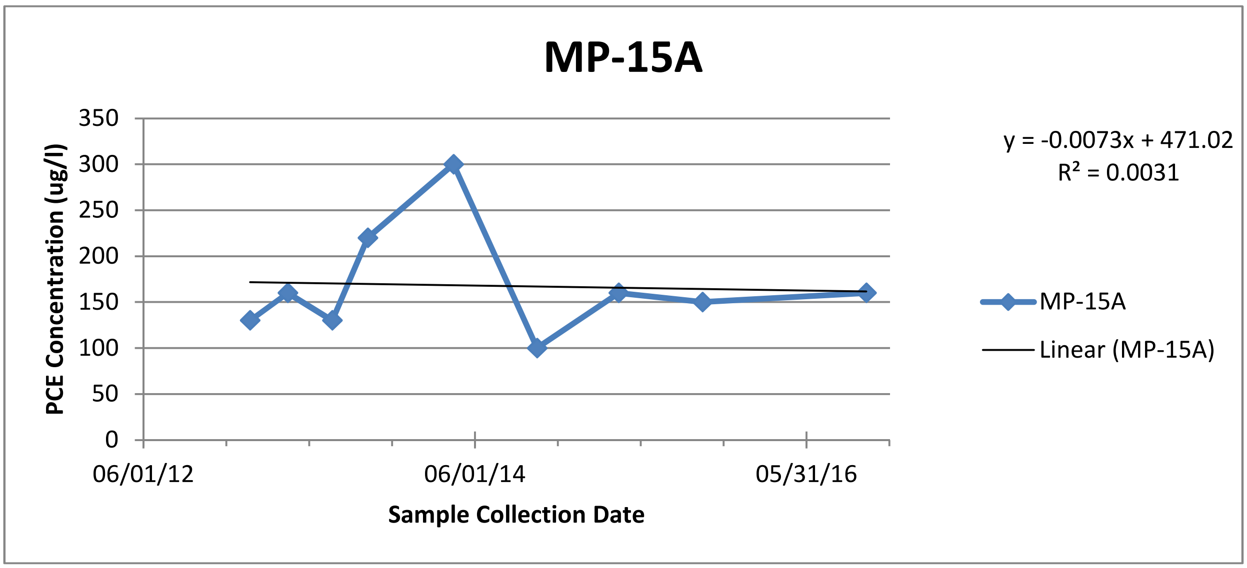

MP-13G
PCE Concentration (ug/l)
1600
1400
1200
1000
800
600
400
200
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = -0.5708x + 24589
R² = 0.5131
MP-13G
Linear (MP-13G)

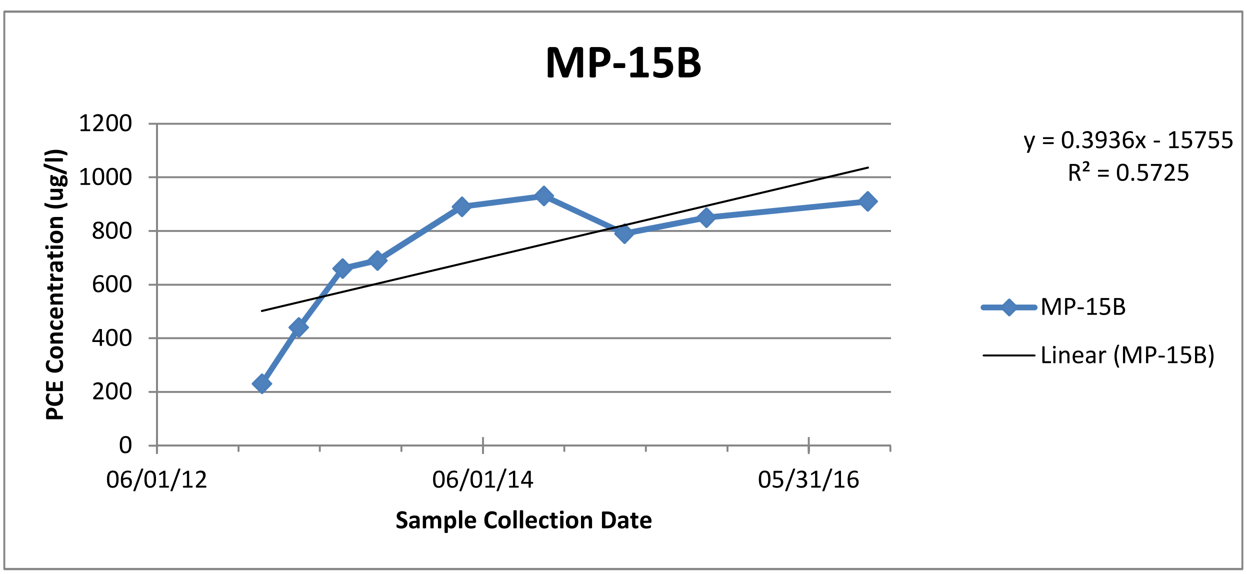

MP-14A
PCE Concentration (ug/l)
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
12/02/12
12/02/13
12/02/14
Sample Collection Date
y = -0.0005x + 20.224
R² = 0.2649
MP-14A
Linear (MP-14A)

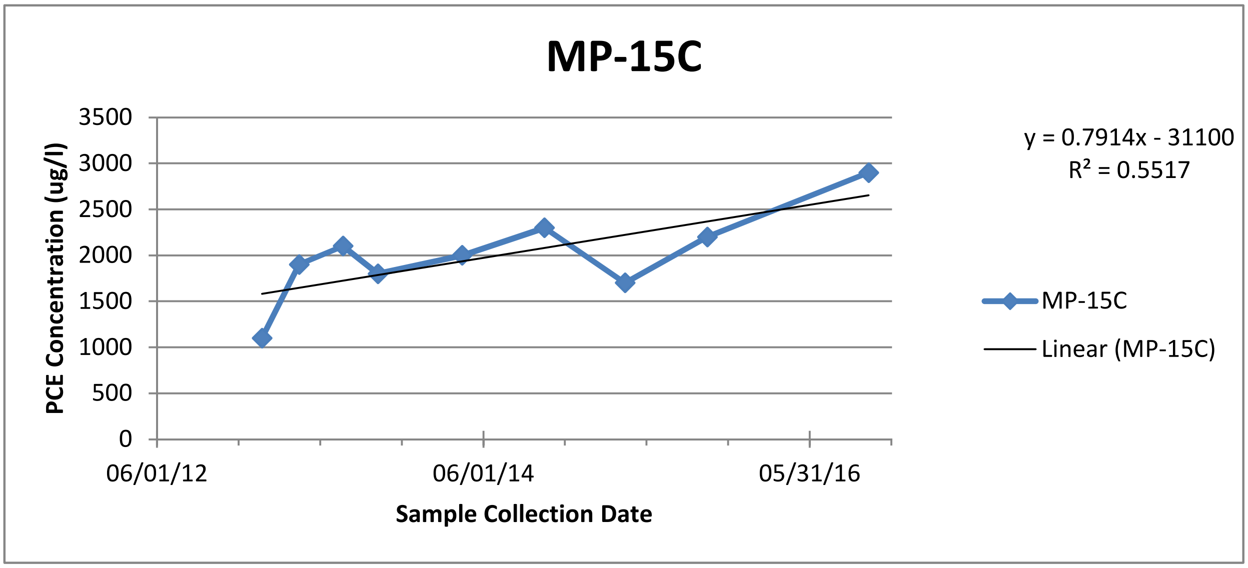

MP-14B
PCE Concentration (ug/l)
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = -0.0003x + 11.898
R² = 0.0414
MP-14B
Linear (MP-14B)

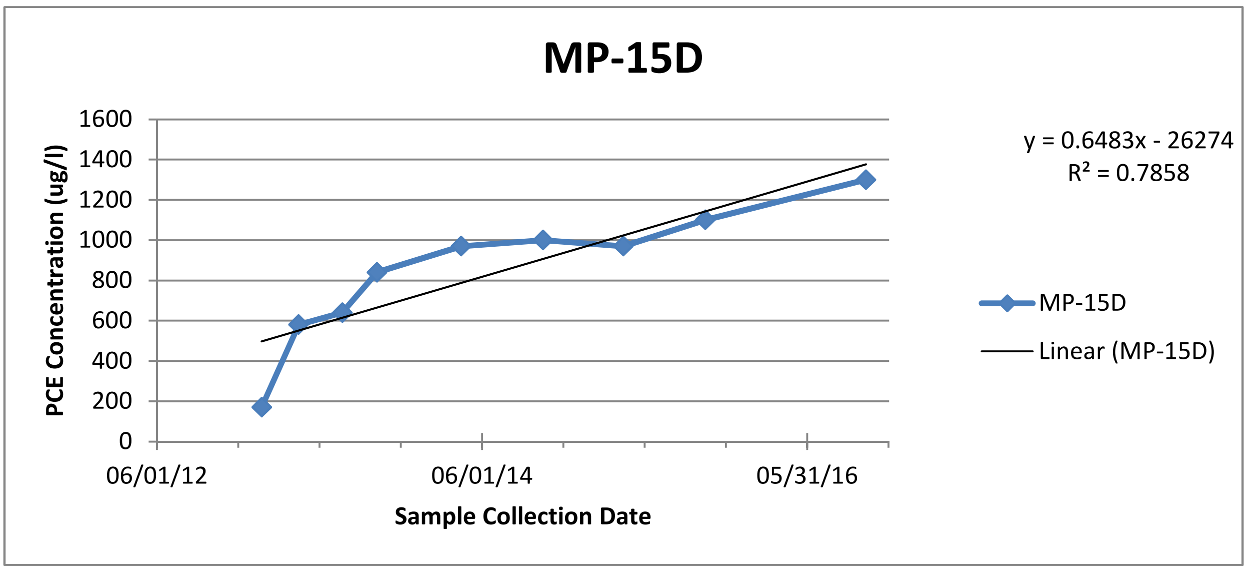

MP-14C
PCE Concentration (ug/l)
1200
1000
800
600
400
200
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = -0.2736x + 11878
R² = 0.1904
MP-14C
Linear (MP-14C)

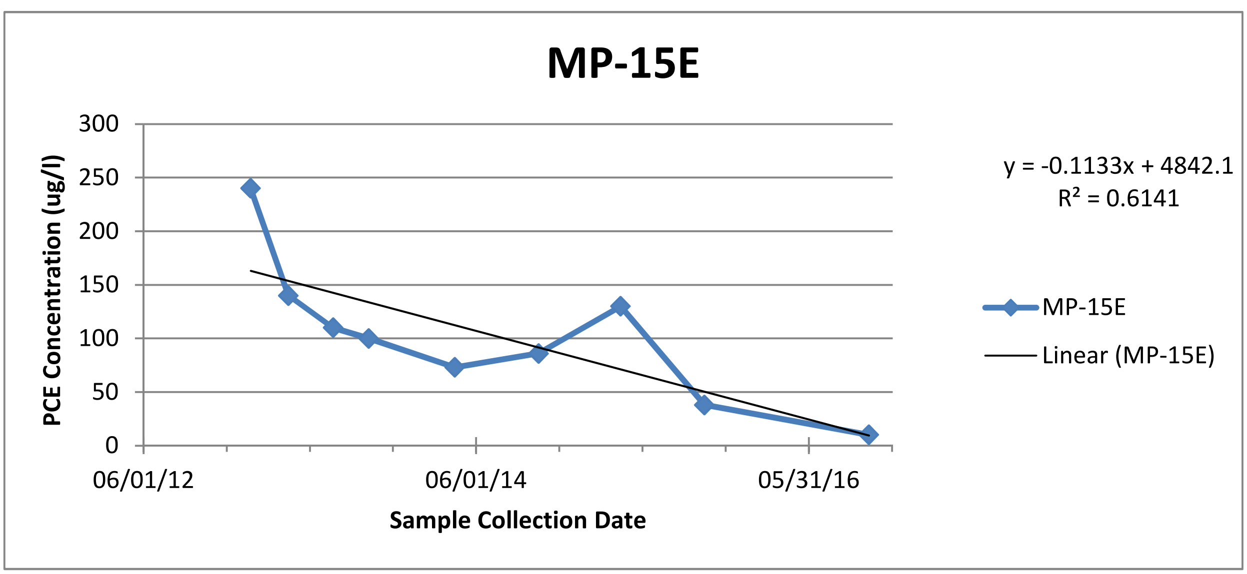

MP-14D
PCE Concentration (ug/l)
1000
800
600
400
200
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = 0.4412x - 17910
R² = 0.4461
MP-14D
Linear (MP-14D)

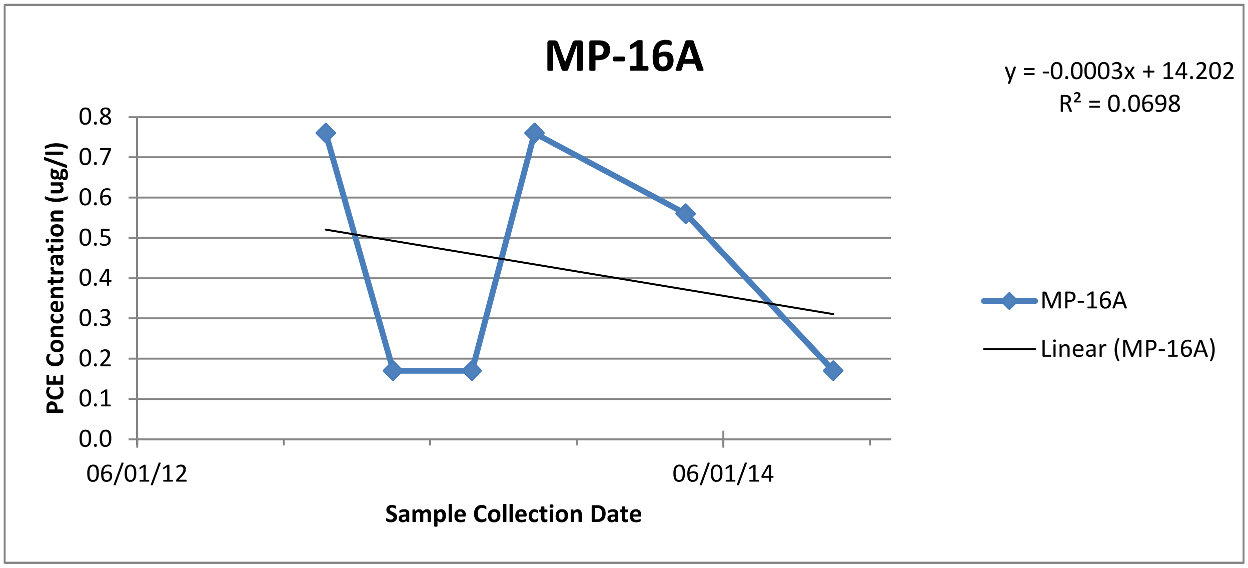

MP-15A
PCE Concentration (ug/l)
350
300
250
200
150
100
50
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = -0.0073x + 471.02
R² = 0.0031
MP-15A
Linear (MP-15A)

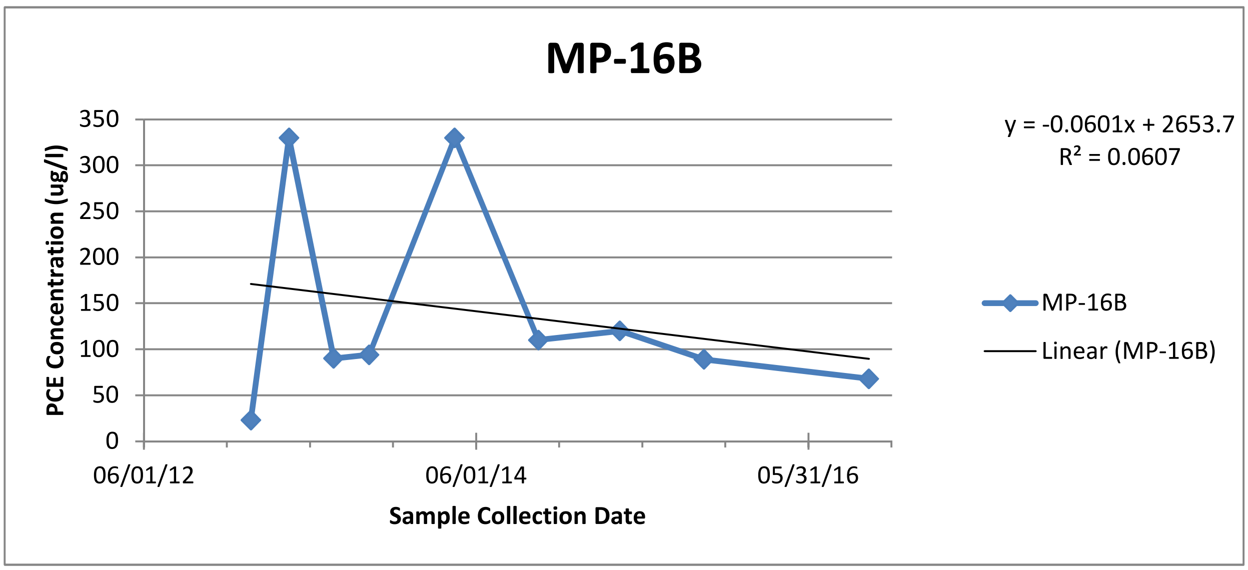

MP-15B
PCE Concentration (ug/l)
1200
1000
800
600
400
200
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = 0.3936x - 15755
R² = 0.5725
MP-15B
Linear (MP-15B)

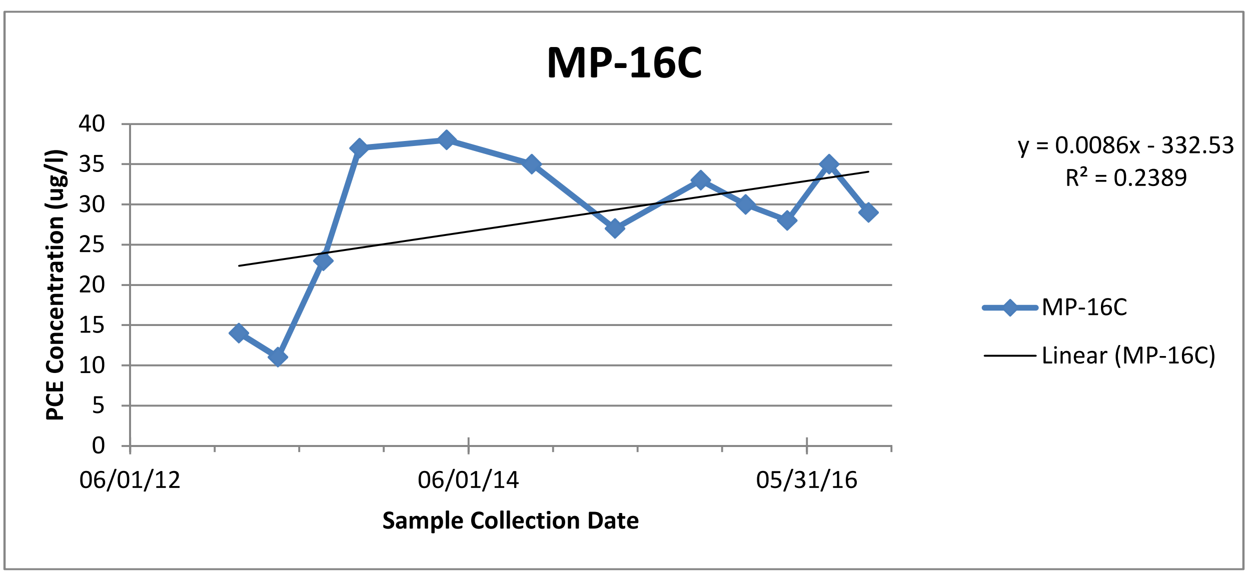

MP-15C
PCE Concentration (ug/l)
3500
3000
2500
2000
1500
1000
500
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = 0.7914x - 31100
R² = 0.5517
MP-15C
Linear (MP-15C)

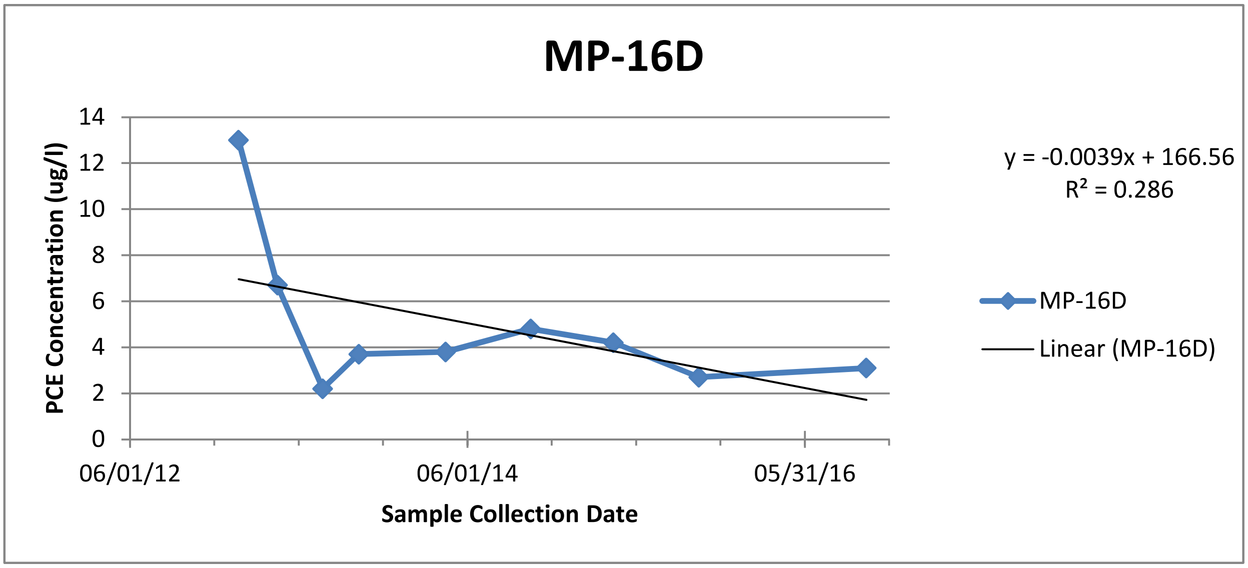

MP-15D
PCE Concentration (ug/l)
1600
1400
1200
1000
800
600
400
200
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = 0.6483x - 26274
R² = 0.7858
MP-15D
Linear (MP-15D)

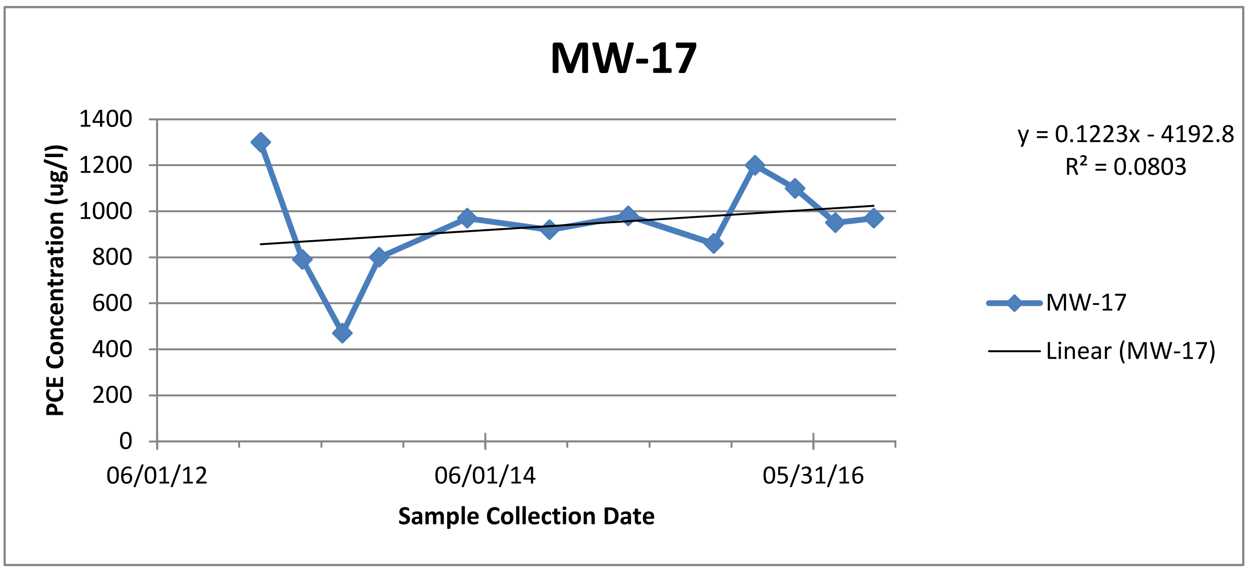

MP-15E
PCE Concentration (ug/l)
300
250
200
150
100
50
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = -0.1133x + 4842.1
R² = 0.6141
MP-15E
Linear (MP-15E)

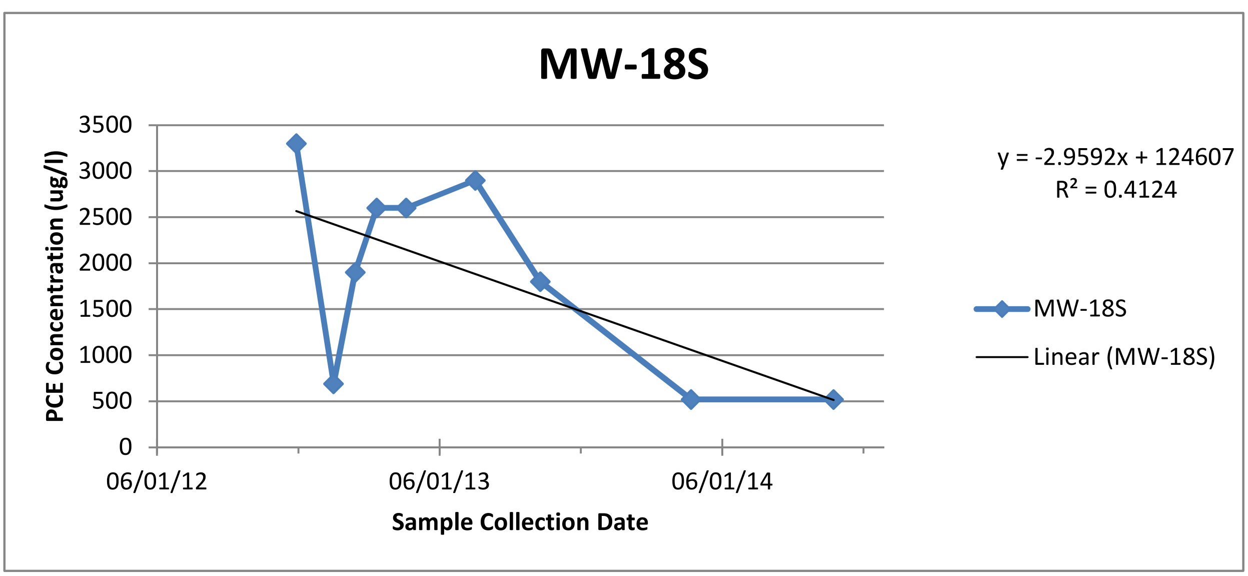

MP-16A
y = -0.0003x + 14.202
R² = 0.0698
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
PCE Concentration (ug/l)
06/01/12
06/01/14
Sample Collection Date
MP-16A
Linear (MP-16A)

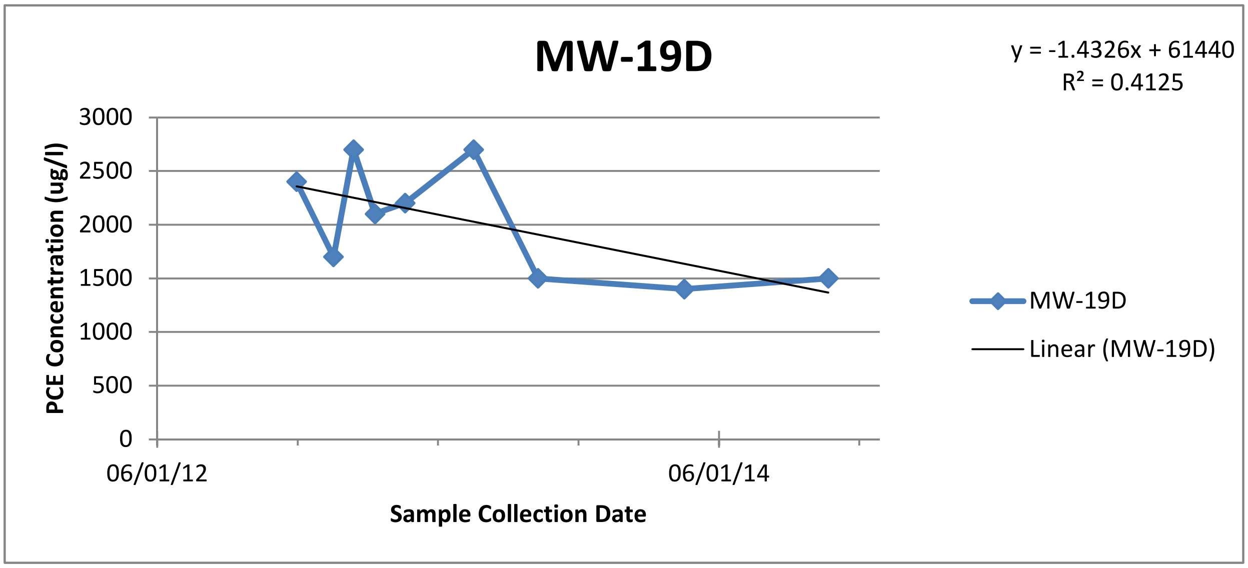

MP-16B
y = -0.0601x + 2653.7
R² = 0.0607
350
300
250
200
150
100
50
0
PCE Concentration (ug/l)
06/01/12
06/01/14
05/31/16
Sample Collection Date
MP-16B
Linear (MP-16B)

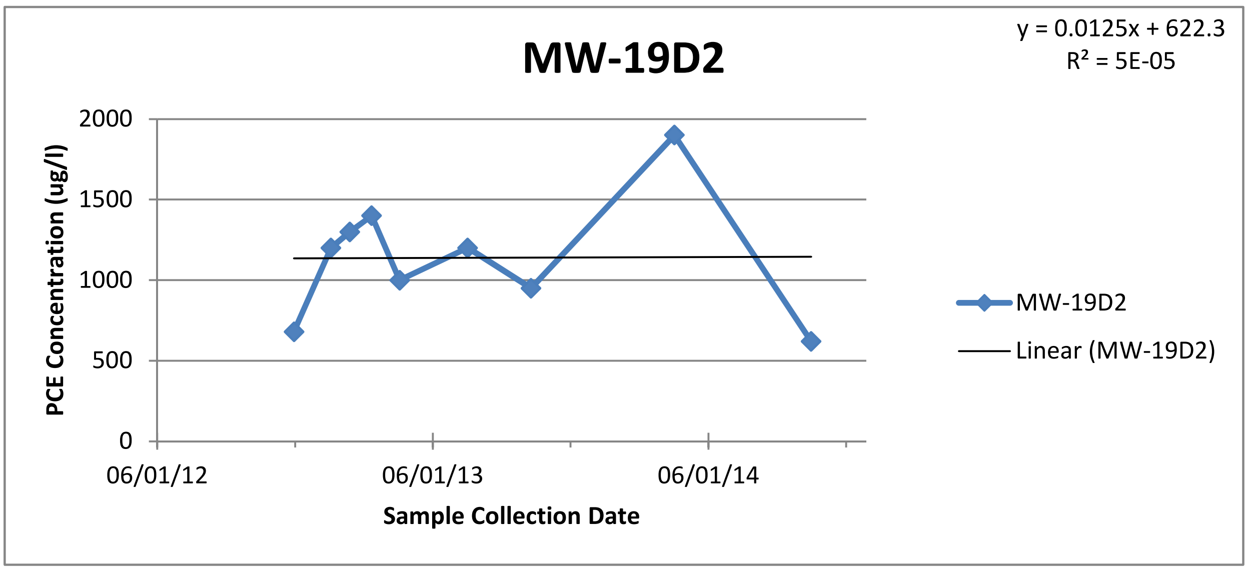

MP-16C
y = 0.0086x - 332.53
R² = 0.2389
40
35
30
25
20
15
10
5
0
PCE Concentration (ug/l)
06/01/12
06/01/14
05/31/16
Sample Collection Date
MP-16C
Linear (MP-16C)

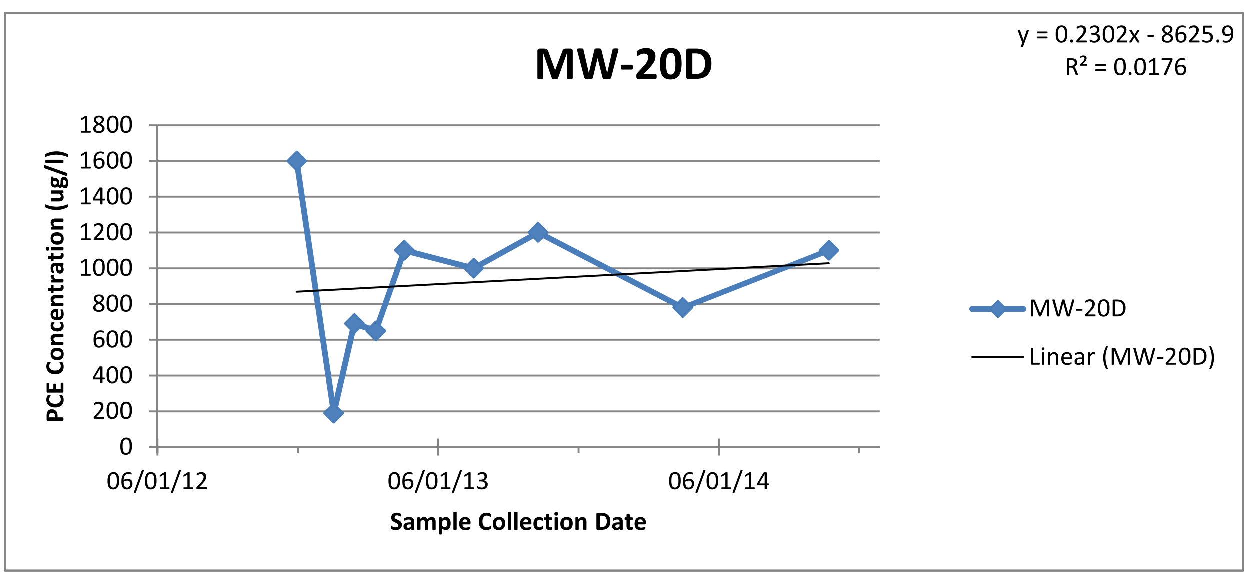

MP-16D
PCE Concentration (ug/l)
14
12
10
8
6
4
2
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = -0.0039x + 166.56
R² = 0.286
MP-16D
Linear (MP-16D)

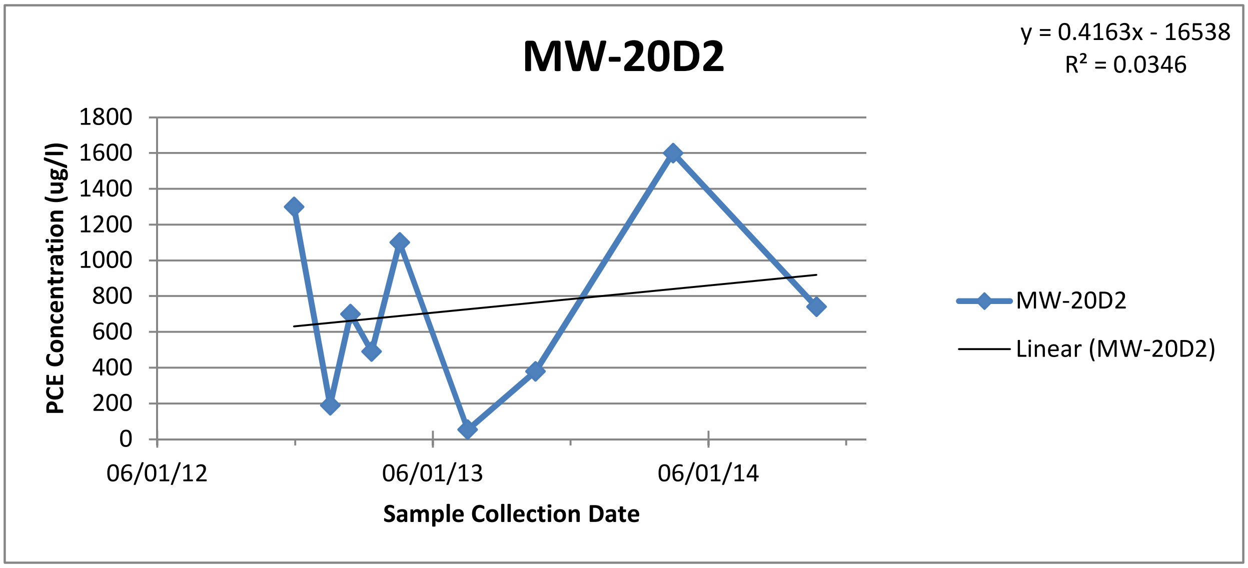

MW-17
PCE Concentration (ug/l)
1400
1200
1000
800
600
400
200
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = 0.1223x - 4192.8
R² = 0.0803
MW-17
Linear (MW-17)

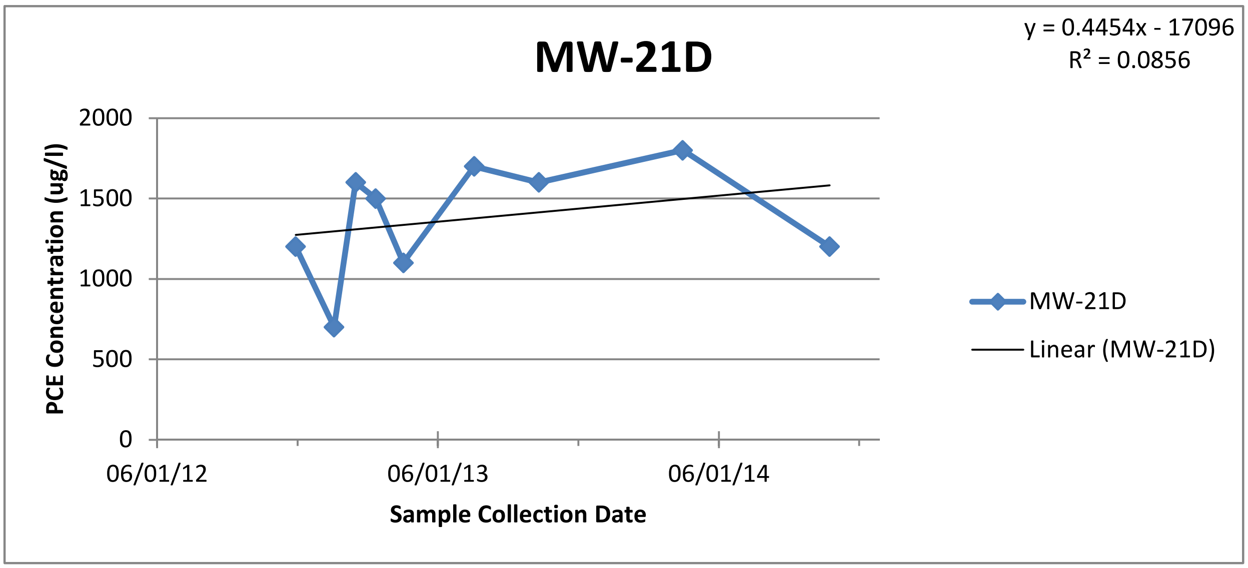

MW-18S
PCE Concentration (ug/l)
3500
3000
2500
2000
1500
1000
500
0
06/01/12
06/01/13
06/01/14
Sample Collection Date
y = -2.9592x + 124607
R² = 0.4124
MW-18S
Linear (MW-18S)

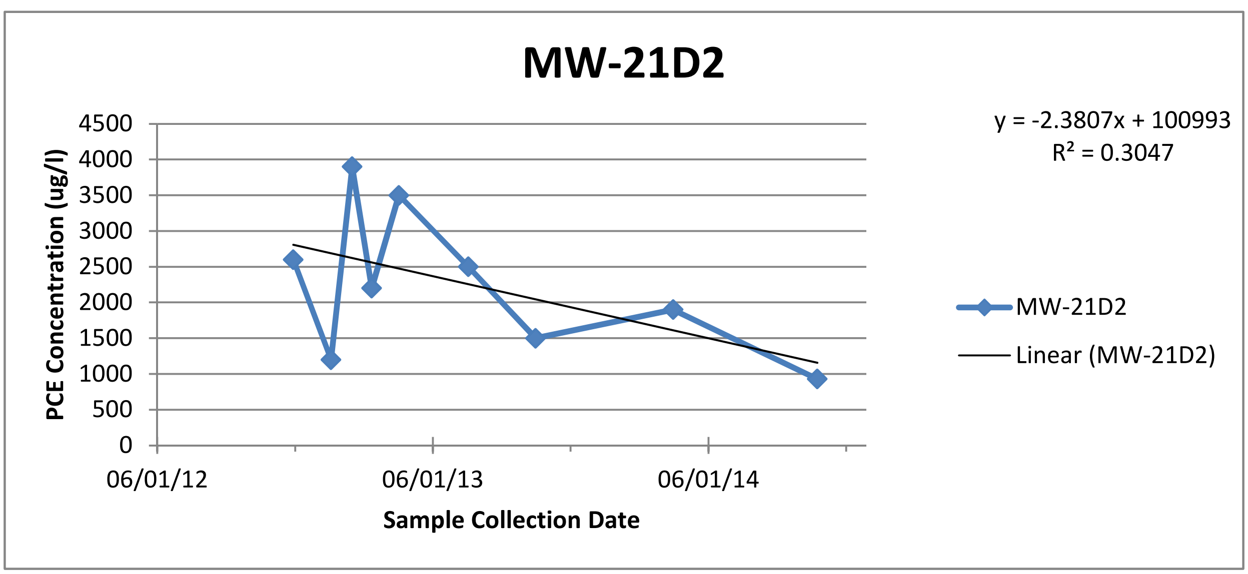

MW-19D
y = -1.4326x + 61440
R^2 = 0.4125
PCE Concentration (ug/l)
3000
2500
2000
1500
1000
500
0
06/01/12
06/01/14
Sample Collection Date
MW-19D
Linear (MW-19D)

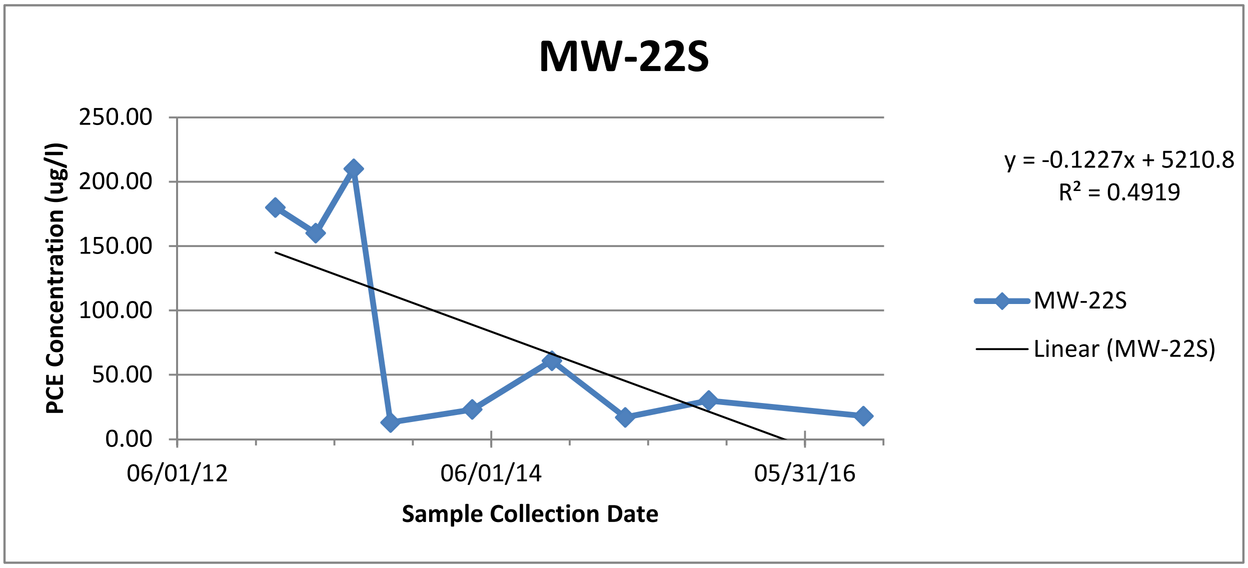

MW-19D2
y = 0.0125x + 622.3
R^2 = 5E-05
PCE Concentration (ug/l)
2000
1500
1000
500
0
06/01/12
06/01/13
06/01/14
Sample Collection Date
MW-19D2
Linear (MW-19D2)

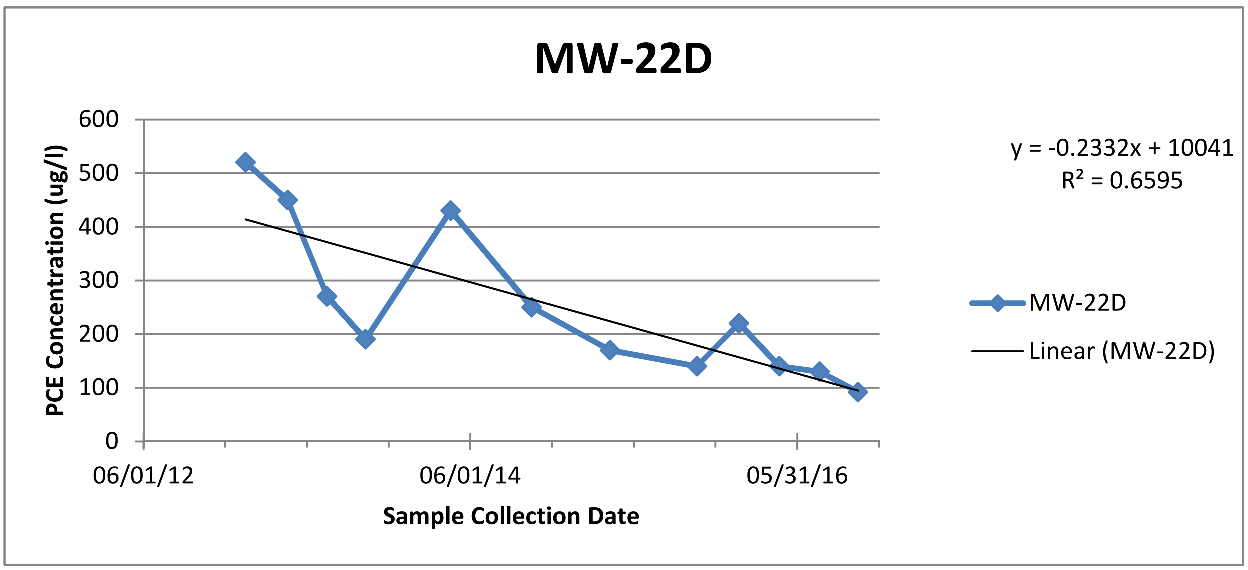

MW-20D
y = 0.2302x - 8625.9
R^2 = 0.0176
PCE Concentration (ug/l)
1800
1600
1400
1200
1000
800
600
400
200
0
06/01/12
06/01/13
06/01/14
Sample Collection Date
MW-20D
Linear (MW-20D)

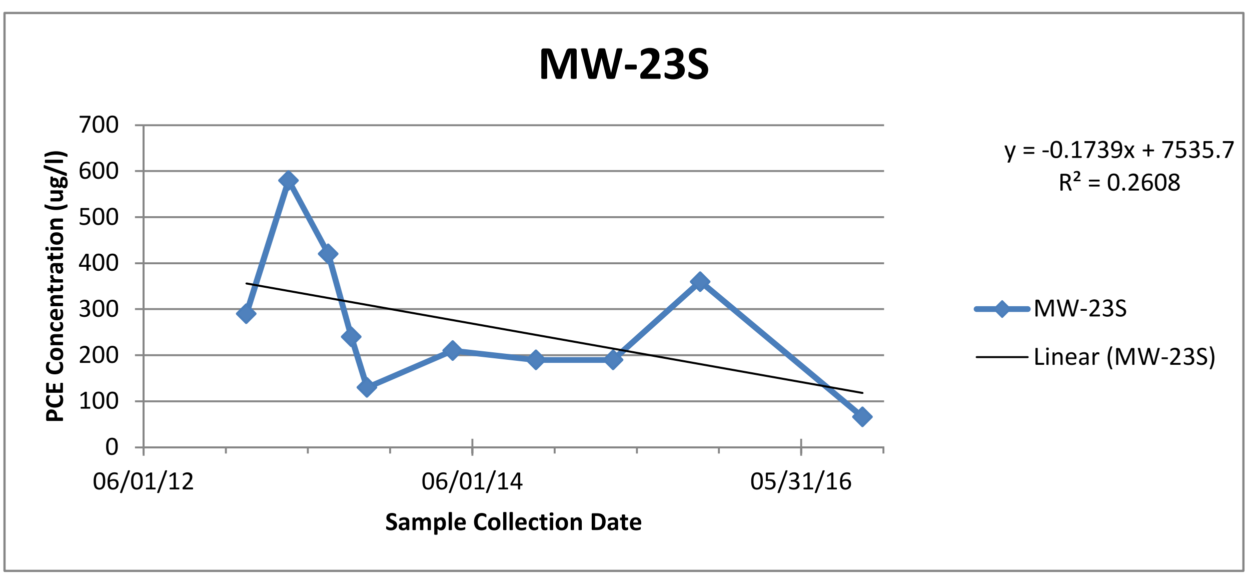

MW-20D2
y = 0.4163x - 16538
R² = 0.0346
PCE Concentration (ug/l)
1800
1600
1400
1200
1000
800
600
400
200
0
06/01/12
06/01/13
06/01/14
Sample Collection Date
MW-20D2
Linear (MW-20D2)

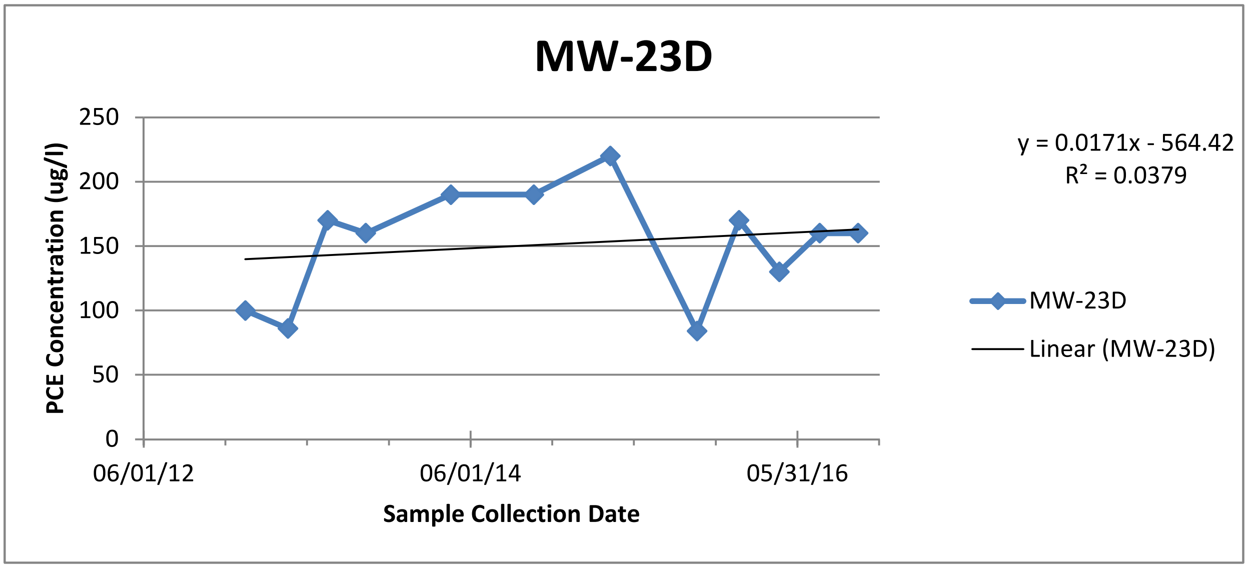

MW-21D
y = 0.4454x - 17096
R² = 0.0856
PCE Concentration (ug/l)
2000
1500
1000
500
0
06/01/12
06/01/13
06/01/14
Sample Collection Date
MW-21D
Linear (MW-21D)

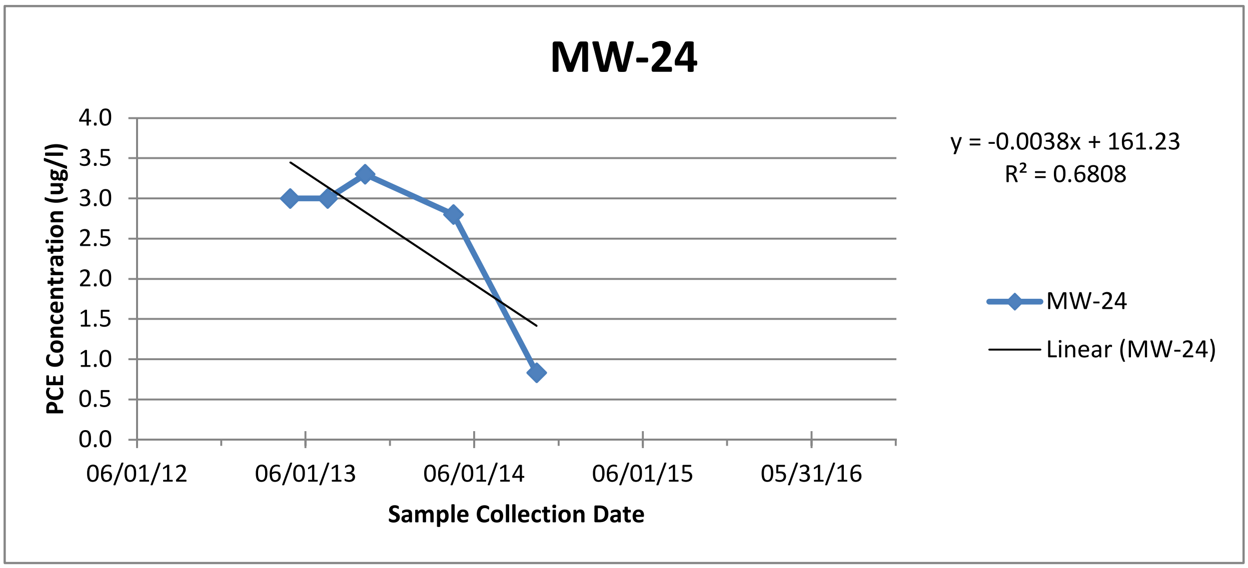

MW-21D2
y = -2.3807x + 100993
R² = 0.3047
PCE Concentration (ug/l)
4500
4000
3500
3000
2500
2000
1500
1000
500
0
06/01/12
06/01/13
06/01/14
Sample Collection Date
MW-21D2
Linear (MW-21D2)

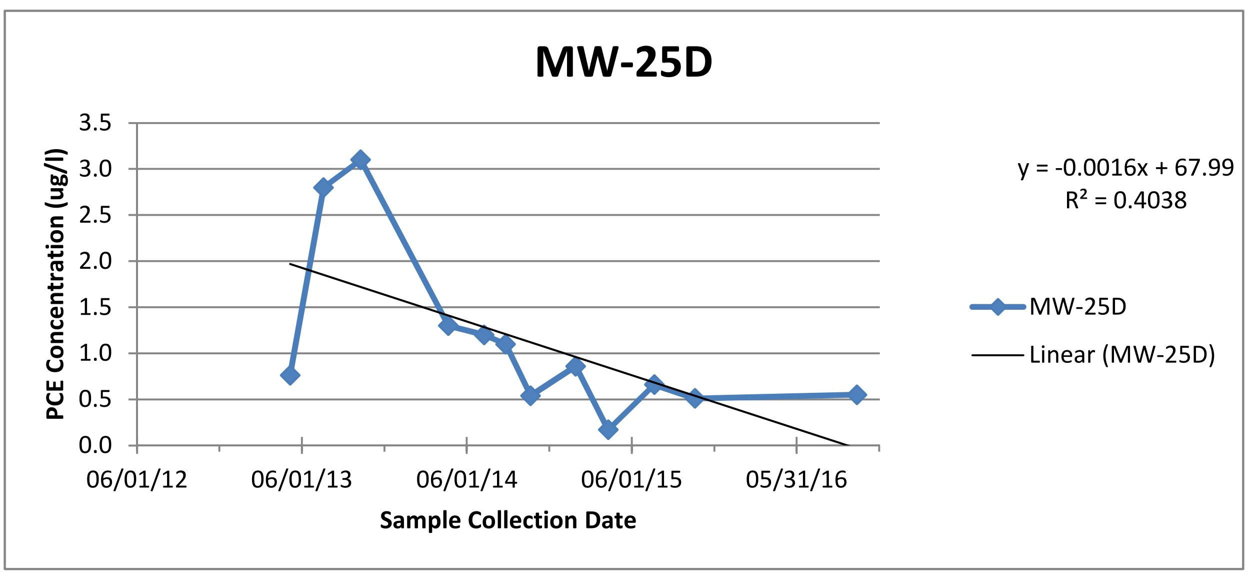

MW-22S
250.00
200.00
150.00
100.00
50.00
0.00
PCE Concentration (ug/l)
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = -0.1227x + 5210.8
R² = 0.4919
MW-22S
Linear (MW-22S)

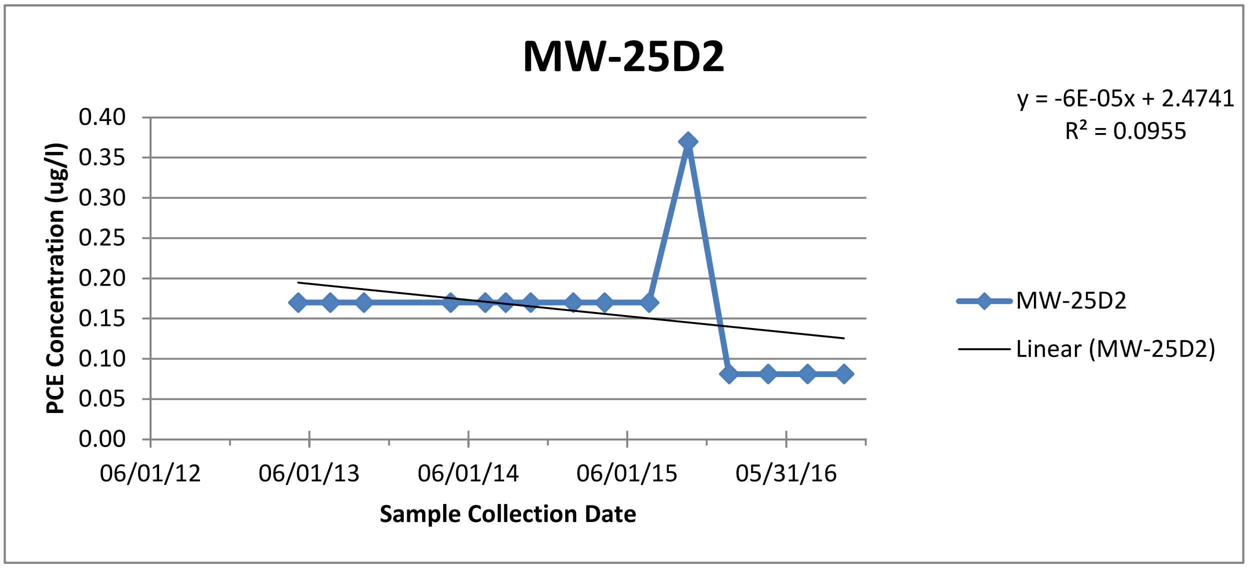

MW-22D
600
500
400
300
200
100
0
PCE Concentration (ug/l)
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = -0.2332x + 10041
R² = 0.6595
MW-22D
Linear (MW-22D)

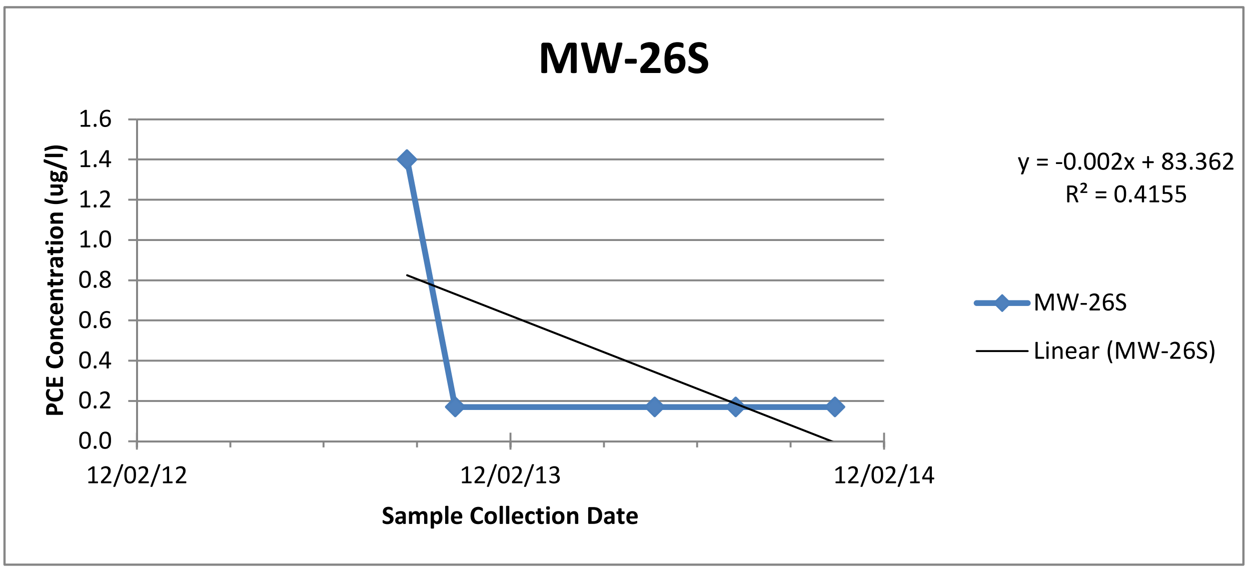

MW-23S
700
600
500
400
300
200
100
0
PCE Concentration (ug/l)
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = -0.1739x + 7535.7
R² = 0.2608
MW-23S
Linear (MW-23S)

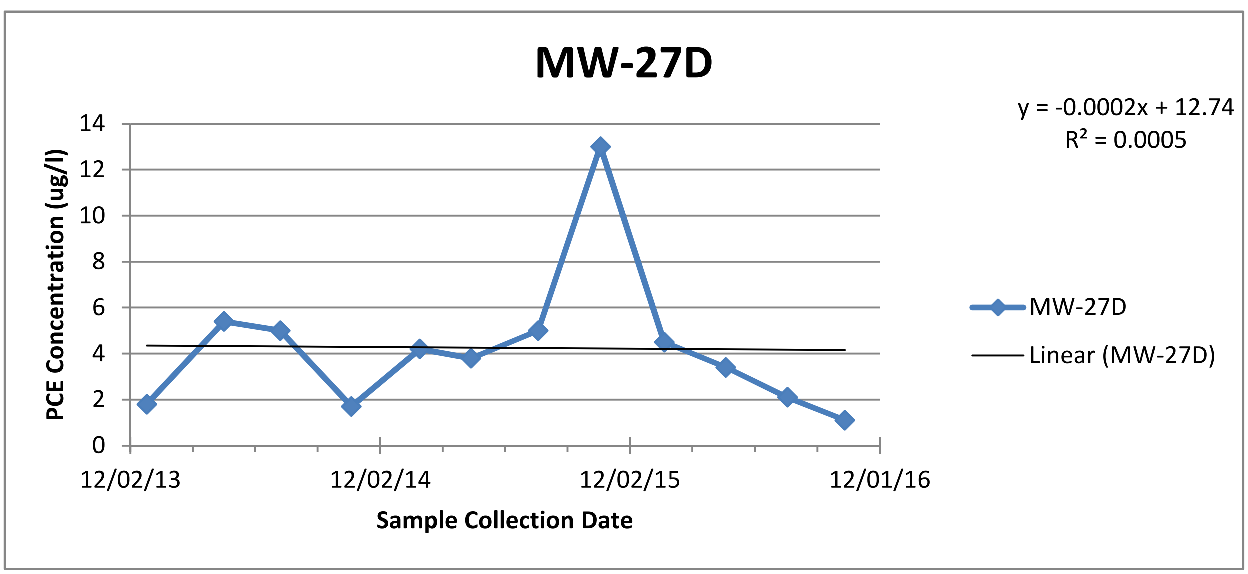

MW-23D
PCE Concentration (ug/l)
250
200
150
100
50
0
06/01/12
06/01/14
05/31/16
Sample Collection Date
y = 0.0171x - 564.42
R² = 0.0379
MW-23D
Linear (MW-23D)

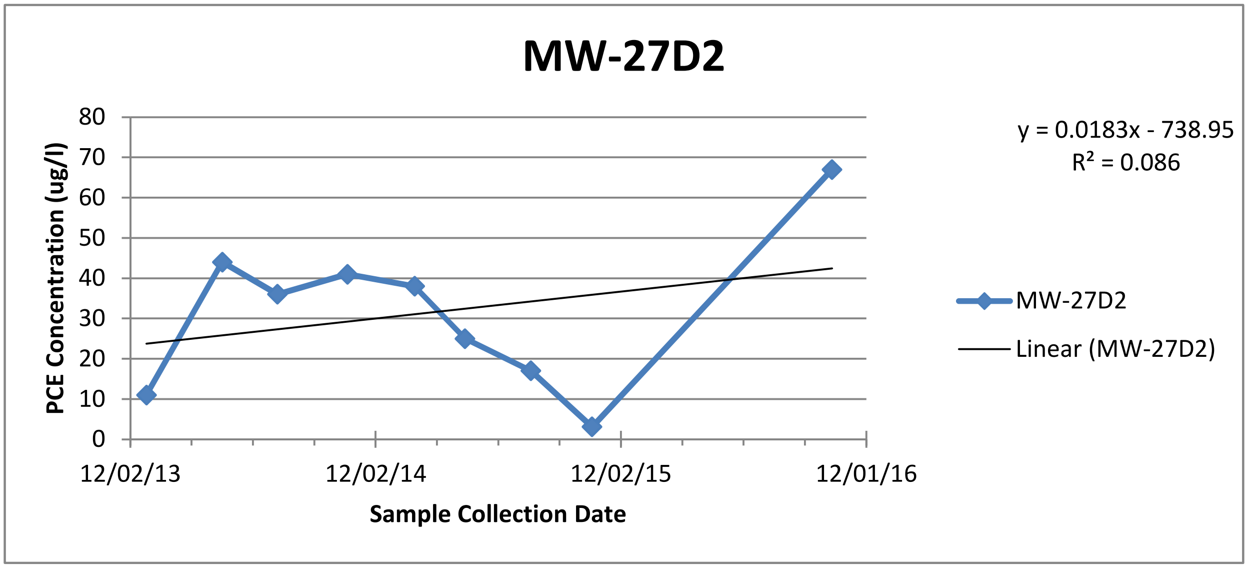

MW-24
PCE Concentration (ug/l)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
06/01/12
06/01/13
06/01/14
06/01/15
05/31/16
Sample Collection Date
y = -0.0038x + 161.23
R² = 0.6808
MW-24
Linear (MW-24)


MW-25D
PCE Concentration (ug/l)
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
06/01/12
06/01/13
06/01/14
06/01/15
05/31/16
Sample Collection Date
y = -0.0016x + 67.99
R² = 0.4038
MW-25D
Linear (MW-25D)


MW-25D2
y = -6E-05x + 2.4741
R² = 0.0955
PCE Concentration (ug/l)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
06/01/12
06/01/13
06/01/14
06/01/15
05/31/16
Sample Collection Date
MW-25D2
Linear (MW-25D2)


MW-26S
y = -0.002x + 83.362
R² = 0.4155
PCE Concentration (ug/l)
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
12/02/12
12/02/13
12/02/14
Sample Collection Date
MW-26S
Linear (MW-26S)


MW-27D
y = -0.0002x + 12.74
R² = 0.0005
PCE Concentration (ug/l)
14
12
10
8
6
4
2
0
12/02/13
12/02/14
12/02/15
12/01/16
Sample Collection Date
MW-27D
Linear (MW-27D)


MW-27D2
y = 0.0183x - 738.95
R² = 0.086
PCE Concentration (ug/l)
80
70
60
50
40
30
20
10
0
12/02/13
12/02/14
12/02/15
12/01/16
Sample Collection Date
MW-27D2
Linear (MW-27D2)

APPENDIX C

Arcadis Trend Analysis

Table 1 – PCE Concentration Trend Analysis Results

Monitoring Well	Location Relative to PCE Plume	Quantitative or Qualitative Analysis	Trend Direction	R^2 Value	p-value
MW-14	Margin	Quantitative	Decreasing	0.01	0.59
MW-2S	Within	Quantitative	Decreasing	0.58	5×10^{-8}
MW-2D	Within	Quantitative	Decreasing	0.85	3×10^{-6}
MW-5S	Within	Quantitative	Decreasing	0.54	4×10^{-6}
MW-5D	Within	Quantitative	Decreasing	0.45	1×10^{-8}
MW-5D2	Within	Quantitative	Decreasing	0.01	0.61
MW-5D3	Within	Qualitative	Decreasing	--	--
MW-22S	Within	Qualitative	Decreasing	--	--
MW-22D	Within	Qualitative	Decreasing	--	--
MW-16	Margin	Quantitative	Decreasing	0.06	0.26
MW-23S	Within	Qualitative	Decreasing	--	--
MW-23D	Within	Qualitative	Stable	--	--
MW-11S	Within	Qualitative	Decreasing	--	--
MW-4S	Margin	Quantitative	Increasing	0.08	0.14
MW-4D	Margin	Quantitative	Decreasing	0.23	0.01
MW-4D2	Margin	Quantitative	Decreasing	0.31	0.003
MW-24	Margin	Qualitative	Decreasing	--	--
MW-17	Within	Qualitative	Decreasing	--	--
MW-6S	Within	Quantitative	Decreasing	0.24	0.003
MW-6D	Within	Quantitative	Stable	0.01	0.65
MW-25D	Margin	Qualitative	Stable	--	--
MW-25D2	Margin	Qualitative	Stable	--	--

Notes:
See Appendix A for data and trend lines.
"Within" = the monitoring well is located within the PCE plume.
"Margin" = the monitoring well is located at the margin of the PCE plume.

Source:
Arcadis, 2014, Evaluation of Plume Stability and Fate and Transport Modeling for PCE in Bedrock Groundwater, Madison Kipp Corporation, Madison, Wisconsin, April16, 2014: Milwaukee, Wisconsin, 45p.