DATE: February 14, 2025

SUBJECT: *Exide Technologies - Vernon NPL Listing RTCs*

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1. Introduction and Background

The EPA Region 9 Superfund and Emergency Management Division (SEMD) Site Assessment Team requested a Technical Memorandum (TM) from the SEMD Technical Support Section summarizing an analysis of (1) aquifer interconnection between perched water and the underlying Exposition Aquifer; and (2) attribution of source contamination in the well MW-11D beneath the former Exide Technologies - Vernon Site in California.

An historical release of trichloroethylene (TCE) has been documented in the South Yard of the former Exide-Vernon facility. The source of the TCE originates from former open storage vats into which TCE was poured as part of the metals extrusion process. The TCE storage vats were used until approximately 1980.

Current sampling and analysis activities at the site are being directed and overseen by California Department of Toxic Substances Control (DTSC). An electronic deliverable of historical water quality data was provided to EPA by Dustin Waite at DTSC on December 17, 2024. Data were analyzed by EPA using various open-source software packages for scientific analyses in the Python computing language.

2. Analytical Approach

Evaluating aquifer connection and attribution at the site requires a systematic approach. First, the flow field and dominant advective pathways must be identified. Then, representative monitoring network locations must be selected. Finally, appropriate ambient and point-source tracers should be selected to enable an unbiased data-driven methodology for source identification. In this context, data-driven analysis relies exclusively on empirical data to identify significant components without external assumptions or predefined parameters. In this case, chlorinated volatile organic compounds (cVOCs) can serve as effective solute tracers for point-sources releases. Ambient solute tracers are useful in more regional aquifer system-scale analyses.

The TM employs multiple analytical methods to establish robust conclusions:

- Principal Component Analysis
- Timeseries analysis
- Non-parametric trend estimation
- Statistical testing

- Graphical methods
- Hydrogeochemical facies analysis
- Spatial analysis

By integrating these diverse analytical techniques, the investigation develops a comprehensive, technically supported assessment of aquifer interconnection and contaminant origin.

3. Analysis and Findings

3.1 Groundwater Flow and Spatial Patterns in cVOC Distribution

An important first step in evaluating the fate and transport of contaminants in an aquifer is to map isocontours of solute chemistry and hydraulic head. The spatial distribution of contaminants can reveal source areas and transport pathways, and flow field gradients provide information about the driving stresses to the system. Figures 1.1-1.21 (attached as Appendix 1) show a timeseries of interpolated TCE concentrations in the Exposition aquifer color mapped to the variable scale on the right of the figure at a monthly timestep. These figures were produced with the GWSDAT open-source software[1]. GWSDAT applies a spatiotemporal model smoother for any time-series components of groundwater solute and water level data.

Figures 1.20-1.21 also show the most recent flow fields for the Exposition aquifer (black water level contours, and blue flow vectors weighted by the local gradient) defined by the 3/11/2024 and 9/27/2021 water level elevation data provided in DTSC's *Former Exide Facility Groundwater Monitoring Program March 2024 Report.* These time periods are the two most recent periods with contemporaneous water level information provided in the Report. The entire period of record is November 2016 to March 2024.

Findings

There are three primary findings:

A. There are two distinct and separate areas within the domain with elevated TCE concentrations, one centered on UMW-34 and the other centered on MW-11D (periodically extending to MW-26D). The areas are defined by local maxima in the smoothed TCE contours of the spatiotemporal statistical model. Note that UMW-34 is associated with the Univar site, and MW-11D is associated with the Exide facility

B. The overall gradient is consistently N-NE to S-SW for the two most recent rounds of data with contemporaneous water level information. Potentiometric surface elevation contours are similar for both events with complete water level data (Figs 1.20-21), suggesting stable flowpaths.

C. Flow vectors suggest that there are three representative groups comprised of nine total wells that integrate flowpaths through the site. The wells are listed from upgradient to downgradient within each category:
    - Western wells: CB-3, MW-27D, MW-1D
    - Central wells: MW-12D, MW-11D, MW-25D
    - Eastern wells: UMW-34, MW-26D, MW-17

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[1] Jones, W.R., Spence, M.J., Bowman, A.W., Evers, L., Molinari, D.A. (2014). A software tool for the spatiotemporal analysis and reporting of groundwater monitoring data. *Environmental Modelling & Software* 55, 242-249.

> These wells are located cross-gradient from each other and therefore advective mixing should be minimal. However, given the heterogenous nature of the subsurface, differences in the elevation of the screened intervals in the wells, and dispersive processes in the aquifer system there may be solute exchange cross-gradient. The nature of this exchange is a primary question that additional lines of evidence will elucidate.

3.2 Data-Driven Analysis of Solute Concentrations in the Exposition Aquifer

Principal Component Analysis (PCA) is a data-driven multivariate statistical technique that transforms a set of possibly correlated variables into a set of linearly uncorrelated variables called principal components[2,3]. Each principal component is a linear combination of the original variables, calculated to maximize the explained variance while maintaining orthogonality to previous components.

The mathematical foundation of PCA involves standardization of the data matrix, computation of the covariance/correlation matrix, Eigendecomposition of the covariance matrix, and finally selection of principal components based on explained variance.

Generally, the transformation is defined by:

$$Z = XT$$

where X is the standardized data matrix, and T is the loading matrix composed of eigenvectors.

Different sources and/or areas within solvent plumes often exhibit characteristic ratios of parent and degradation products that persist as distinct signatures in groundwater. Dechlorination proceeds in the predictable progression of tetrachloroethylene (PCE) → TCE → dichloroethylene (DCE) → vinyl chloride (VC). In the context of cVOCs, PCA can effectively identify source signatures and degradation patterns by analyzing the relationships between parent compounds PCE and TCE and their degradation products (DCE isomers, VC). For this analysis, carbon tetrachloride and total dissolved solids were also included as potentially diagnostic analytes in the data matrix.

Score plots can reveal spatial clustering of similar samples, concentration and degradation gradients, and mixing zones between different source areas. The first principal component (PC1) typically captures the overall concentration gradient, while subsequent components may reveal source-specific patterns, degradation processes, or mixing of multiple water and/or VOC sources. High positive loadings of parent components PCE and TCE on PC1 typically indicate proximity to source zones. High loadings of daughter products DCE/VC on principal component 2 (PC2) often represent degradation zones. Generally, the angle between variable vectors in loading plots indicates their correlation, and specifically in this hydrogeologic context, linear relationships typically reflect relative positions along flow paths.

As with all statistical analyses, there are limitations to the method; all well documented in the scientific literature, but briefly summarized here: PCA assumes linear relationships between variables, results can be sensitive to outliers and missing data, one cannot directly account for temporal variations without additional analysis, and generally, interpretation requires a detailed understanding of site conceptual

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[2] Hotelling, H. (1933). Analysis of a complex of statistical variables into principal components. Journal of Educational Psychology, 24, 417-441.

[3] Pearson, K. (1901). On lines and planes of closest fit to systems of points in space. Philosophical Magazine, 2(11), 559-572.

model. This analysis strives to present all assumptions, and no conclusions are based on single lines of evidence.

3.2.1 Global PCA

In keeping with the analytical approach described in Section 2, the first stage of PCA included data from all locations with contemporaneous observations in the dataset provided by DTSC. The names of wells and analytes presented in this report are replicated exactly as they appear in the electronic data deliverable.

The following wells are included in the analysis:

- 'CB-3'
- 'MW-11D'
- 'MW-12D'
- 'MW-16D'
- 'MW-17'
- 'MW-1D'
- 'MW-20D'
- 'MW-22D'
- 'MW-23D'
- 'MW-24D'
- 'MW-25D'
- 'MW-26D'
- 'MW-27D'
- 'MW-6D'
- 'MW-9D'
- 'UMW-34'

Analytical data for the following analytes was used in the analysis:

- '1,1-DICHLOROETHENE'
- 'CARBON TETRACHLORIDE'
- 'CIS-1,2-DICHLOROETHENE'
- 'TETRACHLOROETHENE'
- 'TOTAL DISSOLVED SOLIDS'
- 'TRANS-1,2-DICHLOROETHENE'
- 'TRICHLOROETHENE'
- 'VINYL CHLORIDE'

Two components explain 75% of the variance within the dataset. Generally, this indicates that two principal components are sufficient to describe most of the variation within the dataset, and bivariate (two-dimensional scatterplot) presentation of results is appropriate. The results are plotted on Figure 2.

The highest loading on PC1 was observed at UMW-34, and the lowest was at MW-1D, suggesting that the overall concentration gradient reflects that of the groundwater flow direction. This observation reinforces the assumption that advective transport along the primary axis of the potentiometric gradient is the dominant mechanism explaining the distribution of cVOCs. PC2 loading shows clustering on the score plots related to the well's position along the axis orthogonal to the primary potentiometric gradient axis, e.g., MW-9D and MW-16D located along the western boundary; CB-3 and MW-27D in the central part of the domain. Deviations from this pattern, particularly as reflected in PC2 loadings, likely reflect localized processes such as microbial activity. Taken together, these findings suggest that reducing the dimensionality of the analysis by targeting wells in representative flowpaths would further elucidate connection and source zones.

3.2.2 Targeted PCA

Refining the approach described in 3.2.1, PCA was performed on the nine well subset identified in Section 3.1, representing the western, central, and eastern portions of the flow field. The analyte list is unchanged. Two components explain 81% of the variance within the dataset, a 6% increase over the global dataset, reinforcing the representative nature of this subset.

Figure 3 shows three distinct linear trends that correlate with their spatial position within the flow field, with the exception of MW-26D, which falls well above the increasing linear trend defined by the other eastern flowpath wells. The western flowpath is characterized by low overall PC1 loading (-2.1 to -1.2) and intermediate PC2 loading (-0.9 to 0.36). The central flow path is characterized by slightly higher PC1 loading (-0.95 to 0.35) and PC2 loading (-0.4 to 1.19). The eastern flowpath is more variable, PC1 loading ranges from -1.1 to a maximum of 5.9; PC1 ranges from -2.31 to 1.96. Loading factors are reported in Table 1.

Table 1: *Targeted PCA Loading Factors*

Well Name	Aquifer	Site*	Principal Component 1	Principal Component 2
CB-3	Exposition	Exide Facility	-1.213475	0.25967
MW-11D		Exide Facility	-0.949357	-0.398231
MW-12D		Exide Facility	-0.235294	0.755412
MW-17		Offsite	-1.104742	-2.313509
MW-1D		Exide Facility	-2.137264	-0.903966
MW-25D		Offsite	0.354167	1.188961
MW-26D		Exide Facility	0.522224	1.963424
MW-27D		Exide Facility	-1.167891	0.358708
UMW-34		Offsite	5.931631	-0.910469

NOTE:** ***Here, and throughout this TM, "Exide facility", "Site" and "Offsite" refer to whether the wells are located within the Exide facility footprint or outside of it as indicated in Figure 7 of the SI Report.

Generally, the western and central flowpaths are more like each other, with the central flow path having generally higher loading on both PCs. The eastern flow path contains the maximum and minimum values for both principal components. The Univar site well UMW-34 is a clear visual outlier with high positive loading on PC1. MW-26D falls close to the trend defined by western and central flowpath wells on the score plot but has the highest PC2 loading in the dataset.

Findings

Both phases of PCA yield the following primary findings:

A. PCA results support the location of hotspots, interpreted flow field, and well groups identified in Section 3.1
B. The eastern flowpath of the site likely has multiple unique solute inputs.
    i. UMW-34 is a clear outlier, falling well outside the linear trends defined by most of the wells at the site. Additionally, the high loading on PC1 and low loading on PC2 indicates

that it is close to a source zone as it defines the upper end of the concentration gradient in both the global and targeted datasets.

ii. MW-26D is likely influenced by localized processes not reflected by a simple mixing line defined by the other eastern flowpath wells. Notably this well lies along the site boundary with the Honeywell/Baker site Boundary and high positive loading on PC2, possibly indicating locally elevated cVOC degradation products. Exploring these potential inputs is beyond the scope of this analysis.

3.3 Timeseries Analysis of Solute Concentrations in the Exposition Aquifer

Recall that the limitations of PCA include the assumption of linearity, sensitivity to outliers and missing data, and lack of temporal variability characterization. Non-parametric trend analysis of the Exposition Aquifer TCE data was conducted to address these issues and provide additional lines of evidence. Non-parametric trend analysis techniques are particularly valuable for timeseries water quality data analysis due to their robustness to non-normal distributions and missing values.

EPA used three primary statistical metrics, summarized in Table 2, to evaluate TCE trends: p-value for statistical significance, Kendall's Tau, and the Theil-Sen slope estimate. To correct for serial autocorrelation in the dataset, EPA used the Yue and Wang[4] modified Mann-Kendall test. "Serial autocorrelation" in this context refers to the tendency for a water quality parameter measured at a given time to be statistically related to its value at the previous time point. If this is true, the data points are not independent—essentially, the current water quality is influenced by the recent past conditions, creating a correlation between successive measurements.

Table 2: *Non-parametric Trend Analysis Metrics for TCE in the Exposition Aquifer for Target Wells*

Well	Flowpath	Trend	Statistical Significance?	p-value	Kendall's Tau	Theil-Sen slope
CB-3	Western	'decreasing'	TRUE	9.61E-05	-0.19	-0.01
MW-27D		'no trend'	FALSE	6.28E-01	-0.04	0.00
MW-1D		'no trend'	FALSE	9.34E-02	0.11	0.00
MW-12D	Central	'no trend'	FALSE	4.91E-01	-0.08	-0.03
MW-11D		'decreasing'	TRUE	2.49E-08	-0.64	-3.90
MW-25D		'no trend'	FALSE	1.56E-01	-0.11	-0.12
UMW-34	Eastern	'increasing'	TRUE	3.84E-04	0.46	19.79
MW-26D		'no trend'	FALSE	2.63E-01	0.10	0.17
MW-17		'decreasing'	TRUE	2.28E-09	-0.40	-1.00

Note: *green highlighting indicates a significant decreasing trend, yellow highlighting indicates a significant increasing trend*

Based upon this analysis, four of the wells had statistically significant trends in TCE concentrations:

- upgradient western flowpath well CB-3 has a decreasing trend with a low slope
- central flowpath well MW-11D has a decreasing trend

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[4] Yue, S., & Wang, C. (2004). *The Mann-Kendall test modified by effective sample size to detect trend in serially correlated hydrological series.* Water resources management, 18(3), 201-218. doi:10.1023/B:WARM.0000043140.61082.60

- upgradient eastern flowpath well UMW-34 has a sharply increasing trend
- downgradient eastern flowpath well MW-17 has a moderately decreasing trend

For completeness, timeseries scatterplots of all cVOC concentrations for each flowpath are presented in Figure 4. The trends described statistically above are visible in the timeseries. Narratively, TCE concentrations at MW-11D are overall decreasing, with the highest observation at the beginning of the period of record and then monotonically decreasing, reaching a global minimum in 2024. TCE concentrations at upgradient location UMW-34 are overall increasing. If UMW-34 concentrations were representative of a dissolved phase source of TCE to downgradient areas around MW-11D, one would expect higher initial TCE concentrations near UMW-34 and then generally in-phase, temporally lagged concentration responses near MW-11D. Instead, UMW-34 concentrations are initially lower than MW-11D and are increasing with time, indicating connection to a source upgradient from UMW-34. Concentrations at central flowpath well MW-12D, which is upgradient from MW-11D, support the interpretation of distinct source areas. TCE concentrations observed at MW-12D are not in phase with the overall increasing trend at UMW-34 or decreasing trend at MW-11D, suggesting that this is an appropriate background location.

Findings

Timeseries and statistical analyses yield the following primary finding:

A. The observed timing, magnitude, and trend of TCE concentrations in MW-12D and MW-11D at the Exide site, and UMW-34 at the Univar site are not consistent with the same TCE source.
B. MW-12D appears to be an appropriate background location.

3.4 Relative Fractions of cVOC Concentrations in the Exposition Aquifer

Groundwater conditions such as redox conditions, microbial populations, electron donor availability, temperature, and pH all affect the rate and extent of reductive dichlorination in an aquifer system. These parameters can be locally variable but as discussed in Section 3.2, the predictable progression of PCE → TCE → DCE → VC and relative fractions of these compounds can provide valuable information. Given the relatively small geographic area and transmissive lithology, many of the relevant ambient groundwater parameters can be assumed to be similar, or at least affected by the same set of environmental stressors to the system, and therefore the relative concentrations of degradation products can provide an estimate of the time since the release of parent compounds. Specifically, the relative concentrations of DCE isomers can be an indicator of how much degradation has occurred, and in simple terms, using daughter product generation as a proxy for time, the “age” of the plume. There are clearly limitations to this assumption, especially related to the composition of the initial release, but such a simplification is useful as one of many lines of evidence.

A. Figure 5 shows aggregated cVOC concentrations for each of the wells in the three flowpaths described in Section 3.1. Well names on the x-axis outlined in blue boxes are western flowpath wells, orange are central flowpath wells, and green are eastern flowpath wells. The boxplots for each well are plotted in the order of reductive dichlorination from left to right. Eastern flowpath wells have higher concentrations of PCE and TCE, and notably higher relative fractions of DCE isomers then central flowpath wells. UMW-34 had the highest concentrations of both PCE and TCE and widely divergent concentrations of the DCE isomers. MW-11D had high concentrations of TCE, but order of magnitude lower concentrations of PCE as well as more consistent concentrations of DCE isomers relative to UMW-34. Western flowpath wells have order of magnitude lower cVOC concentrations than the eastern and central flowpath wells and low to nonexistent fractions of degradation products.

Findings

Qualitative analyses of the relative fractions of cVOCs yield the following primary findings:

A. UMW-34 and MW-11D appear to reflect distinct sources.
B. Western flowpath water chemistry does not strongly reflect either source.

3.5 Inorganic Hydrogeochemistry and Aquifer Connection

All the analyses presented so far have focused on hydraulic head and cVOC solute geochemistry in the Exposition Aquifer. Section 3.5 expands the scope of the analysis to the perched system and uses a different suite of dissolved geochemical parameters to elucidate connections between the aquifer systems. Generally, it is more advantageous to use inorganic geochemistry vs. cVOCs to explore fundamental questions about the nature of aquifers. Inorganic parameters such as calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), bicarbonate (HCO_3), carbonate (CO_3), chloride (Cl), sulfate (SO_4), and total dissolved solids (TDS) are more representative of natural background conditions due to long-term equilibrium with aquifer materials, their propensity to show more stable and predictable patterns, and they are less affected by point-source contamination. Using multiple ions provides independent lines of evidence and different ions reflect different processes. Typically, the inorganic parameters are less affected by degradation and sorption and have more predictable mixing patterns making them more appropriate for elucidating regional patterns.

3.5.1 Hydrogeochemical Facies Analysis

Piper plots are trilinear diagrams that have been widely used to graphically identify hydrogeochemical facies[5]. The basic Piper plot is composed of three parts: two triangular plots at the base, one on the left for major cations (Ca^{2+}, Mg^{2+}, $Na^{+}+K^{+}$) and one on the right for major anions (Cl^{-}, SO_4^{2-}, HCO_3^{-}). There is a diamond shaped central plot that combines information from both lower plots and shows overall water chemistry. To prepare a Piper plot, ion concentrations are first converted to percentages, then each sample is plotted on all three fields, points in the triangles project upwards into the central diamond that shows ionic character. Trends and grouping illustrate patterns in the groundwater system.

Figure 6, panel A shows a Piper plot of all wells with a complete set of analytes necessary to perform the analysis on the DTSC dataset for both the Exposition and Perched Aquifer systems. The list of wells is:

> *Exposition:* CB-3, MW-11D, MW-12D, MW-16D, MW-1D, MW-23D, MW-27D, MW-6D, MW-9D, MW-17, MW-20D, MW-22D, MW-24D, MW-25D
>
> *Perched:* CB-2, MW-10R, MW-12, MW-5, SI-1, SI-2, SI-3, SI-4, SI-5

Notably, this is not the full set of wells, and unfortunately there are important omissions from the dataset that may have been illustrative. Red symbols denote Perched wells, and green symbols denote Exposition wells.

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[5] Piper, A.M., 1944, A graphic procedure in the geochemical interpretation of water analyses: American Geophysical Union Transactions, v. 25, p. 914–923

Very generally, there is a wide range of hydrogeochemical facies represented in the dataset. Exposition wells are classified as predominantly calcium-chloride, magnesium-bicarbonate and mixed hydrogeochemical facies waters. In contrast, Perched wells are predominantly sodium-chloride and mixed type waters. With respect to major cations, calcium dominates the Exposition group and sodium and potassium dominate the Perched group. For major anions, all Perched wells are sulfate type waters, and Exposition waters range from bicarbonate to chloride type waters, but notably all less than 50% sulfate.

There are some areas of notable overlap between the two aquifers, and these likely represent zones of mixing. Locations lying within the mixed facies zone include Exposition wells CB-3, MW-11D, MW-9D, MW-22D, MW-24D and Perched wells CB-2, MW-10R, and SI-4. These locations are marked with black stars in Figure 6 panels A and B. In the context of this study, the most interesting spatial patterns lie along the flowpath extending roughly from Perched/Exposition pairs CB-2/CB-3 to MW-11D/SI-4. This potential line of mixing is comprised of five wells listed from up- to downgradient, three Perched (CB-2, MW-10R, and SI-4) and three Exposition (CB-3, MW-11D, MW-27D). The geochemical facies mixing line is contained within the dashed black lines on Figure 6, panel A. Connecting the wells within the mixed facies spatially on Panel B reveals a trend roughly along the CB-3 flow vector in Figures 1.20 and 1.21. In both the up- and downgradient portions of this flowpath, there are Perched and Exposition wells with water chemistry falling within a mixing line. The spatial and geochemical relationship is striking and illustrative. Notably, this potential mixing zone passes through the South Yard source area at the former Exide facility.

Findings

A. Spatial, hydrogeochemical facies, and flow vector relationships indicate a mixing zone between the Perched and Exposition Aquifers along a zone from CB-3, through the source area, to MW-11D.

3.5.2 Distribution of Total Dissolved Solids in Aquifers

In the Los Angeles Basin, TDS values serve as a valuable indicator for distinguishing between aquifer systems for all of the reasons described in Section 3.5. Figure 7 shows boxplots of all TDS values for wells in DTSC's electronic data deliverable. TDS concentrations range well over two orders of magnitude. Generally, the Perched system is characterized by higher TDS concentrations than the Exposition Aquifer. Average Exposition TDS values range from 4,253-798 mg/L. Perched Aquifer TDS ranges from 40,926-2,335 mg/L.

The highest median value is observed at Perched well MW-22, and the lowest is observed at Exposition well MW-15, though this is likely an outlier, and the next lowest median TDS concentration is Exposition well UMW-34. The highest average TDS concentration in the Exposition Aquifer is 4,253 mg/L observed at MW-9D; and the highest average Perched TDS concentration was 40,926 mg/L at MW-22. The lowest average concentration in the Exposition Aquifer is 798 mg/L observed at UMW-34; and the lowest average Perched TDS concentration (excluding MW-15) was 2,335 mg/L at MW-6R.

The bracketing median TDS concentrations for wells within the suspected mixing zone are shown as dashed lines on Figure 7. Average values for these wells are presented in Table 3:

Table 3: Mixing Zone Well TDS Concentrations

Well	Aquifer	TDS (mg/L)
SI-4	Perched	6,138
MW-9D	Exposition	4,253
MW-10R	Perched	4,048
MW-24D	Exposition	4,006
CB-2	Perched	3,766
MW-11D	Exposition	3,186
MW-22D	Exposition	2,901
CB-3	Exposition	2,589
	Geometric Mean:	3,739
	Standard Deviation:	1,096

All these wells fall in the middle of the distribution (10^3 – 10^4 mg/L) and between visual breaks at the tails of the distribution where the upper tail is comprised of only Perched wells, and the lower tail is comprised of only Exposition wells. This supports the interpretation that the wells identified in Section 3.5.1 probably contain a mixture of Perched and Exposition water. Notably, MW-12 and MW-6R are Perched aquifer wells with anomalously low TDS concentrations. These wells fall along the northern margin of the suspected mixing zone, adding an additional line of evidence to support the validity of that zone and potentially expanding the spatial extent of that zone.

Findings

A. TDS concentrations support the mixing zone identified in the inorganic chemistry analysis and could potentially expand the spatial extent, though the additional wells do not plot within the mixed zone of the Piper plot.

3.5.3 Perched Groundwater Conditions and Interconnections to the Exposition Aquifers

Analysis of regional hydrology and perched groundwater conditions was conducted to assess the hydrogeologic connection to deeper aquifers beneath the contaminant source area. Water level data collected over the last 37 years (1987 to 2024) from perched groundwater monitoring wells were graphed to illustrate groundwater elevations trends over time. The groundwater elevations are compared to seasonal precipitation data compiled from the Downtown Los Angeles weather observation site at the University of Southern California campus. The average seasonal precipitation of 14.83 inches was calculated using precipitation data from 1878 to 2024. Additionally, periods of the 10 wettest and 10 driest total seasonal precipitation years were identified and presented in the graph to identify historical precipitation extremes that occurred over the course of groundwater monitoring at the site (Figure 8).

Groundwater elevation data from perched monitoring wells PW-2, MW-11, MW-12, and MW-14 were selected for analysis due to their proximity to the TCE release area at the site. The wells were installed to the depth of the perched water aquitard at a depth of approximately 89 feet below ground surface (bgs) (elevation of 85 feet). The depth to water measured in the wells historically ranged from 71 feet bgs (elevation of 104 feet) to 89 feet bgs (elevation of 85 feet). The perched groundwater elevations rose and fell in correlation with total season rainfall. Notable declines in the perched water occurred between 1991 and 1993 (when well MW-11 was first observed dry) and a longer decline from 2013 through the 2023 where well MW-11 was dry again in 2013 and PW-2 became dry in 2021. The period of 2013 to

2021 was some of the driest years of seasonal rainfall in the analysis period. Perched groundwater rose in wells MW-12 and MW-14 in 2023 and 2024, corresponding to two years of significantly greater than normal rainfall; wells MW-11 and PW-2 remain dry during the same time. A replacement well for MW-11 had anomalous water levels shortly after it was installed in 2014 and was caused by the addition of water during well development activities.

The Perched Aquifer occurs as irregular, unconfined saturated zones associated with low permeability materials present within the Holocene alluvium throughout much of the subbasin and are often discontinuous over relatively short distances. Evapotranspiration (ET) extinction depth is typically no greater than 10 feet in most aquifer systems. Therefore, declines in Perched Aquifer water levels must be due to lateral and vertical migration of groundwater as the lenses of perched water are not being pumped for water supply at the site and the water is not being statically retained in storage. The flow paths in these systems are often highly tortuous, exploiting vertically discontinuous, stratigraphically controlled higher permeability zones within the heterogenous subsurface.

Findings

A. Perched groundwater elevations fluctuate in response to seasonal precipitation events, most notably during periods of drought.

B. Periodic drought induced declines of perched water elevations levels demonstrate that the water is not statically remaining in storage. Given that the Perched zone is below the ET extinction depth, TCE contaminated groundwater must be migrating vertically through the heterogenous aquitard material or flowing laterally a short distance on perched lenses to more permeable material in the partially saturated zone above the Exposition Aquifer.

4. Conclusions

This TM analyzes groundwater contamination at the former Exide site in California. Using various data-driven methods including Principal Component Analysis (PCA) and non-parametric trend analysis, the report investigates aquifer interconnection and the source of trichloroethylene (TCE) contamination. The analysis reveals two distinct TCE concentration areas and suggests that contamination at Exposition aquifer well MW-11D originates from the Exide site's South Yard, not from an offsite source (UMW-34). Hydrogeochemical facies analysis further supports a mixing zone between the perched and Exposition aquifers, proving a plausible transport pathway from the source zone to downgradient monitoring locations.

Each of these conclusions is based upon multiple lines of evidence, summarized in more detail below:

- Two distinct areas of elevated TCE concentrations are observed: one centered on UMW-34 and the other on MW-11D.
- Groundwater flow direction is consistently from north-northeast to south-southwest, suggesting stable flow paths.
- Three representative well groups integrate flowpaths through the site: Western (CB-3, MW-27D, MW-1D), Central (MW-12D, MW-11D, MW-25D), and Eastern (UMW-34, MW-26D, MW-17).
- Global PCA results suggest that advective transport along the primary axis of the potentiometric gradient is the dominant mechanism for cVOC distribution.

- Targeted PCA shows three distinct linear trends correlating with spatial positions within the flow field, indicating unique source(s) in the eastern flowpath relative to the MW-11D source.
- Non-parametric trend analysis of TCE concentrations revealed significant trends in four wells, including a decreasing trend in MW-11D and a sharply increasing trend in UMW-34.
- The inconsistent timing, magnitude, and trends of TCE concentrations in MW-12D, MW-11D, and UMW-34 suggest distinct TCE sources.
- Relative fractions of cVOCs show that eastern flowpath wells have higher concentrations and notably higher relative fractions of DCE isomers compared to central flowpath wells.
- Inorganic hydrogeochemical facies analysis using Piper plots reveals a mixing zone between the Perched and Exposition Aquifers along a zone from CB-3, through the source area, to MW-11D.
- Total Dissolved Solids (TDS) concentrations support the identified mixing zone and potentially expand its spatial extent.
- Periodic drought induced declines in perched groundwater elevations support the identified mixing zone and downward migration of TCE impacted groundwater to the Exposition Aquifer.

These multiple lines of evidence, derived from distinct data-driven analyses, strongly suggest that the contamination in Exposition aquifer well MW-11D originates from a release in the South Yard of the Exide site and not from an offsite source.

5. Data Sources

Tech Memo Data Source 1: Advanced GeoServices, 2012, Revised Current Conditions Report, Exide Technologies, Advanced GeoServices Corp. October 2012

Tech Memo Data Source 2: DTSC 2024 Electronic data deliverable of historical water quality data, provided to EPA by Dustin Waite at DTSC on December 17, 2024

Tech Memo Data Source 3: WSP USA Environment & Infrastructure, 2024 Former Exide Facility Groundwater Monitoring Program, March 2024 Report

Tech Memo Data Source 4: DUDEK 2017 Second Quarter 2017 Groundwater Monitoring Report, Exide Technologies. September 2017

Tech Memo Data Source 5: DUDEK 2018 Fourth Quarter 2017 and Annual Groundwater Monitoring Report, Exide Technologies. July 2018

Tech Memo Data Source 6: DUDEK 2018 Second Quarter 2018 Groundwater Monitoring Report, Exide Technologies. August 2018

Tech Memo Data Source 7: DUDEK 2019 Fourth Quarter 2018 and Annual Groundwater Monitoring Report, Exide Technologies. Revised August 2019

Tech Memo Data Source 8: E2 Environmental, Inc. 2014 Well Replacement and Development Report, Exide Technologies. E2 Environmental, Inc. December 2014

Tech Memo Data Source 9: E2 Environmental, Inc. 2016 Ground Water Monitoring Report Fourth Quarter and Annual 2015, Exide Technologies. February 2016

Tech Memo Data Source 10: E2 Environmental, Inc. 2017 Ground Water Monitoring Report First Quarter 2017, Exide Technologies. May 2017

Tech Memo Data Source 11: EPA 2025 Region 9 Tech Support source code for analyses

Tech Memo Data Source 12: Geosyntec Consultants, 2020 Fourth Quarter and Annual 2019 Groundwater Monitoring Report, Exide Technologies. Geosyntec Consultants. May 2020

Tech Memo Data Source 13: Los Angeles Almanac 2025 Historical Monthly Rainfall by Season, Los Angeles Almanac, https://www.laalmanac.com/weather/we08aa.php accessed February 2025.

Tech Memo Data Source 14: Weston 2023 Site Inspection Groundwater Sampling and Analysis Plan, Exide Technolgies. Weston Solutions, Inc. October 2023

Tech Memo Data Source 15: Weston 2024 Site Inspection Report, Exide Technologies. June 2024

Figure 1.1: *Interpolated TCE Concentrations in the Exposition Aquifer*

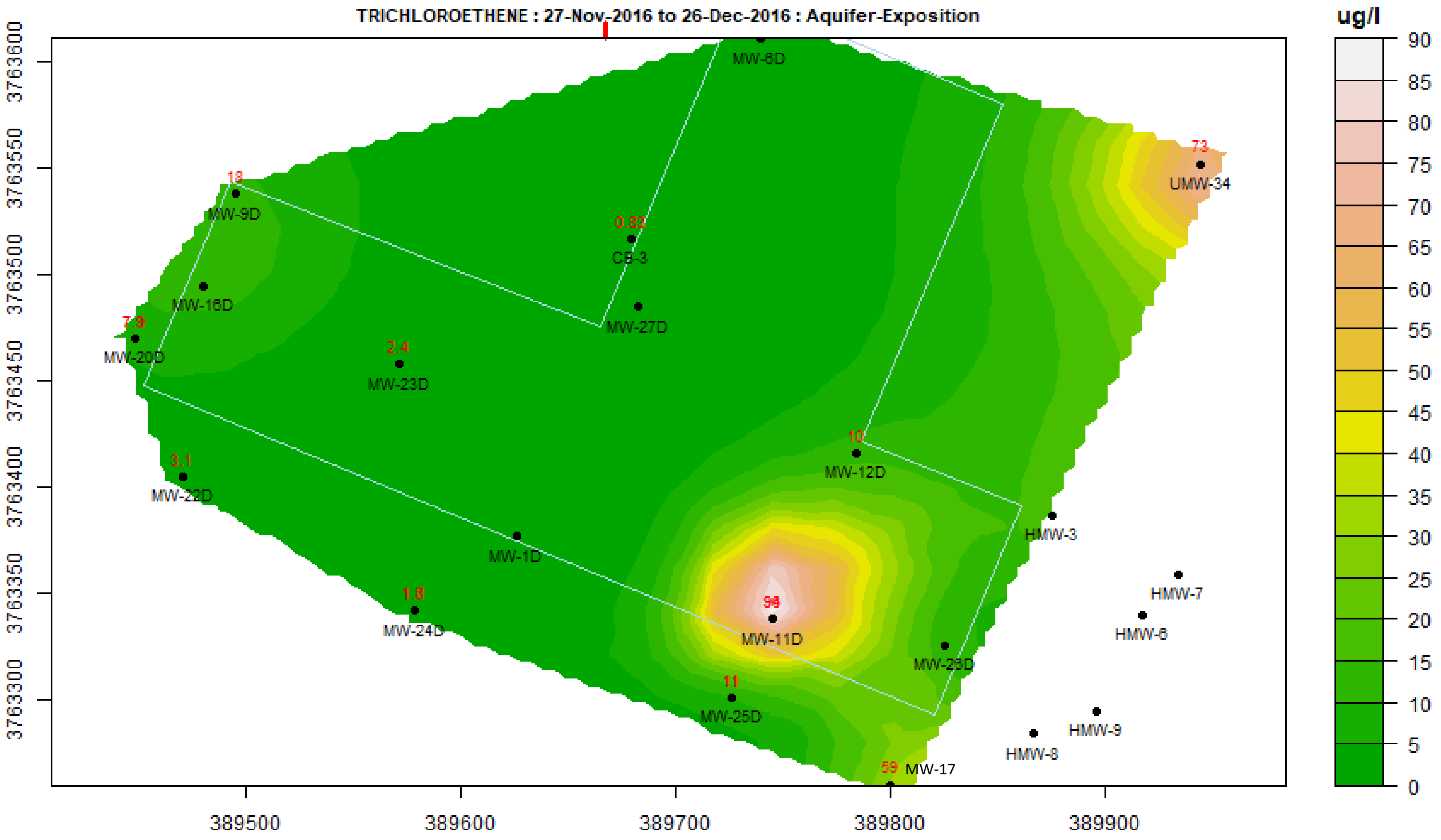


Figure 1.2: *Interpolated TCE Concentrations in the Exposition Aquifer*

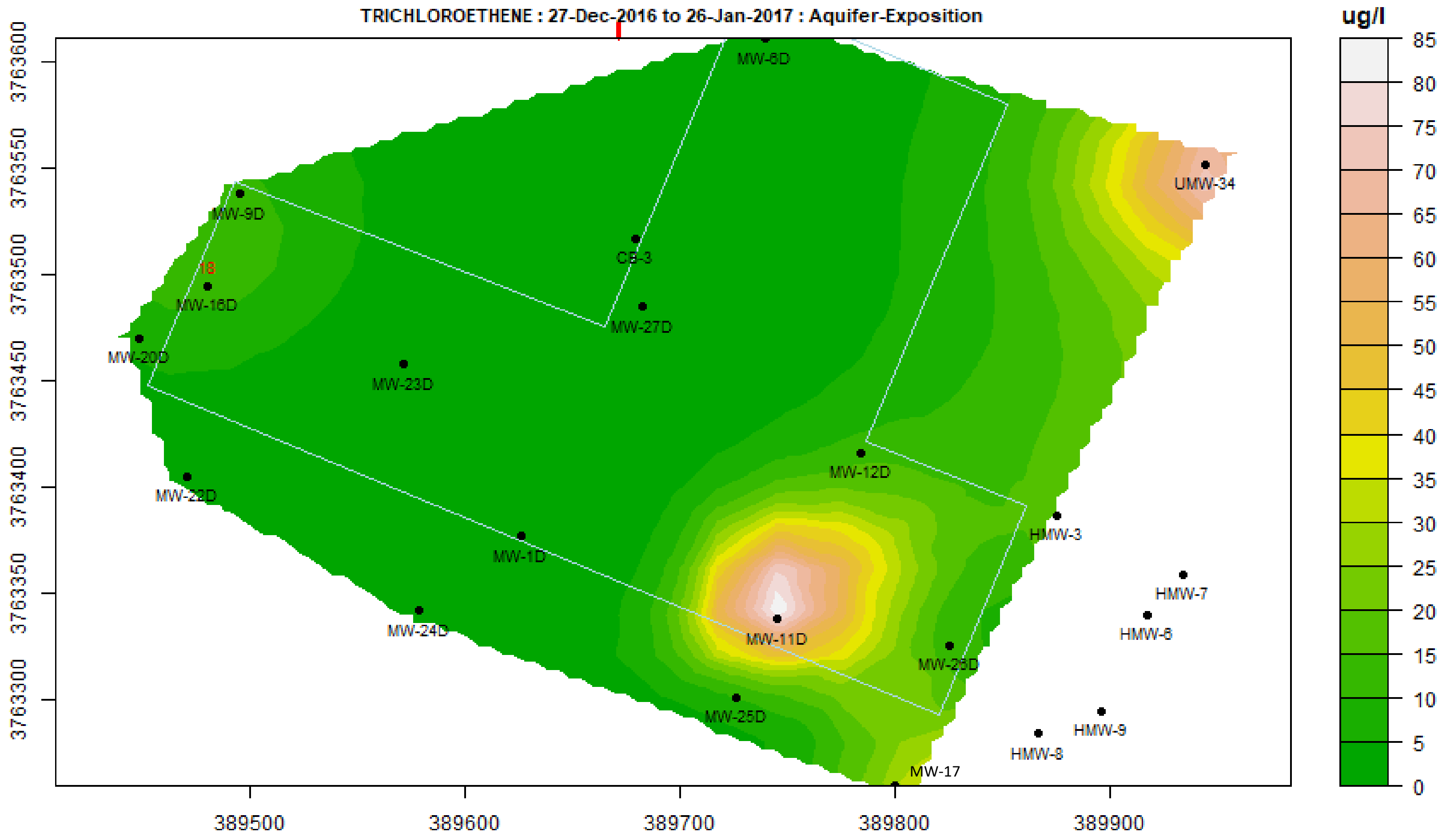
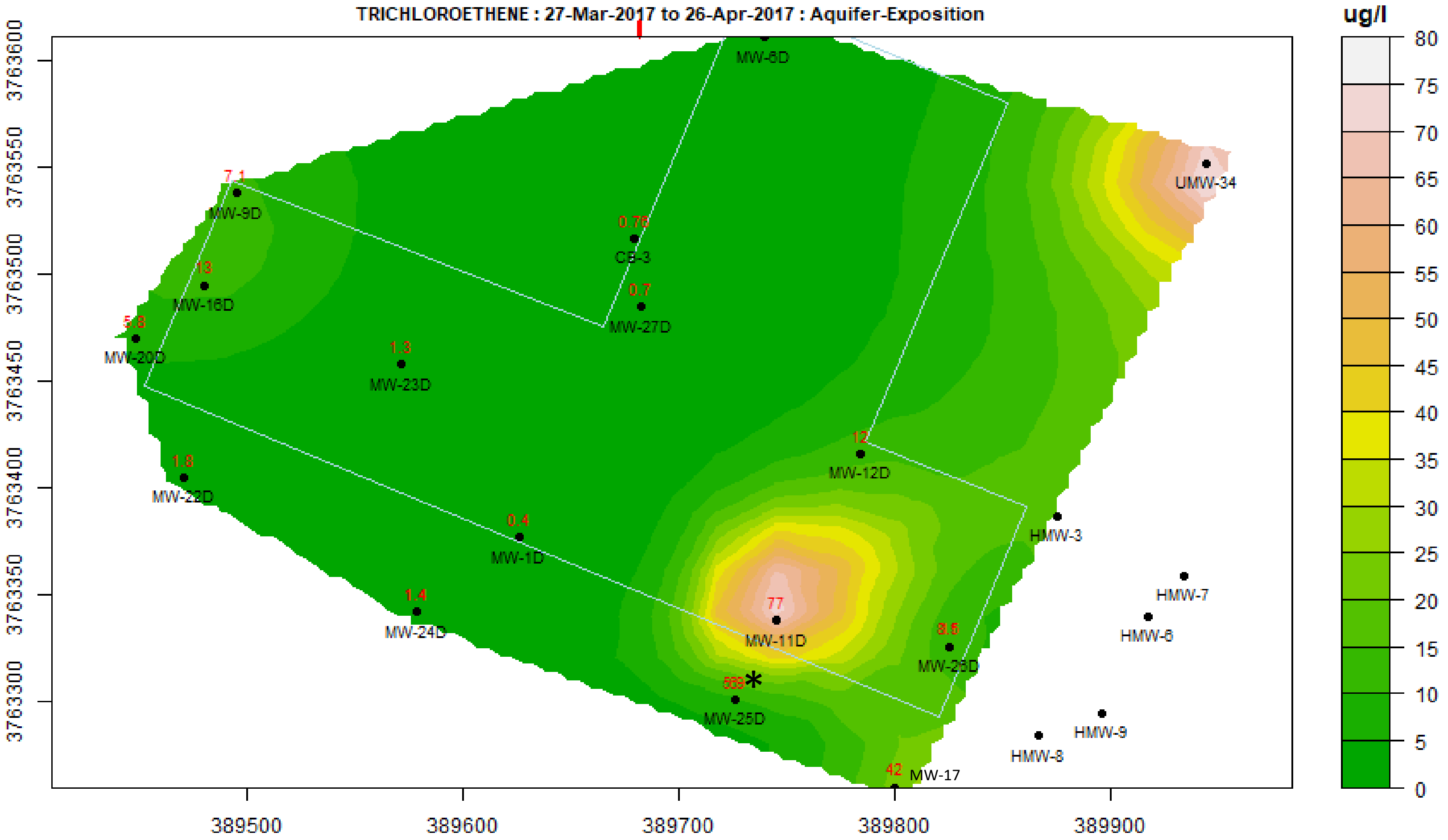


Figure 1.3: *Interpolated TCE Concentrations in the Exposition Aquifer*



*Note: Duplicate results are plotted concurrently for MW-25D: 5.9 and 6 ug/L, appearing as '569'

Figure 1.4: *Interpolated TCE Concentrations in the Exposition Aquifer*

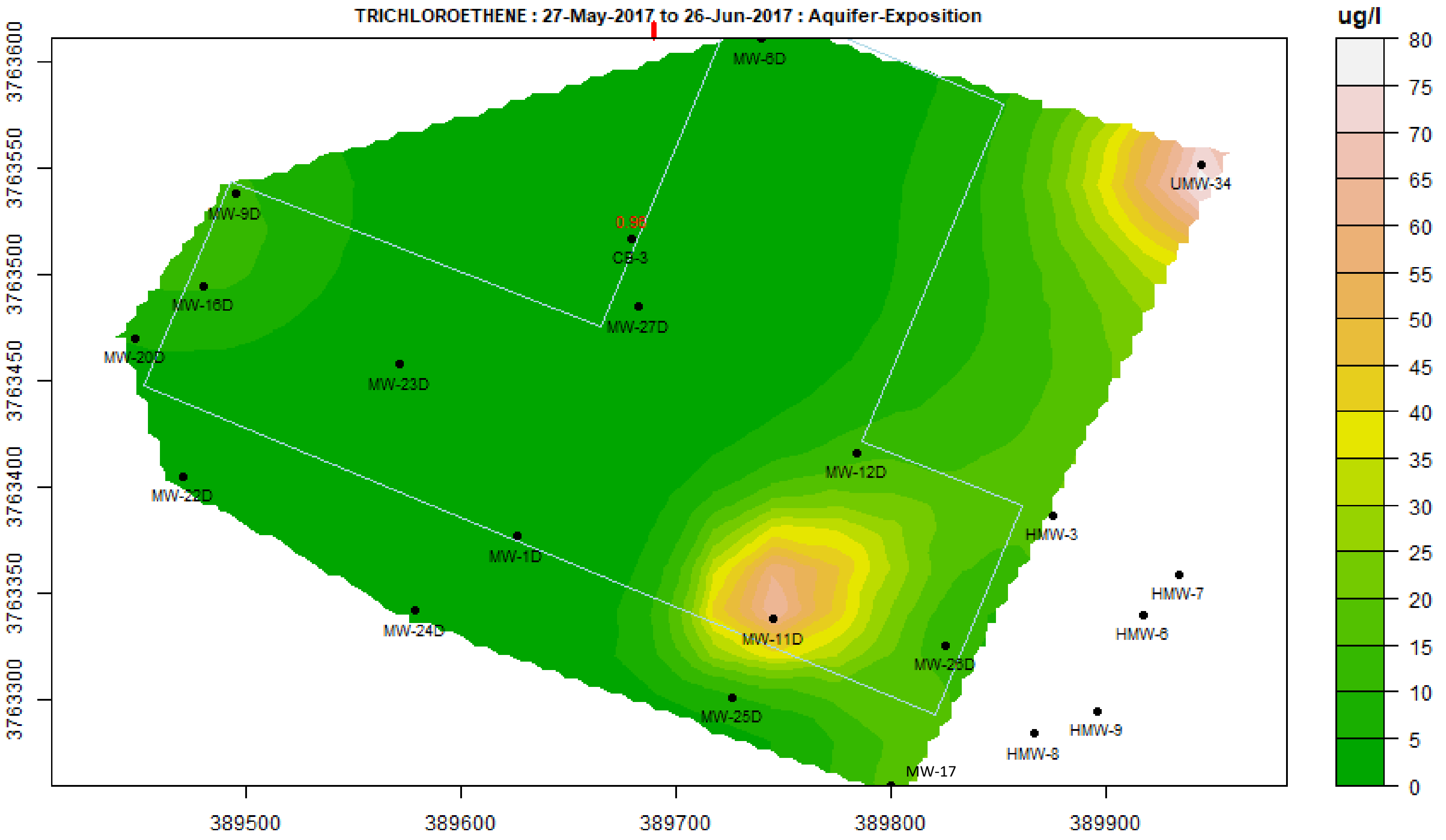


Figure 1.5: *Interpolated TCE Concentrations in the Exposition Aquifer*

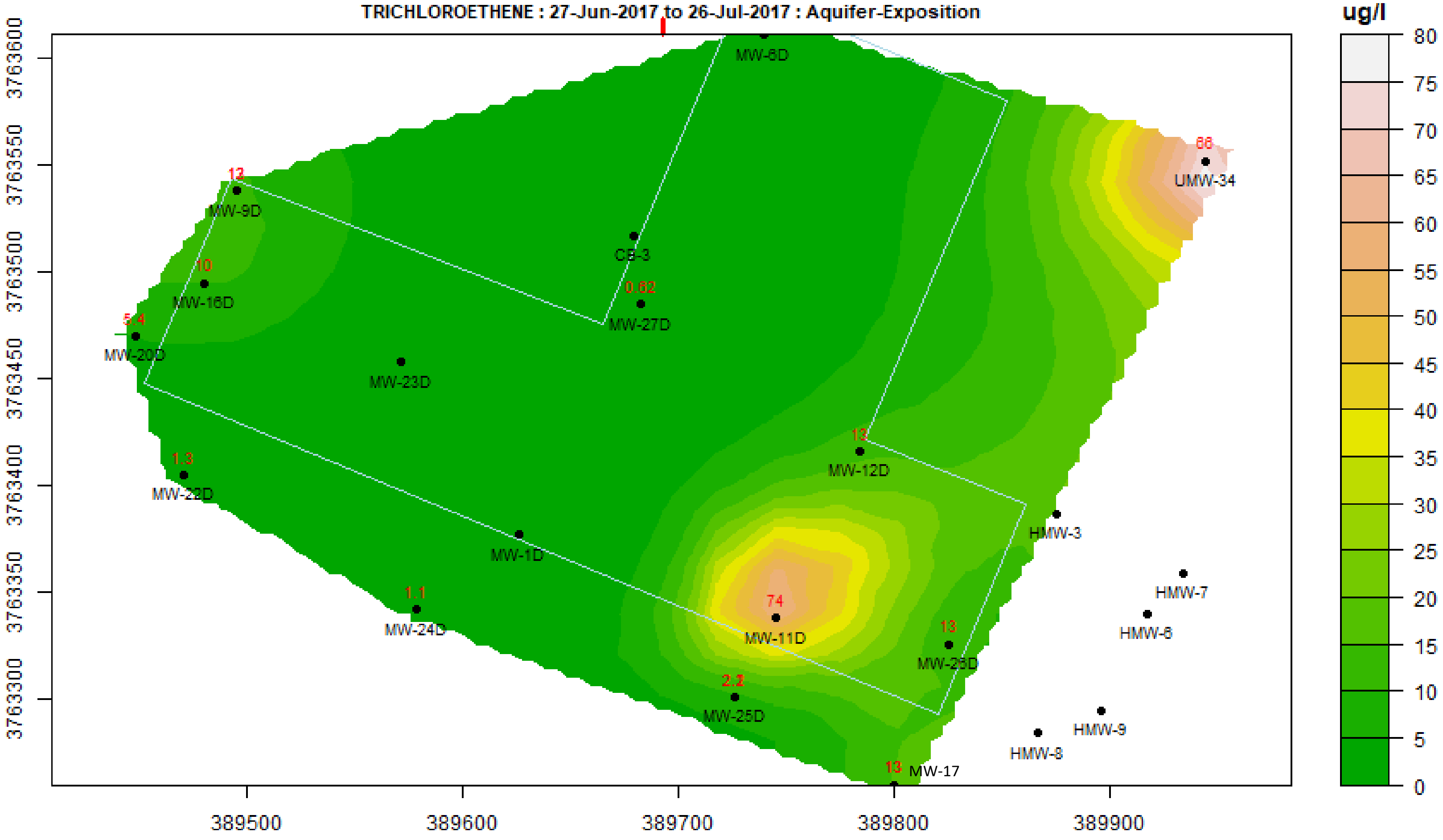


Figure 1.6: *Interpolated TCE Concentrations in the Exposition Aquifer*

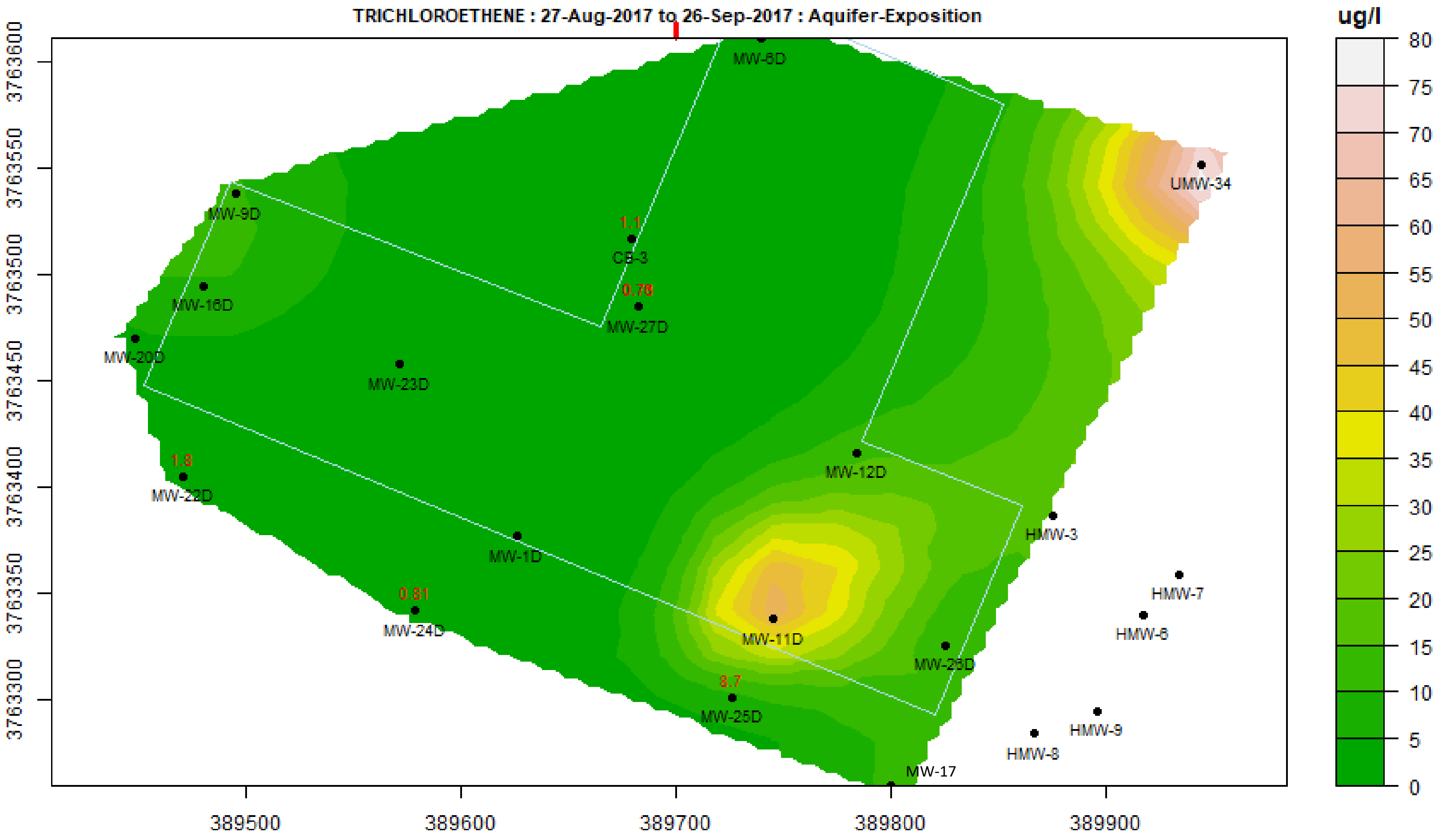


Figure 1.7: *Interpolated TCE Concentrations in the Exposition Aquifer*

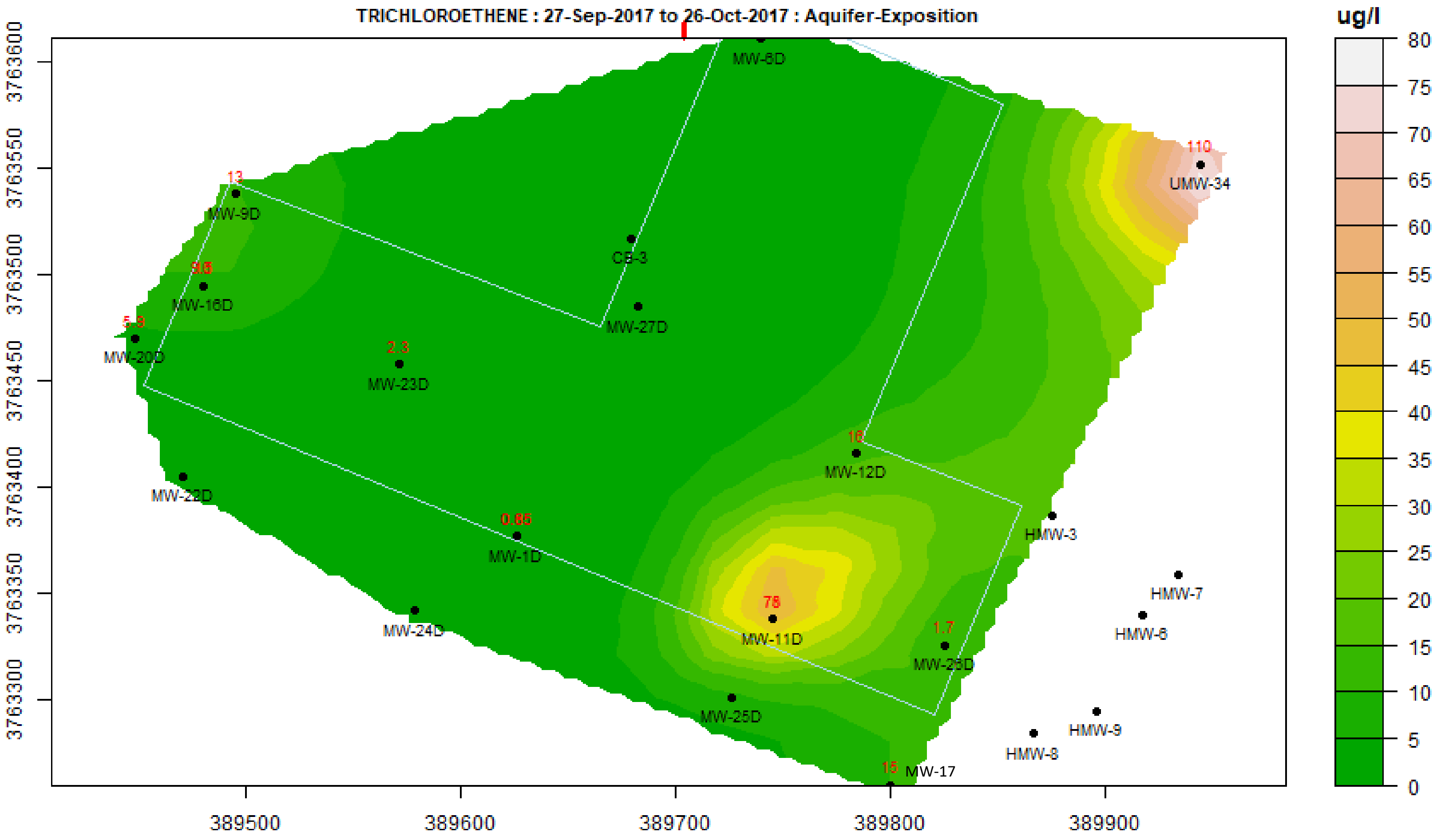


Figure 1.8: *Interpolated TCE Concentrations in the Exposition Aquifer*

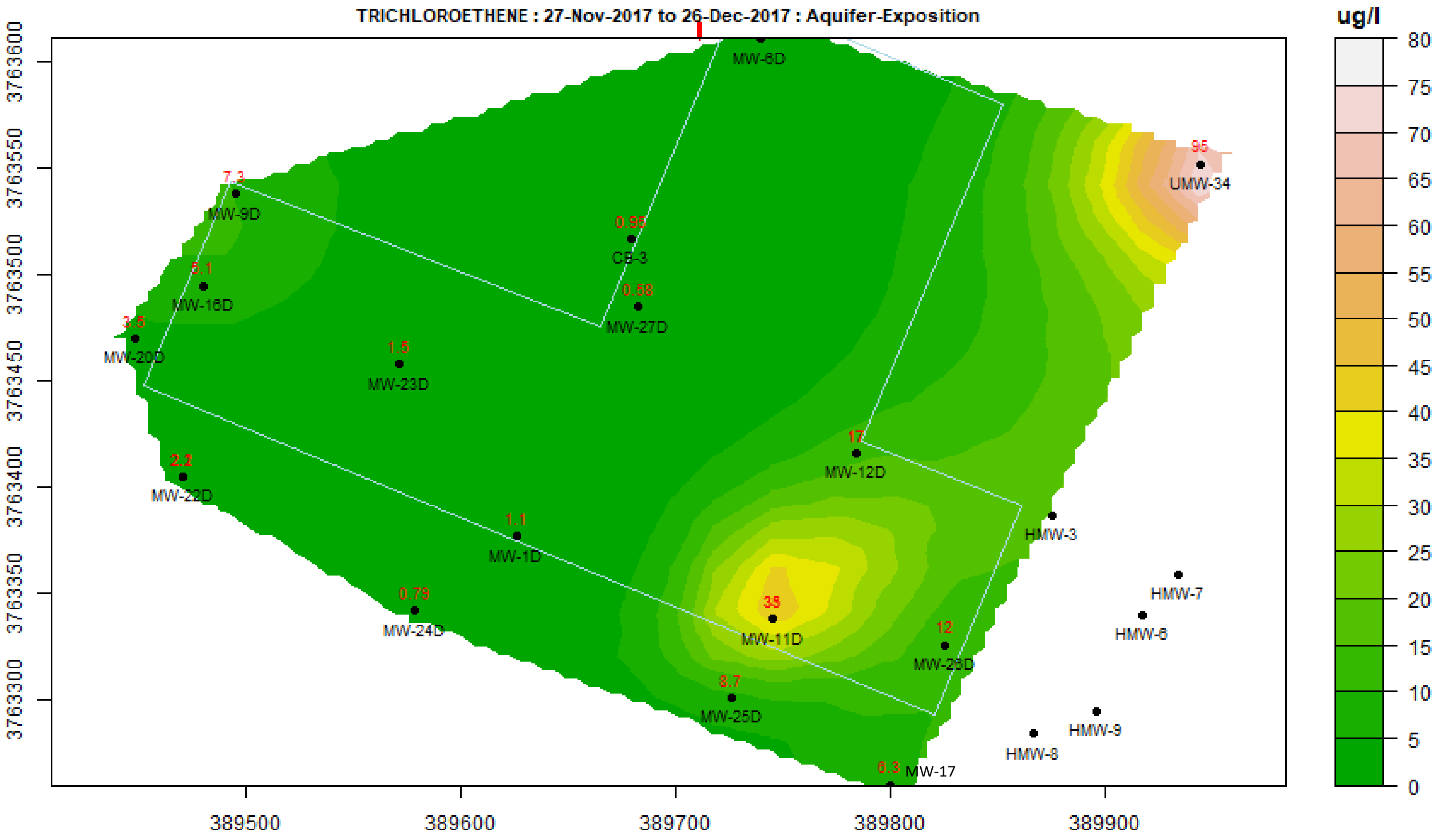


Figure 1.9: *Interpolated TCE Concentrations in the Exposition Aquifer*

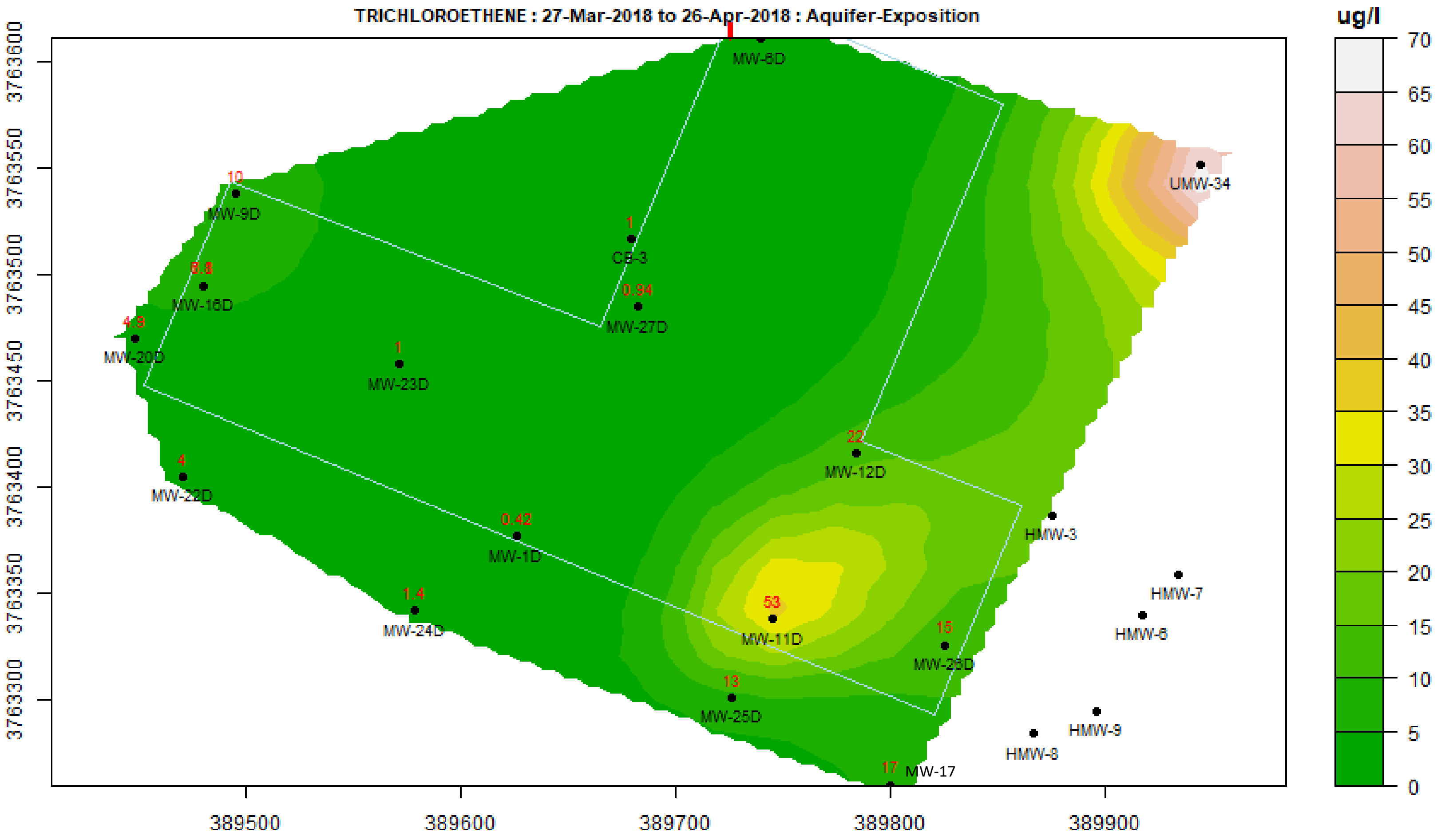


Figure 1.10: *Interpolated TCE Concentrations in the Exposition Aquifer*

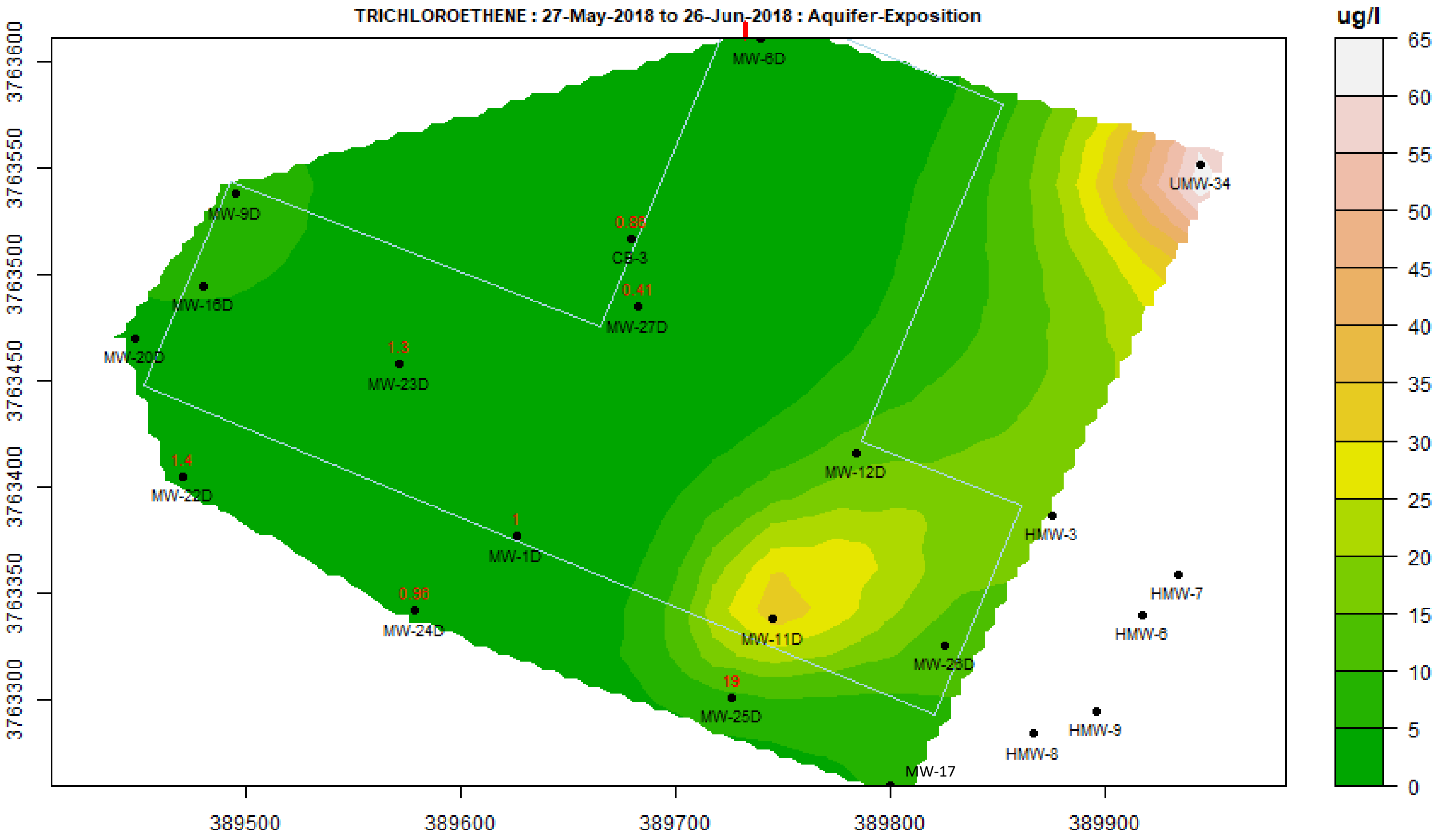


Figure 1.11: *Interpolated TCE Concentrations in the Exposition Aquifer*

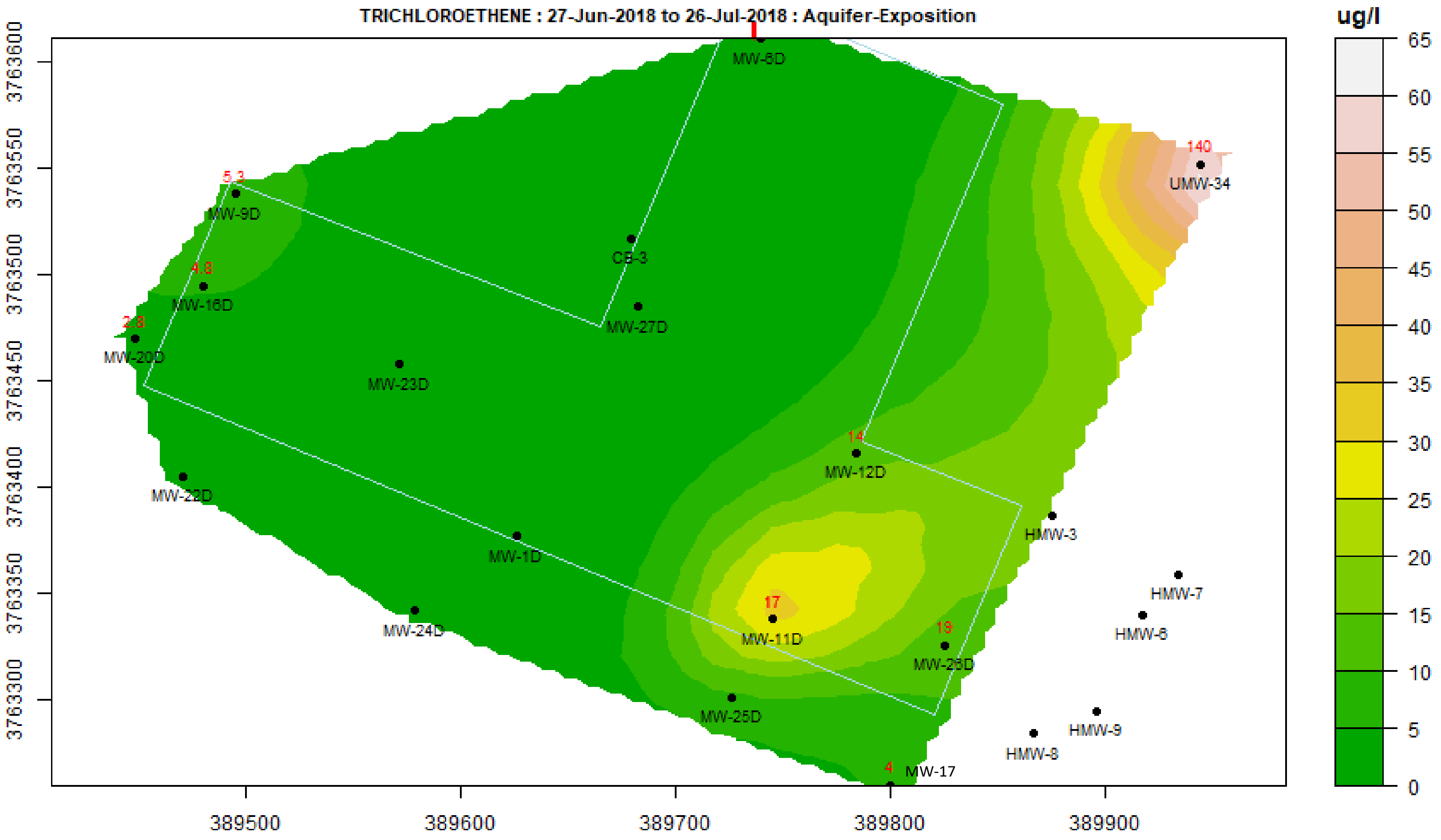


Figure 1.12: *Interpolated TCE Concentrations in the Exposition Aquifer*

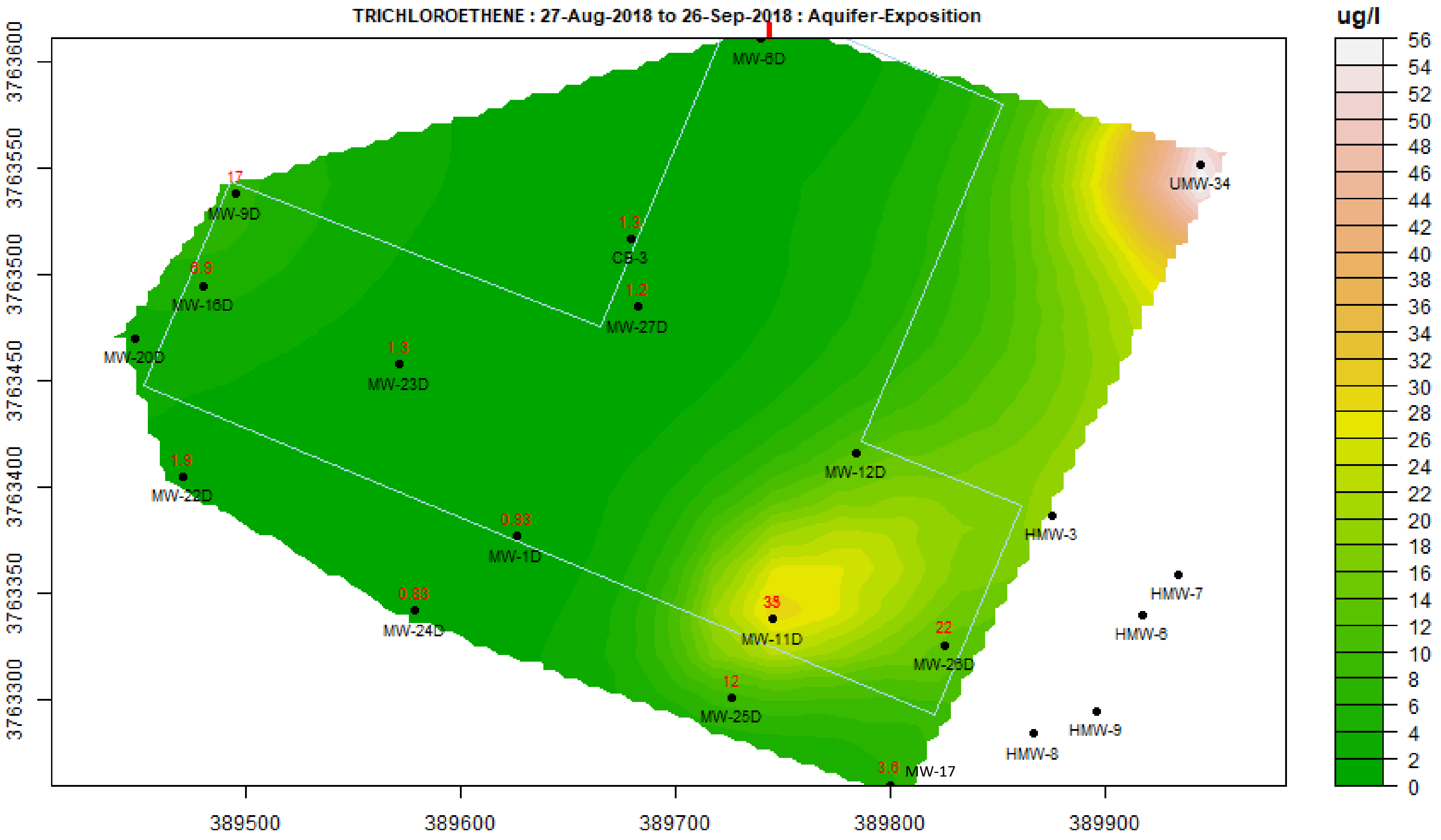


Figure 1.13: *Interpolated TCE Concentrations in the Exposition Aquifer*

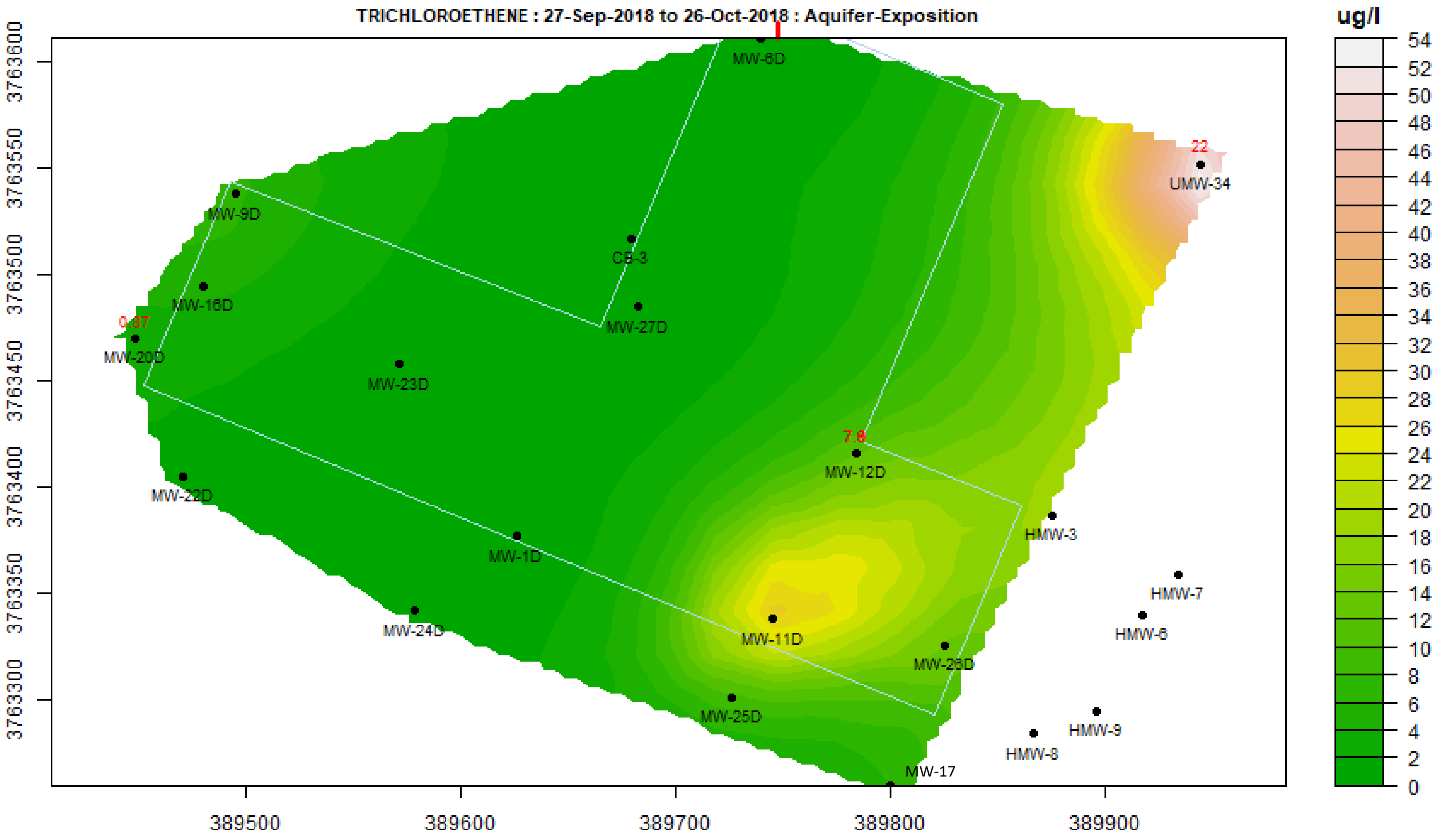


Figure 1.14: *Interpolated TCE Concentrations in the Exposition Aquifer*

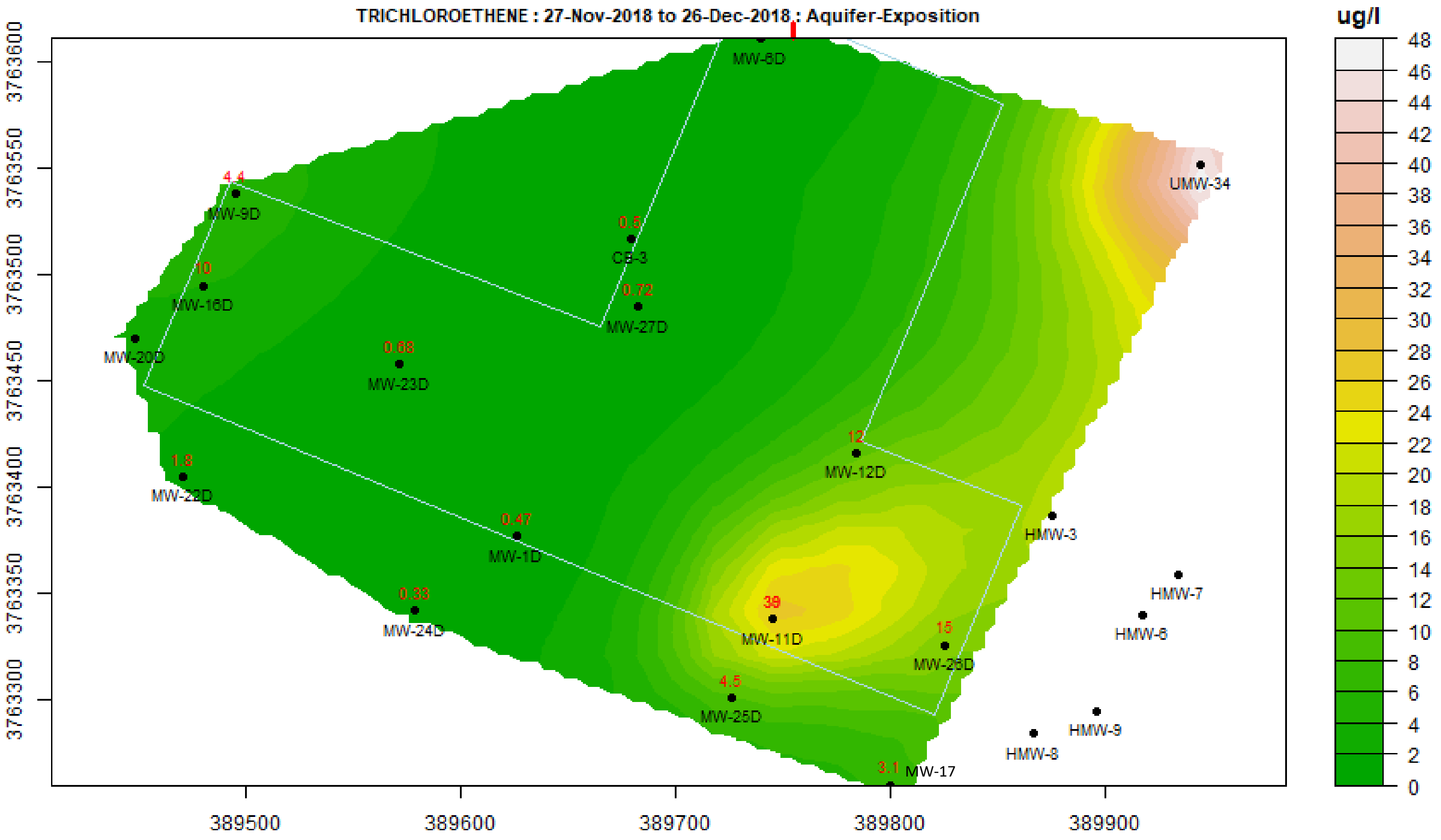
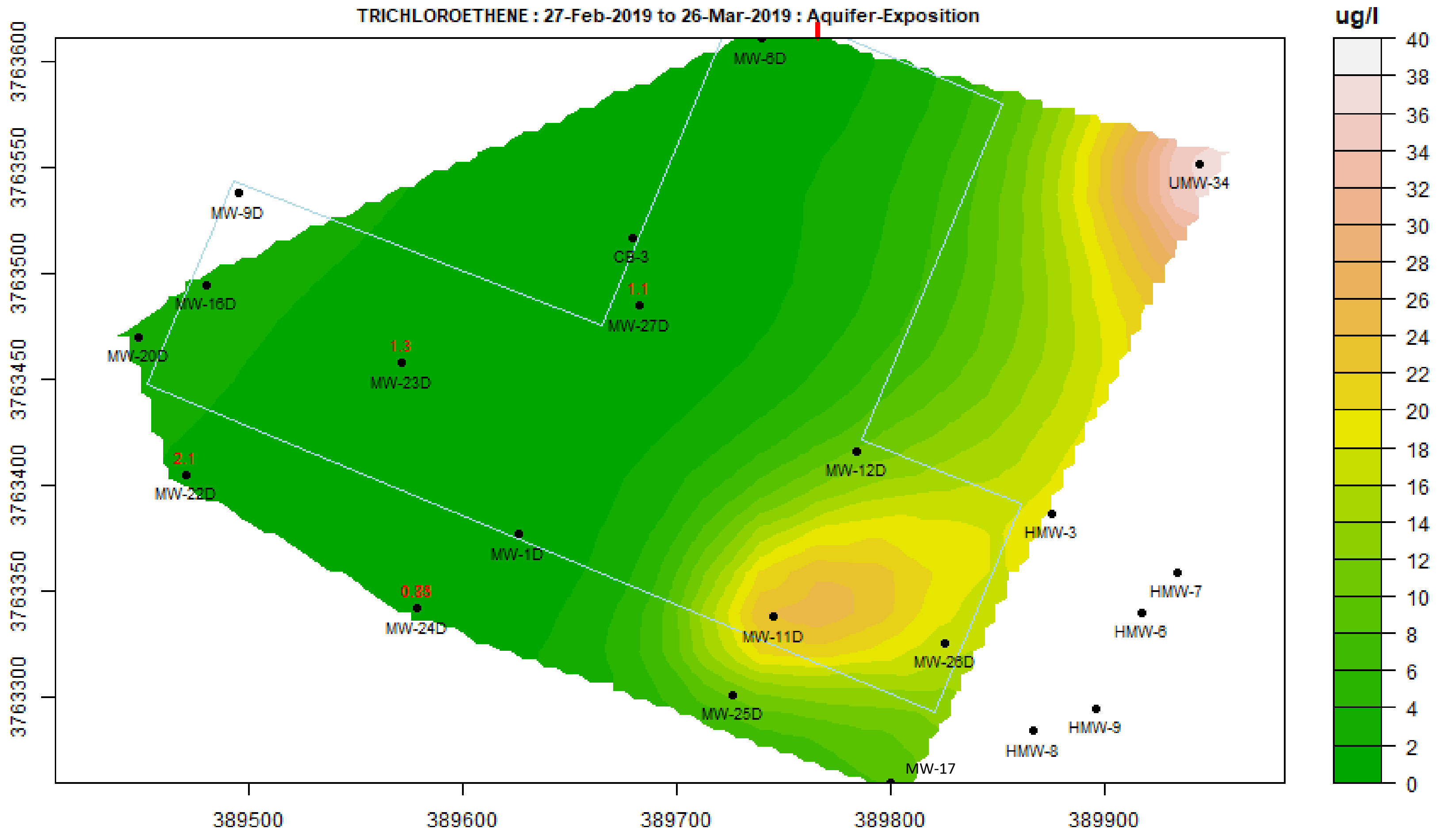


Figure 1.15: *Interpolated TCE Concentrations in the Exposition Aquifer*



TRICHLOROETHENE : 27-Feb-2019 to 26-Mar-2019 : Aquifer-Exposition

Figure 1.16: *Interpolated TCE Concentrations in the Exposition Aquifer*

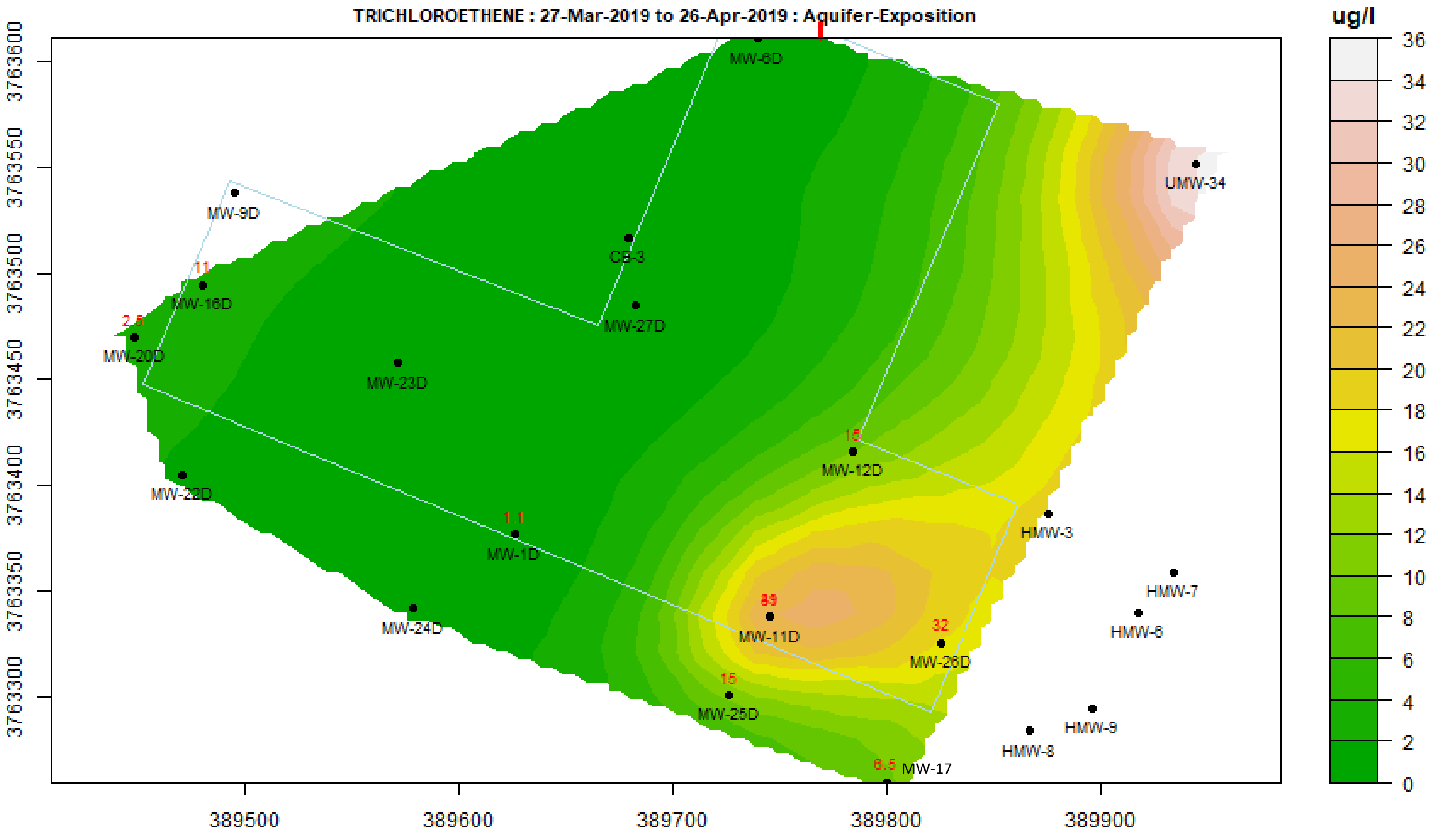


Figure 1.17: *Interpolated TCE Concentrations in the Exposition Aquifer*

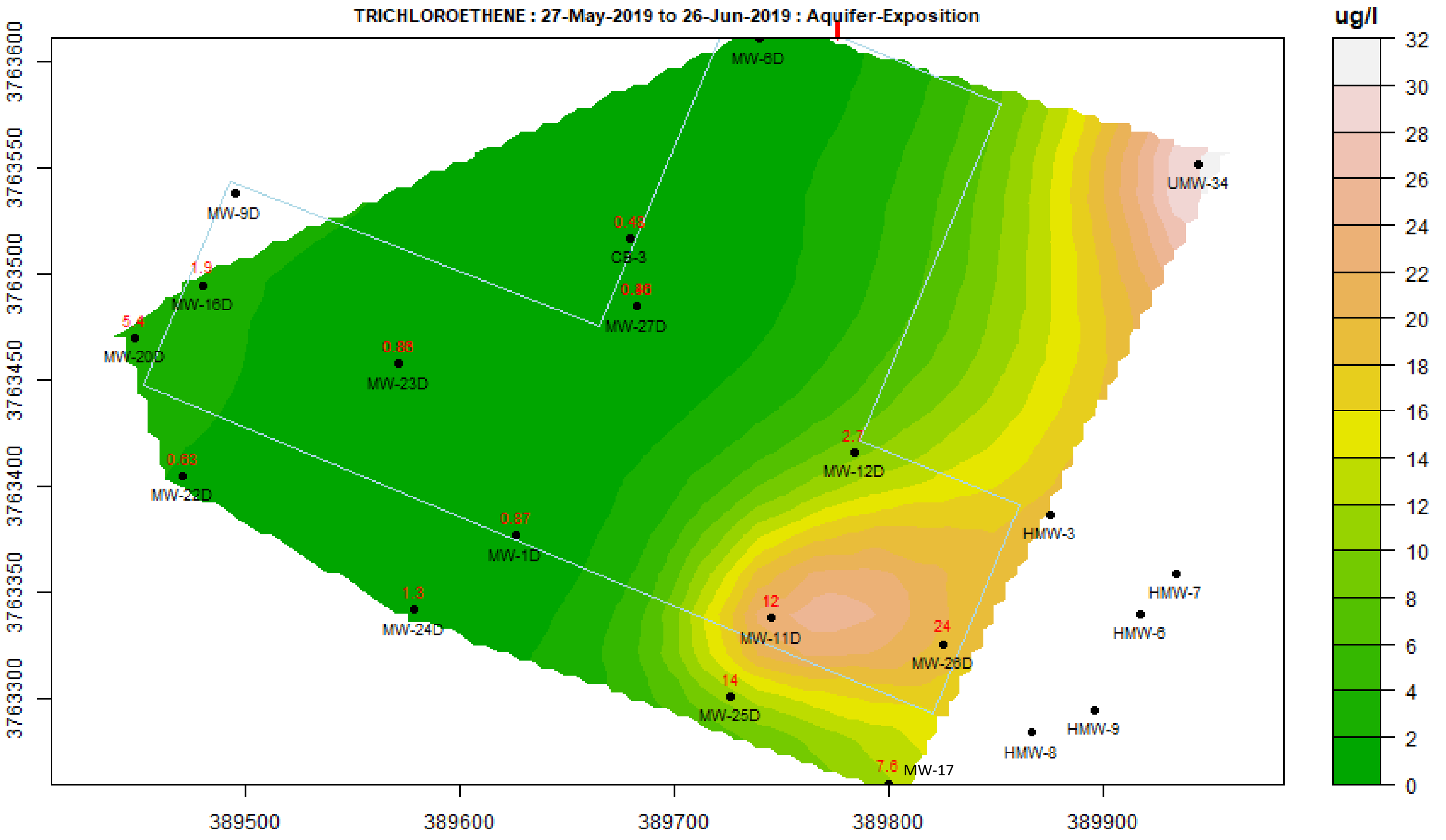


Figure 1.18: *Interpolated TCE Concentrations in the Exposition Aquifer*

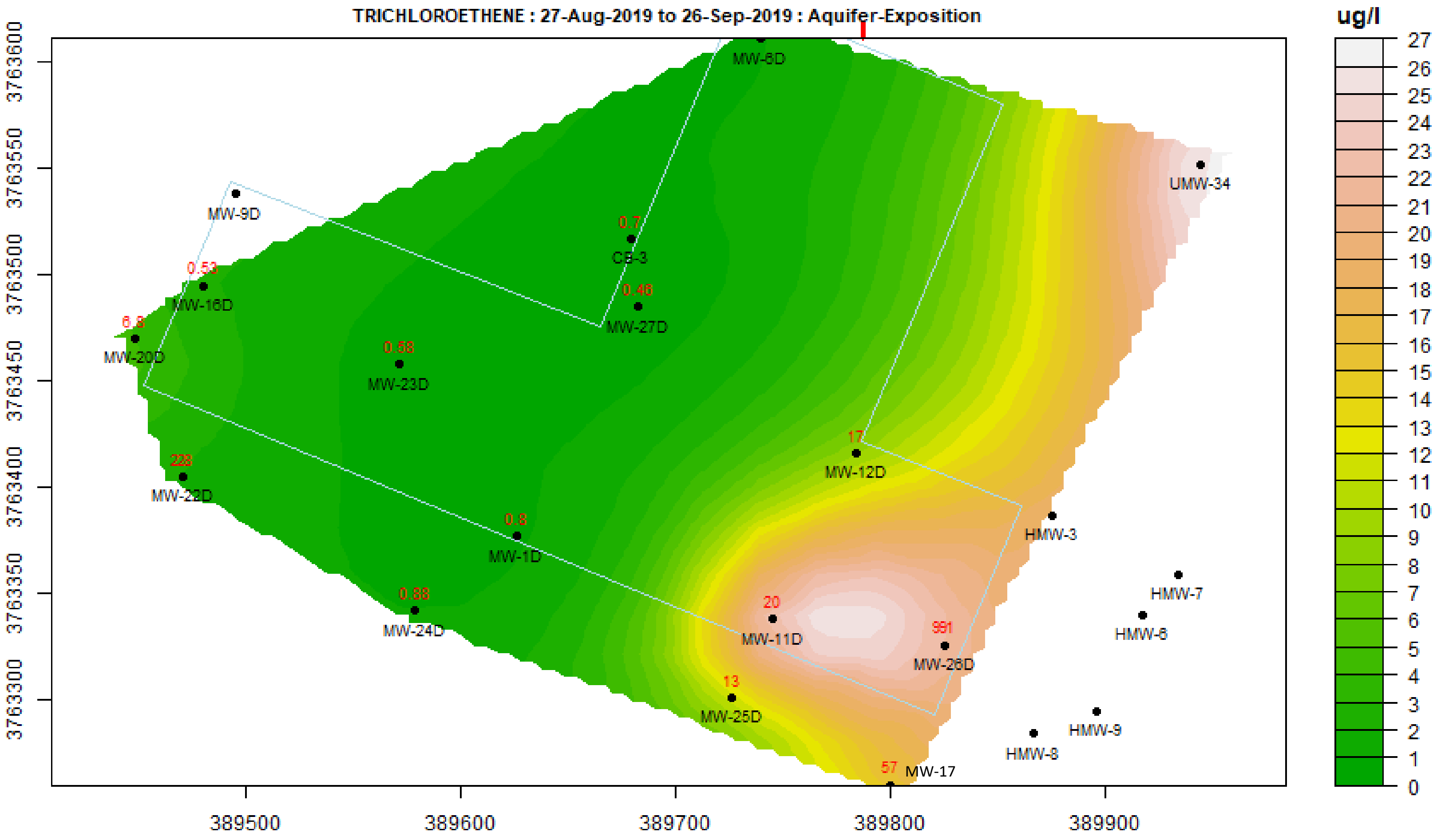
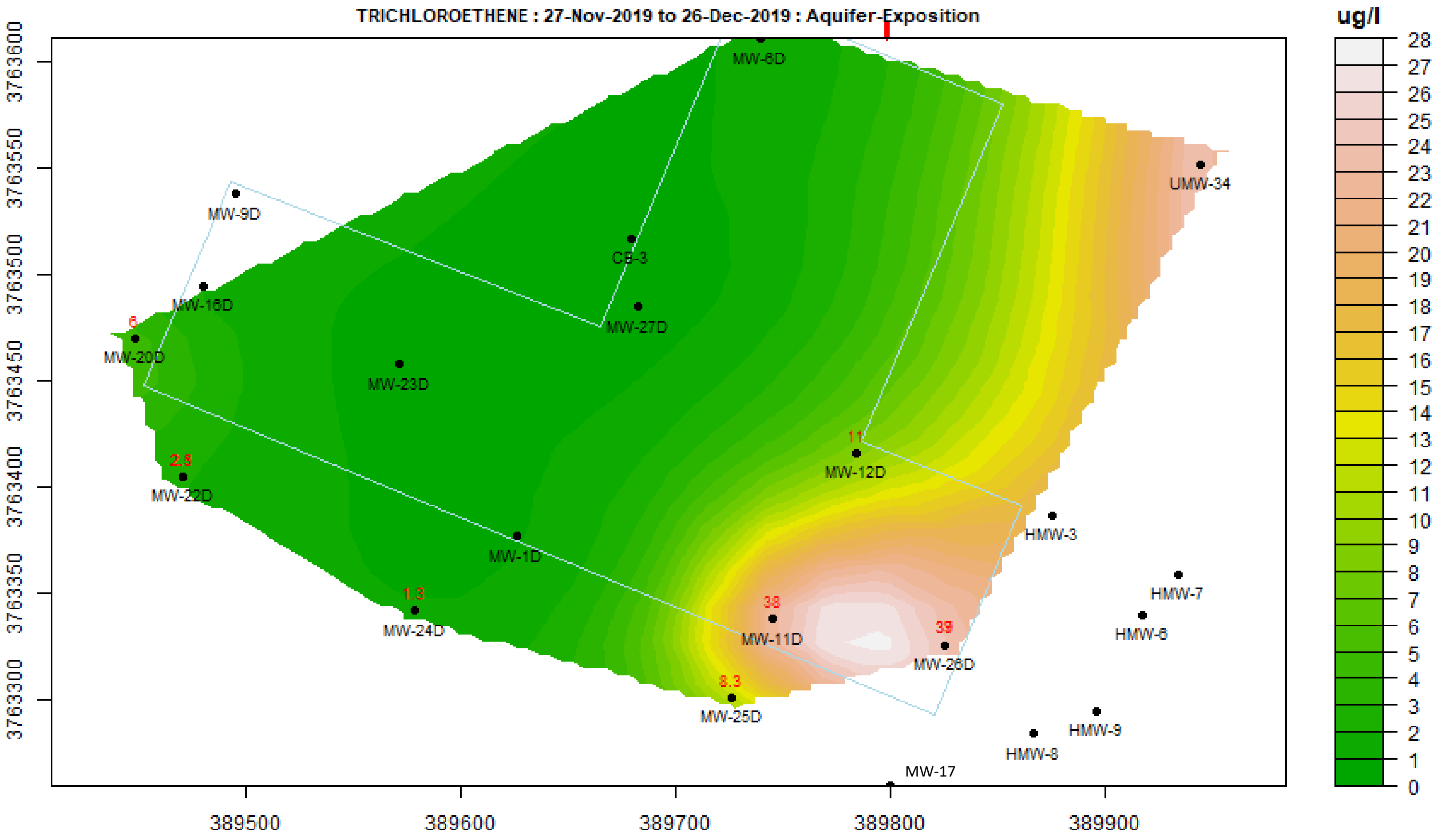


Figure 1.19: *Interpolated TCE Concentrations in the Exposition Aquifer*



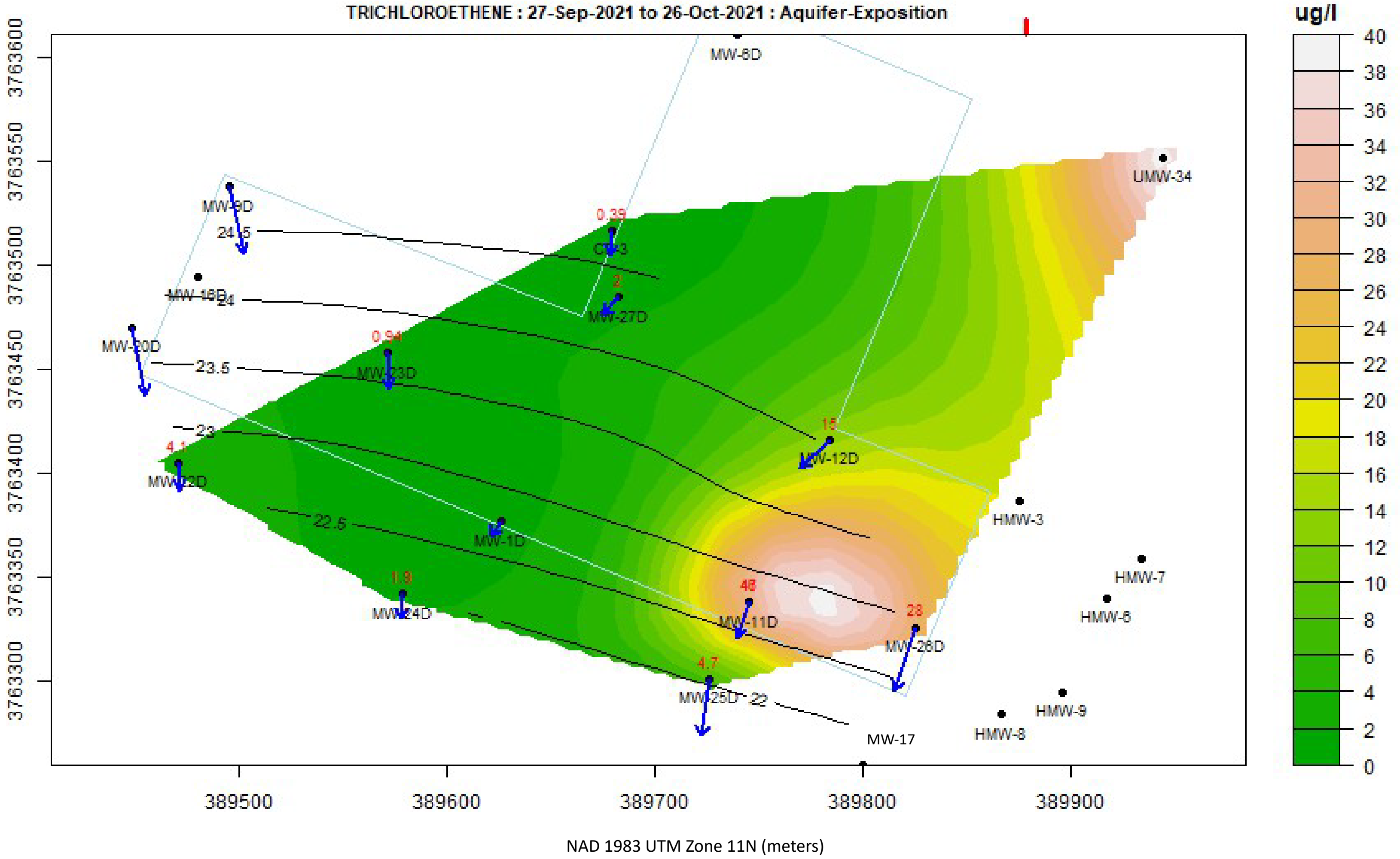


Figure 1.20: *October 2021 Interpolated Groundwater Flow Field and TCE Concentrations*

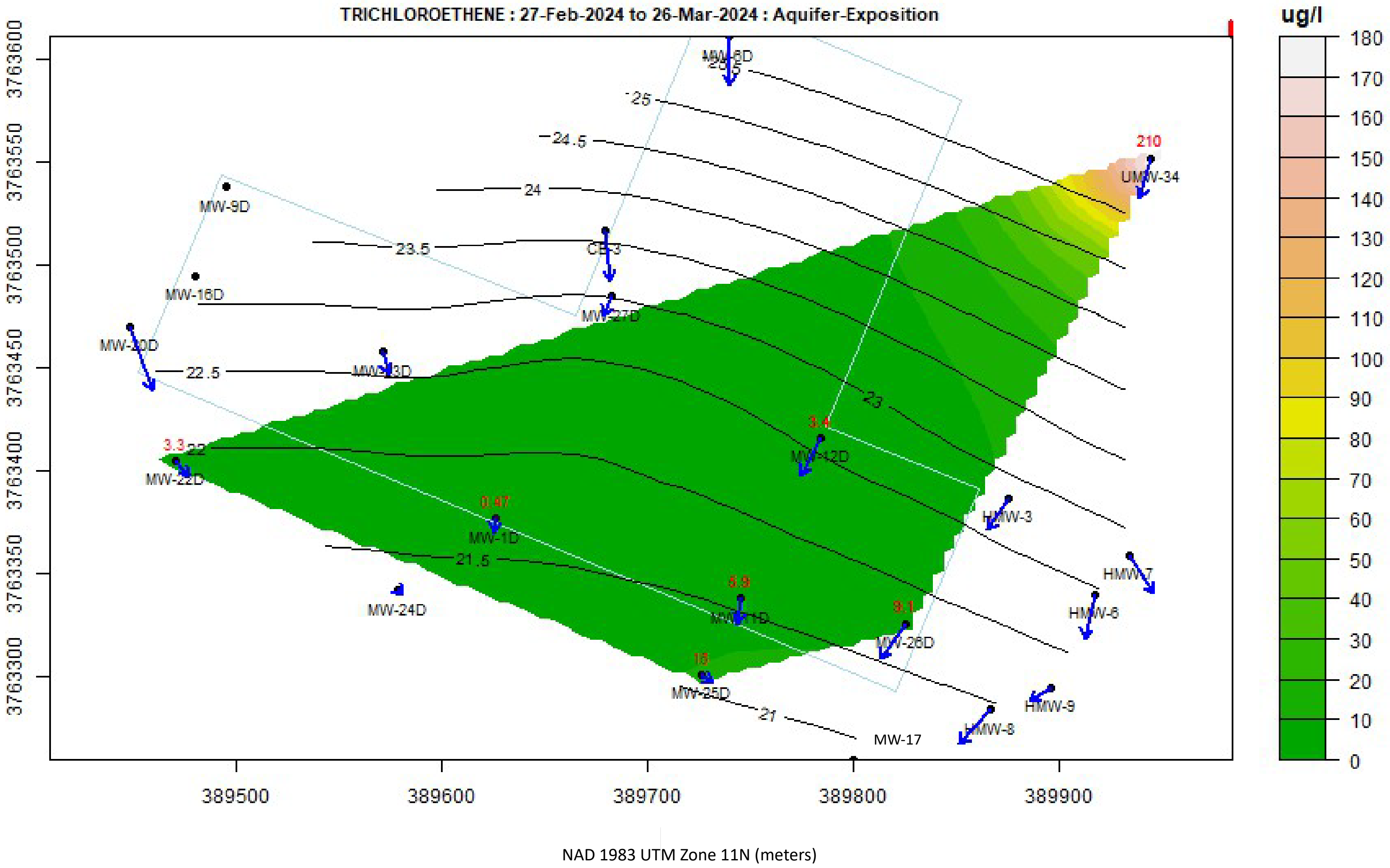


Figure 1.21: *March 2024 Interpolated Groundwater Flow Field and TCE Concentrations*

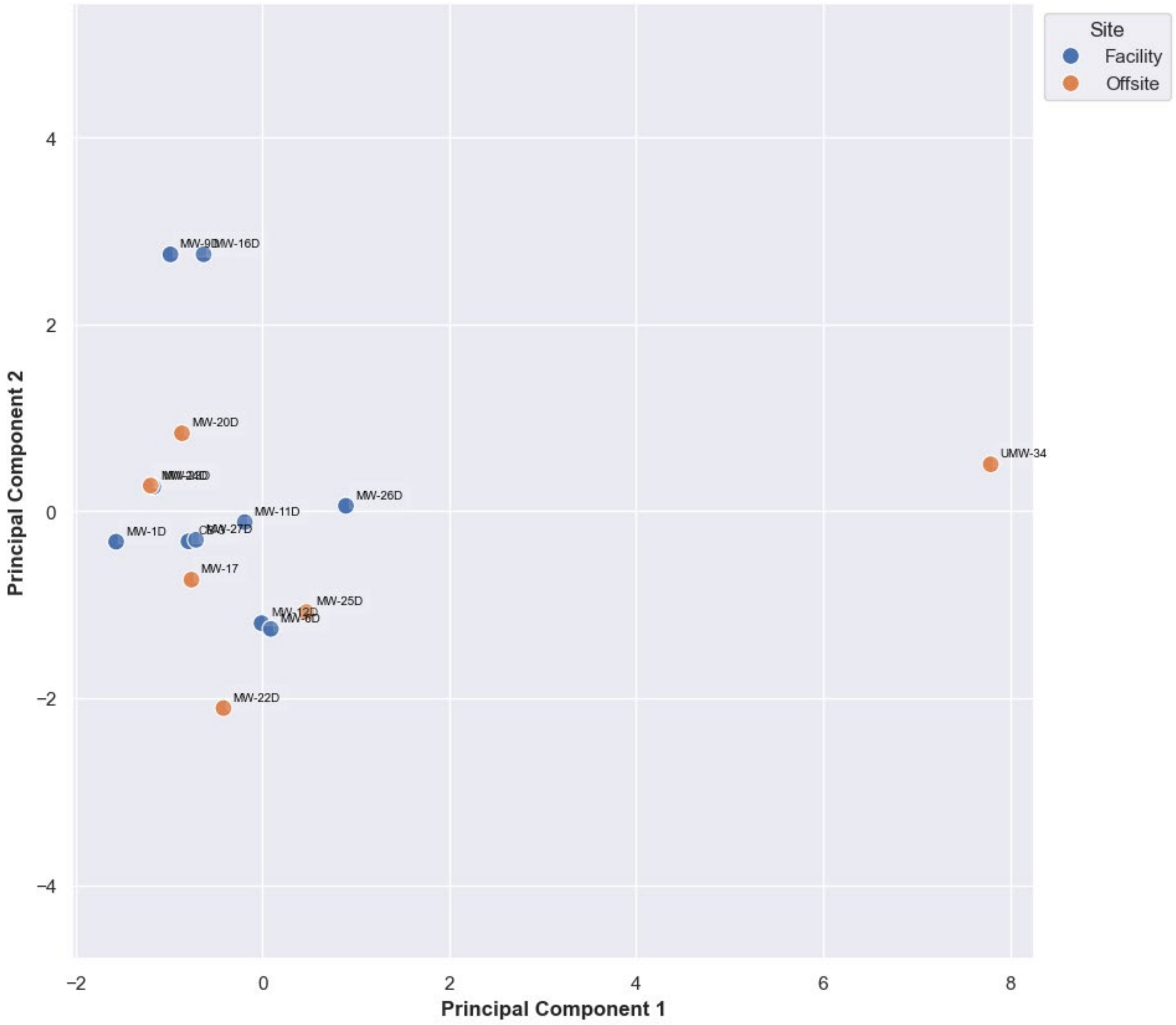


Figure 2: *Global PCA Results - "Facility" and "Offsite" refer to whether the wells are located within the Exide facility footprint or outside of it as indicated in Figure 7 of the SI Report*

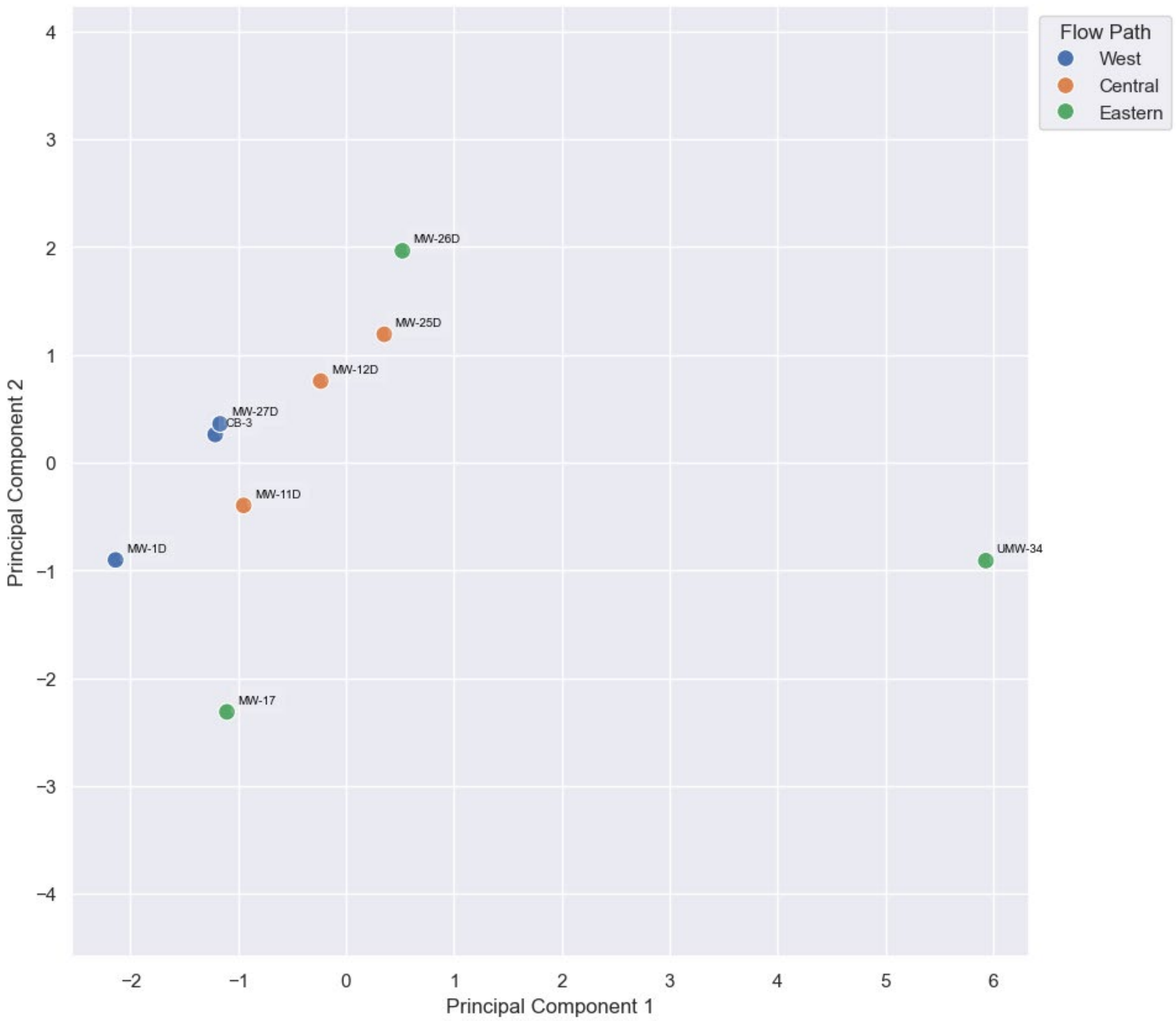


Figure 3: *Targeted PCA Results*

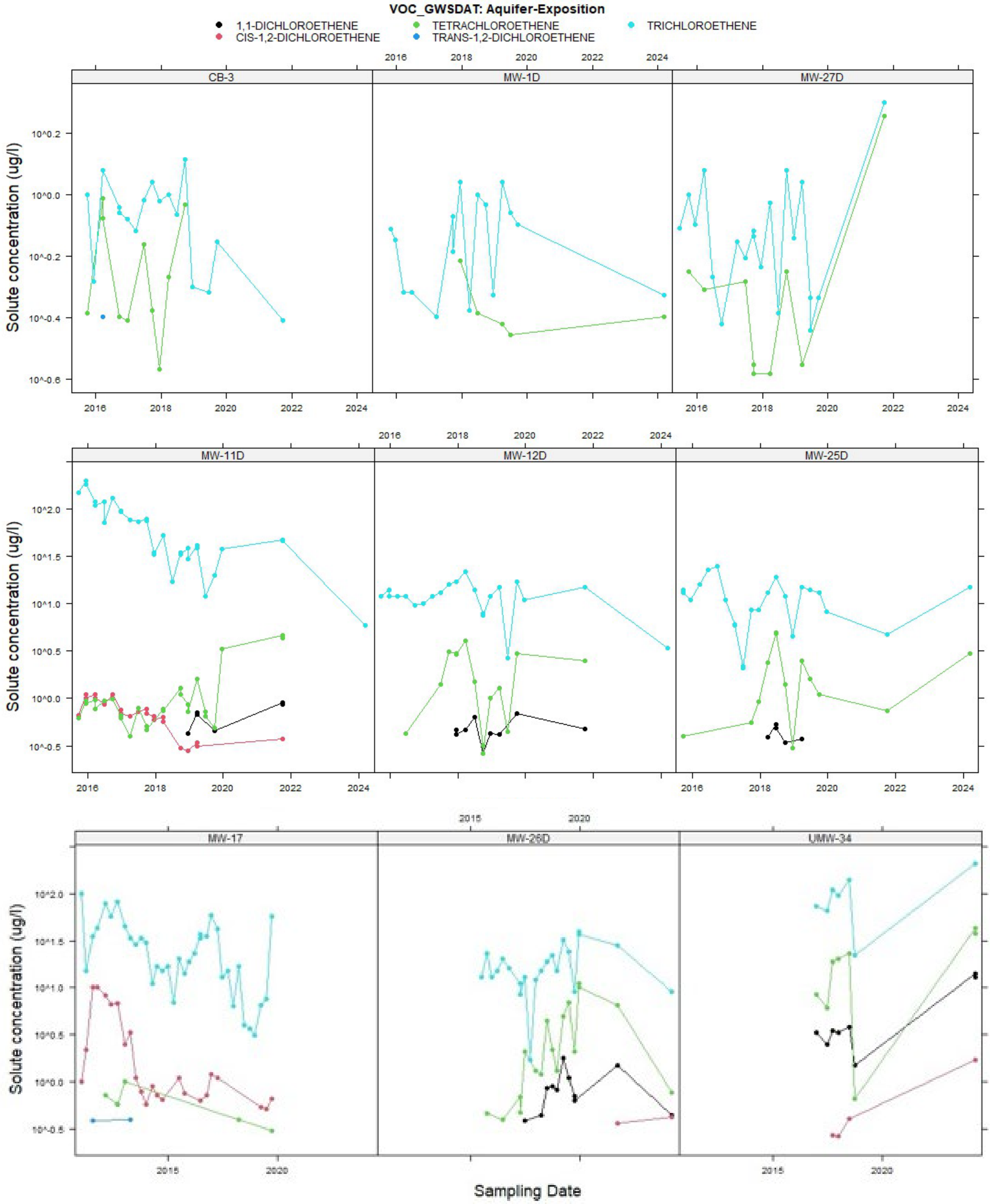


Figure 4: *cVOC Timeseries - Panel A: West; Panel B: Central; Panel C: East*

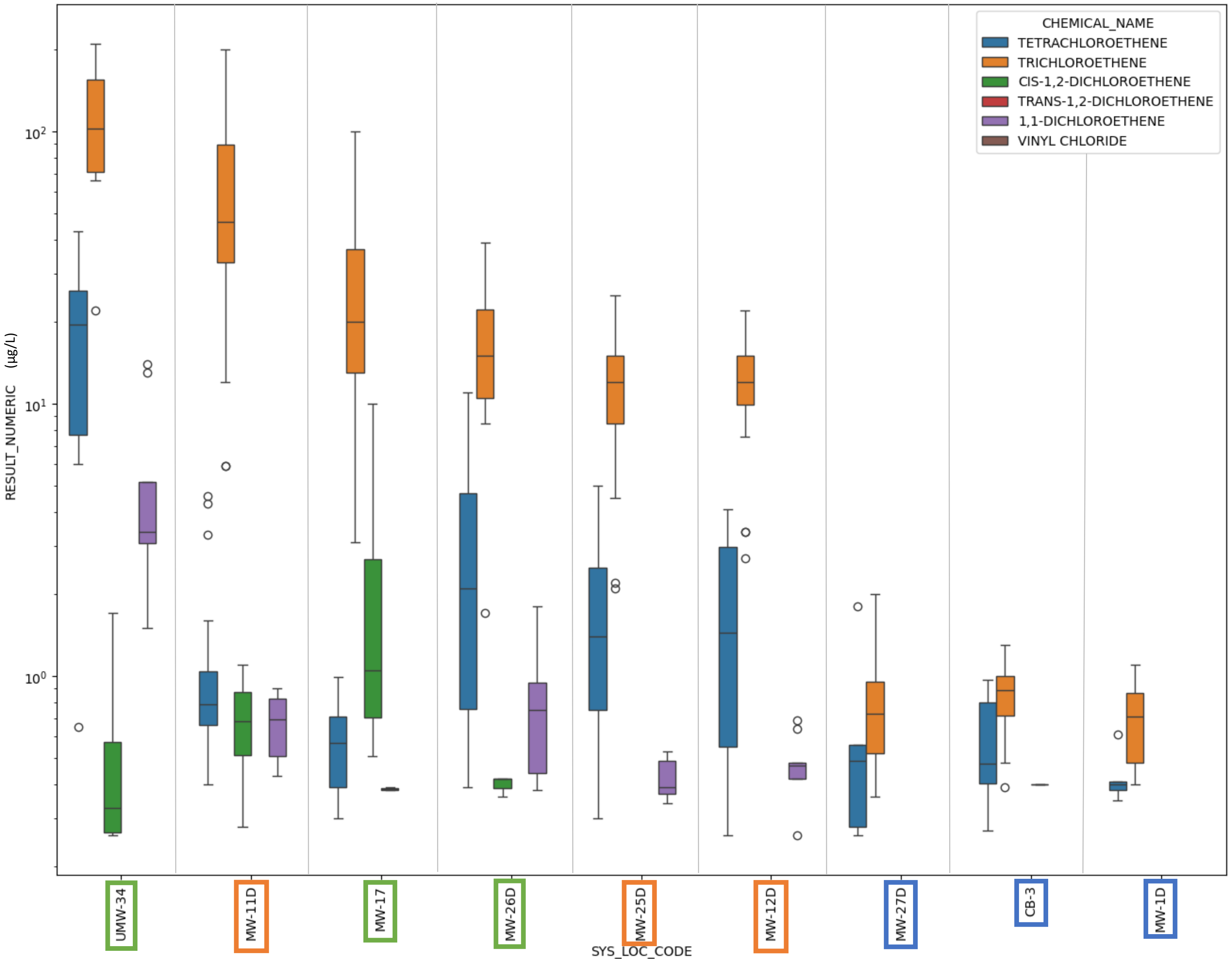


Figure 5: *Relative Fractions of cVOC Concentrations by Well*

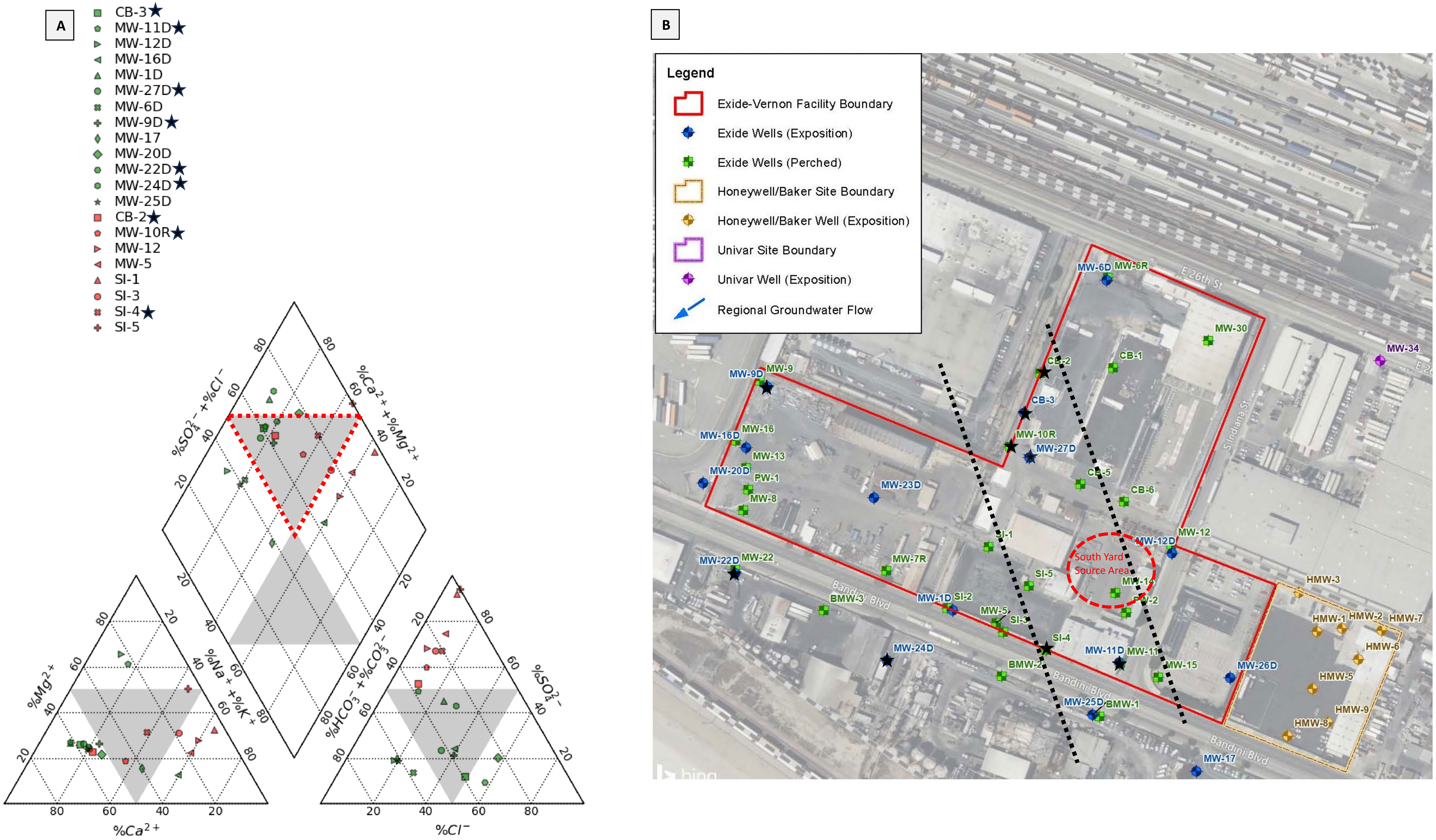


Figure 6: *Piper Plot of Inorganic Water Quality Parameters-Exposition (green) and Perched (red) Aquifers. Note that Black stars represent mixed hydrogeochemical facies water (topmost dark gray triangle in red), dashed black lines in Panel B denote inferred spatial extent of mixing zone*

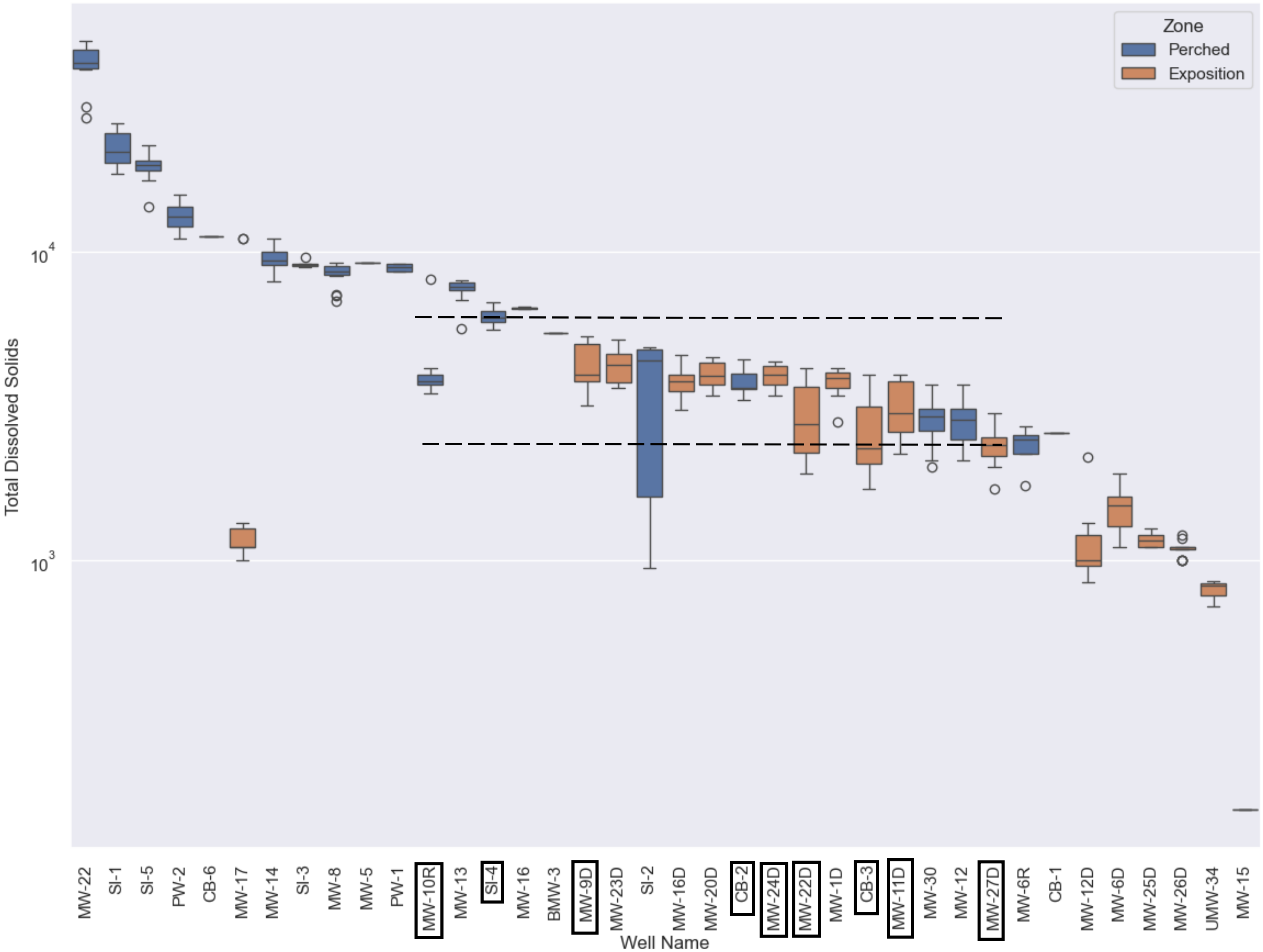


Figure 7: *Boxplots of TDS Distribution in the Exposition and Perched Aquifers – dashed zone indicates mixed water*

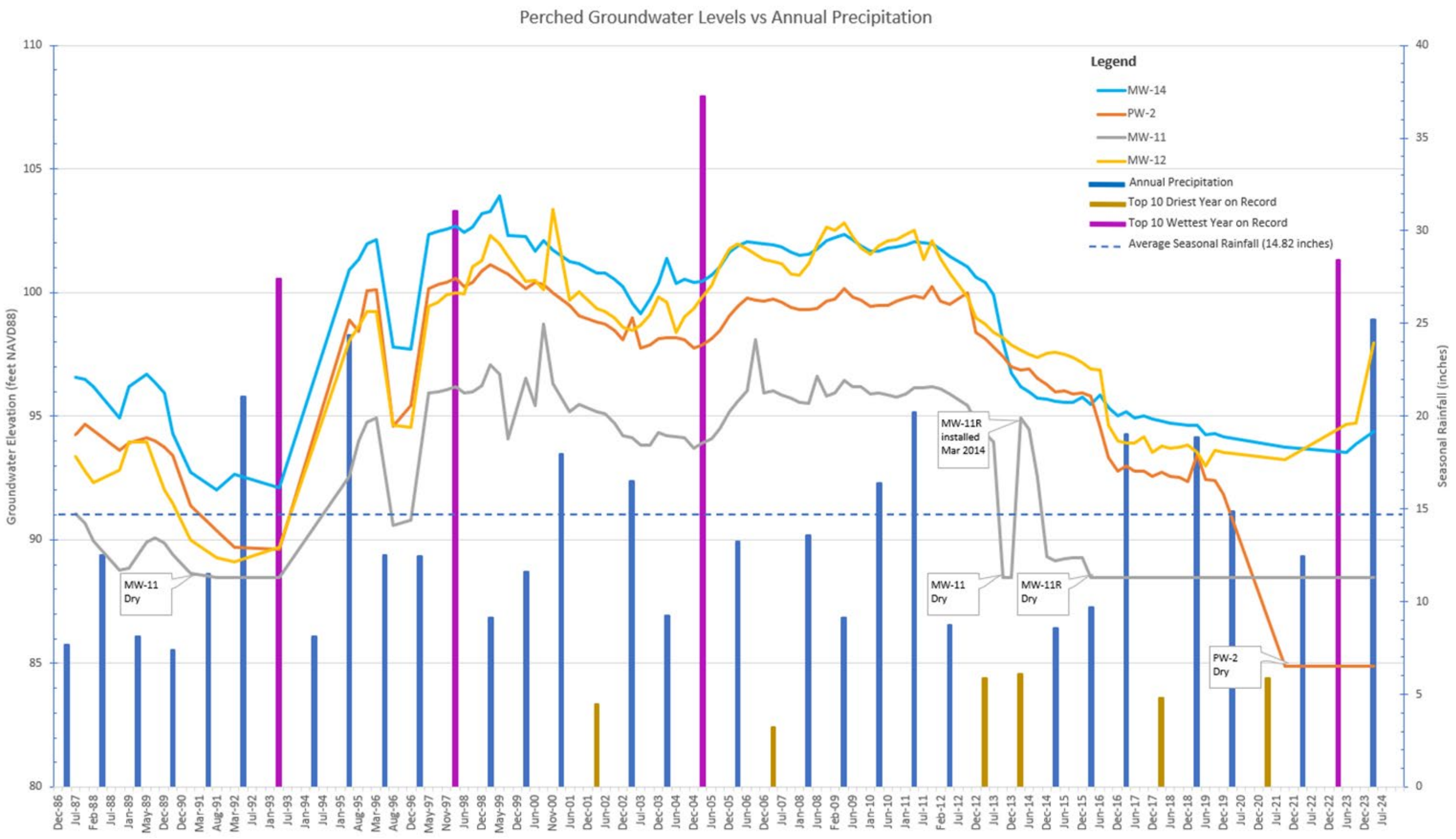


Figure 8: *Precipitation and Perched Well Water Levels*

Note fluctuations in the perched groundwater elevations with response to periods of extremely dry periods (brown bars) and the wettest periods (purple bars). The declines in water levels demonstrate the perched groundwater aquitard is discontinuous over relatively short distances south of the source area between dry wells (MW-11 and PW-2) and wells retaining water (MW-12 and MW-14).