Alabama Department of Transportation

TCE Trends Through April 2010

Coliseum Boulevard Plume

March 2011

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1. Introduction

1.1. Introduction

The Coliseum Boulevard Plume (CBP) Site is an area in north Montgomery, Montgomery County, Alabama that contains trichloroethylene (TCE) in the groundwater (Figure 1-1). Groundwater samples have been collected from monitoring wells and Continuous Multichannel Tubing (CMT) wells at the CBP Site from 2001 through April 2010 to document TCE concentrations. Samples are collected from 147 monitoring wells in accordance with the Groundwater Monitoring Plan approved by the Alabama Department of Environmental Management (ADEM).

To develop valid statistical trends, only wells with a minimum of eight sampling events, which had TCE concentrations above the detection limit, are evaluated. There were 97 wells that met this criterion. Data collected from these wells provide information for qualitative and quantitative statistical evaluations to determine:

- Changes in TCE concentrations throughout the CBP Site.
- Effects of groundwater levels on TCE movement throughout the CBP Site.
- Distributions of compounds that result from the degradation of the TCE.

These topics are discussed in the following sections. Section 2 provides the results of trends (changes in TCE concentrations and effects of groundwater levels) in TCE concentrations at the CBP Site. Section 3, "Degradation of TCE," discusses the distributions of compounds that result from the degradation of TCE. Section 4 presents a summary of findings.

1.2. Purpose

A groundwater model has been developed and calibrated for the CBP to predict changes in TCE concentrations and effects of groundwater levels on TCE movement. The model is also used to continuously evaluate the effectiveness of corrective measures that are used to control, capture and treat TCE. Based on model predictions and review of historical data, TCE concentration changes are predicted in groundwater over time within the CBP. Annual TCE trend analyses are useful to verify that the TCE concentrations in groundwater, as determined by routine sampling and analysis, are within model-predicted concentration changes and corrective measures are functioning as designed.

A detailed description of the CBP groundwater model is provided in the, "Final, Site-Wide Corrective Measures, Coliseum Boulevard Plume Site, Montgomery, Alabama", revised July 2008. This report was prepared by the Alabama Department of

Transportation (ALDOT) and submitted to ADEM as part of the investigative work to document the nature and extent of the CBP and evaluation and selection of appropriate Corrective Measures.

2. Temporal Changes in TCE Concentrations

2.1. Methodology

Time-series plots and intrawell Shewhart-Cumulative Sum (CUSUM) control charts were used to evaluate the trends in TCE concentrations. Trends were evaluated only for wells where TCE concentrations were above the detection limit for at least eight sampling events to develop valid trends. TCE has been consistently detected only in samples from wells completed in the Shallow Zone (above the first restrictive clay). Thus, trends for only 100- and 200- series wells are evaluated. The 100- series wells are screened in the upper Shallow Zone (SZ) and at most locations correspond to the top of the aquifer (water table). The 200- series wells are screened in the lower SZ. Where there is a cluster of three wells, the 100–series well is screened in the top, the 200B-series well is screened at an intermediate depth, and the 200C-series well is at the base of the SZ.

2.1.1. Time-series Plots

Time-series plots for both TCE and groundwater levels, presented in Appendix A, provide for visual interpretation of trends.

2.1.2. Shewhart-CUSUM Statistical Analysis:

The Shewhart-CUSUM statistical analysis provides two statistics that are based on comparison of recent monitoring results to results from the first four sampling events for each well. The Shewhart statistic represents the "short-term" trend relative to baseline, whereas the CUSUM statistic represents the long-term trend relative to baseline (the CUSUM statistic retains a "memory" of previous values because it is a summed statistic). The numeric values that determine statistical significance for the Shewhart and CUSUM trend methods are provided in Table 2-1.

Table 2-1.
Shewhart-CUSUM Tests for Significant Trend

Statistical Significance	Shewhart Statistic	CUSUM Statistic
Significant Increase	> 4.5	> 5
No Significant Trend	<= 4.5 and >= -4.5	<= 5 and >= -5
Significant Decrease	< -4.5	< -5

2.2. Results

Of the wells from which water samples contained detectable TCE, approximately 60 percent are lower Shallow Zone wells. Recharge from precipitation to the top of the aquifer causes stratification of TCE such that higher concentrations are near the base of the aquifer. The well locations used for the trend analyses are presented on Figure 2-1. Table 2-2 provides a comparison of the Shewart and CUSUM statistics for data from the upper Shallow Zone and lower Shallow Zone monitoring wells. Statistical analyses for long-term trends (CUSUM statistic) and short-term trends (Shewhart statistic) indicate the following:

<u>CUSUM statistic (long-term trends)</u>

- 78 percent of **all monitoring wells** evaluated in the trend analysis have either **no trend** (7%) or a **decreasing trend** (71%).
- 16 percent of the **upper Shallow Zone wells** have an **increasing trend.**
- 25 percent of the **lower Shallow Zone wells** have an **increasing trend.**

<u>Shewhart statistic (short-term trends)</u>

- 89 percent of **all monitoring wells** have either **no trend** (62%) or a **decreasing trend** (27%).
- 6 percent of the **upper Shallow Zone wells** have an **increasing trend.**
- 14 percent of the **lower Shallow Zone wells** have an **increasing trend.**

Table 2-2.
Distributions of Time Trends between Upper and Lower Shallow Zone Wells

Well Screen Interval	Shewhart Statistics				CUSUM Statistics			
	Increase	No Trend	Decrease	Total	Increase	No Trend	Decrease	Total
SITE WIDE								
Upper SZ	6%	72%	22%	100%	16%	9%	75%	100%
Lower SZ	14%	57%	29%	100%	25%	6%	69%	100%
All Wells	11%	62%	27%	100%	22%	7%	71%	100%
PH12 AREA								
All Wells	7%	72%	21%	100%	14%	0%	79%	100%

Note: "Increase" and "decrease" are statistically significant trends.

Distributions of the trends are presented on Figures 2-2 and 2-3. The Shewhart (short-term trend) for each well is presented on Figure 2-2 and the distribution of the CUSUM statistic for each well is presented in Figure 2-3. The values for the Shewhart statistics and CUSUM statistics are provided in Appendix A. The wells with increasing trends in TCE concentration are along the southwest-northeast axis of the CBP (Figures 2-4 and 2-5). This axis coincides with the dominant directions of groundwater flow. Wells with no trend or decreasing trends are principally around open fields (Figure 2-1 shows locations of open fields) where recharge to the shallow zone is higher than the surrounding residential properties. Wells in the PH12 area, which is the area contiguous with the groundwater divide and is the area with the highest TCE concentration in the groundwater, also generally exhibit no trend or decreasing trends (Figures 2-6 and 2-7).

2.3. Changes in TCE Trends

The trend analyses have been evaluated annually since 2005, with the Shewhart-CUSUM statistics used to characterize trend direction (increasing trend, no trend, decreasing trend). The following sections identify wells where the trend direction changed since the previous report (e.g.; increasing in the previous report but currently decreasing). Wells where the trend direction has changed may be due to changes in the groundwater flow path, changes to groundwater recharge, or internal variation in TCE distribution within the CBP. Factors influencing groundwater flow path may include Southwest Area dewatering; groundwater withdrawals; or other activities that artificially modify direction of groundwater flow. Changes to groundwater recharge can be effected by long term precipitation fluctuations (e.g., extended droughts or above average rainfall periods); land cover modifications (increase or decrease in impervious areas); and changes to stormwater control systems. Variation in TCE distribution in the CBP is a function of the past non-uniform introduction of TCE to the groundwater over a period of several decades ending in the early 1980's and heterogeneity in the aquifer.

2.3.1. Change in TCE Trend in an Increasing Direction

Only two monitoring wells, shown in Table 2-3 below, exhibited a change in TCE trend in an increasing direction.

Table 2-3.

Changes in TCE Trend in an Increasing Direction

100 Series			200 Series		
Location	**SH**	**CU**	**Location**	**SH**	**CU**
MW-124	✓				
			MW-2A	✓	

Note: SH = Shewhart Statistic
CU = CUSUM Statistic

The short-term (Shewhart) trend for MW-124 changed from its previous classification of "no trend" to an "increasing trend". This well is clustered with MW-224, which is screened four feet below MW-124 and has exhibited a decreasing trend over time (see Intrawell Time Series Plots for MW-124 - MW-224 in Appendix A). The increase in TCE in MW-124 is attributable to an upward vertical movement of the CBP from the lower Shallow Zone to the upper Shallow Zone. Given the close proximity of this well to an area of groundwater discharge, an increase at MW-124 is consistent with the Conceptual Site Model.

MW-2A is located near the northern boundary of the CBP and the short-term TCE trend for this well changed from a "decreasing trend" to "no trend". The time period that TCE decreased in this well coincided with higher groundwater recharge from near normal rainfall levels following the drought that occurred in 2002. Current TCE levels in MW-2A are consistent with historic levels (thereby "no trend").

2.3.2. Change in TCE Trend in a Decreasing Direction

Twenty-two monitoring wells, shown in Table 2-4 below, exhibited a change in TCE trend in a decreasing direction.

Table 2-4.
Change in TCE Trend in a Decreasing Direction

100 Series			200 Series		
Location	**SH**	**CU**	**Location**	**SH**	**CU**
MW-1A	✓				
			MW-207		✓
MW-108	✓				
MW-111	✓	✓			
			MW-216		✓
MW-125	✓		MW-225	✓	
MW-128	✓				
			MW-227	✓	
MW-130	✓				
MW-131	✓		MW-231	✓	
MW-133	✓				
			MW-235C	✓	
			MW-238B	✓	
			MW-247B	✓	
MW-150A		✓	MW-250C		✓
MW-151A		✓	MW-251B		✓
MW-152A	✓	✓			
MW-153	✓				

Note: SH = Shewhart Statistic
CU = CUSUM Statistic

Of the 22 wells exhibiting a decreasing change in TCE trends, 18 wells (82 percent) are along the northeast axis of the CBP. The decreasing changes in these trends are attributable to a combination of: 1) increased groundwater recharge from higher rainfall through April 2010, and 2) changes in the dewatering rates in the southwest portion of the CBP, which induced greater flow toward the southwest. The wells that exhibited a change in TCE trend in a decreasing direction along the southwest axis of the CBP are screened in the upper Shallow Zone (100-series) wells. Changes in TCE concentrations in these wells correlate with changes (increases) in water levels due to higher rainfall through April 2010.

3. Degradation of TCE

Few TCE degradation products have been detected in groundwater samples from within the CBP site; and, where detected, they are predominately from wells within the PH12 area. These degradation products have been detected in four CMT wells within the PH12 area and result from localized elevated pH (averaging 6.13) around the CMT wells. The higher pH associated with the CMT wells occurs where the groundwater contacts grout used to seal the annular space around the CMT wells and, as a consequence, allows for localized growth of dehalococcoides. The elevated pH in the groundwater extends generally less than 15 feet from the CMT wells. The design and installation of a CMT well is significantly different compared to the Type II groundwater wells installed throughout the CBP. Thus, groundwater pH changes due to the presence of grout near the well screen are not a significant issue with the Type II wells. Vinyl chloride has been detected in only one monitoring well (MW-238C) other than the CMT wells at a concentration of 2.7 µg/L. MW-238C is located only 15 feet from CMT-4, where vinyl chloride concentrations have been detected as high as 152 µg/L. Groundwater samples collected throughout the CBP site from Type II well are significantly more acidic (average pH of 4.97), which prevents growth of dehalococcoides. There is no evidence that significant biodegradation is occurring within the CBP (see Figures B-1 through B-4 in Appendix B).

The following compounds associated with the TCE degradation have been detected:

1,1-dichloroethene (1,1-DCE) is a typical impurity in TCE. Its concentration is directly correlated to the corresponding TCE concentration at a specific monitoring well (Figures B-1 and B-2).

cis 1,2-dichloroethene (cis 1,2-DCE) is a biodegradation product of TCE and is above detectable levels in the PH12 area and parts of the Kilby Ditch. The highest concentrations are associated with the CMT wells (Figure B-3).

Vinyl Chloride (VC), like cis 1,2-DCE, is a biodegradation product of TCE detected only in samples from the CMT wells and MW-238C (Figure B-4). Vinyl chloride has been detected only since October 2005 (see trend graphs in Appendix B). The presence of vinyl chloride coincides with the presence of dehalococcoides, which is affected by the pH of the groundwater.

4. Findings

Based on the Trend Analysis results, the following findings are offered:

- Of the wells from which water samples contained detectable TCE, approximately 60 percent are lower Shallow Zone wells. Recharge from precipitation to the top of the aquifer causes stratification of TCE such that higher concentrations are near the base of the aquifer.

- Site wide, most of the wells exhibit TCE trends that are either decreasing or have no significant change (89% for short-term trends and 78%, for long-term trends). The trends observed coincide with the trends predicted by the numeric groundwater site-wide model and the Conceptual Site Model.

- Wells with no trend or decreasing trends are principally around open fields where recharge to the shallow zone is higher than the surrounding residential properties. Wells in the PH12 area, which is the area contiguous with the groundwater divide, also generally exhibit no trend or decreasing trends.

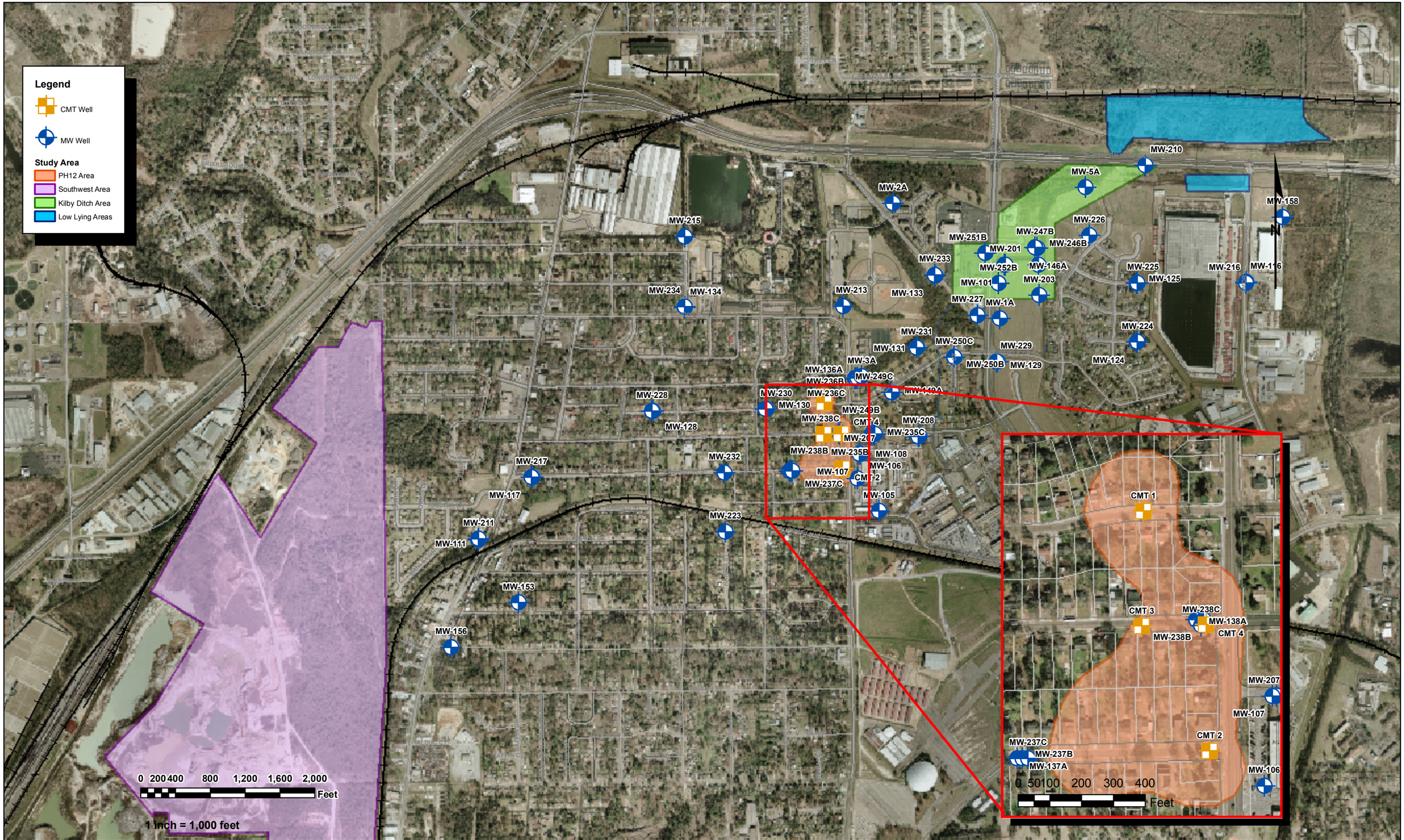
- The low percentage of wells with increasing trends in TCE concentration are along the southwest-northeast axis of the CBP. This axis coincides with the dominant directions of groundwater flow.

- Only two monitoring wells (MW-124 and MW-2A) exhibited a change in TCE trend in an increasing direction. The trends observed coincide with the trends predicted by the site-wide model and the Conceptual Site Model (ALDOT Corrective Measures Evaluation, R2008).

- Twenty-two monitoring wells exhibited a change in TCE trend in a decreasing direction. The decreasing changes in these trends are attributable to a combination of: 1) increased groundwater recharge from higher rainfall through April 2010; and, 2) changes in the dewatering rates in the southwest portion of the CBP.

- There is no evidence that significant biodegradation is occurring within the CBP. TCE degradation has not been observed within the CBP, with the exception of a small area associated with the CMT wells in the PH12 Area. This degradation is attributable to the relative higher pH near the CMT wells caused by the grout used in construction.

FIGURES



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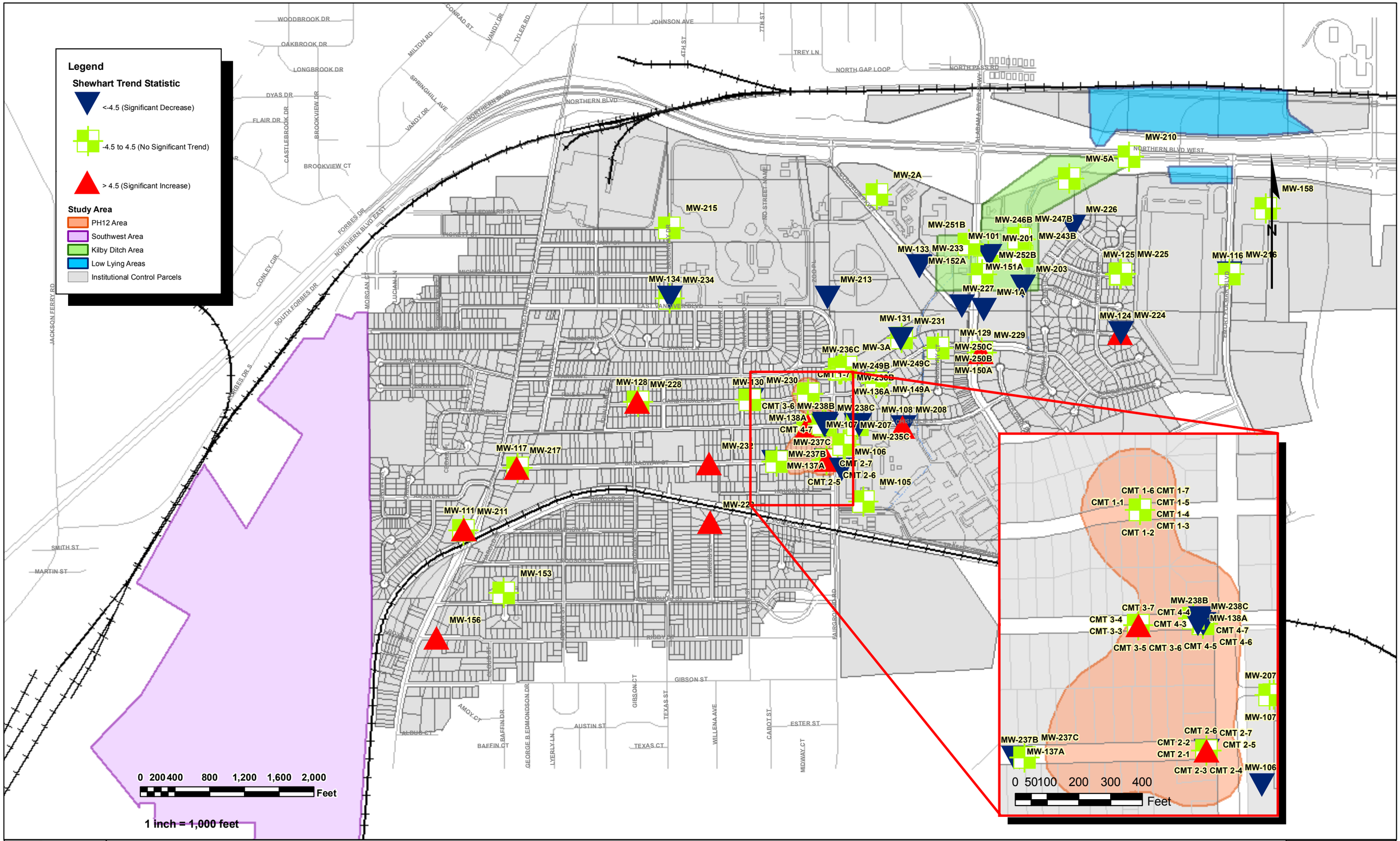
Wells Used in Trend Analysis

FIGURE 2-1

September 2010



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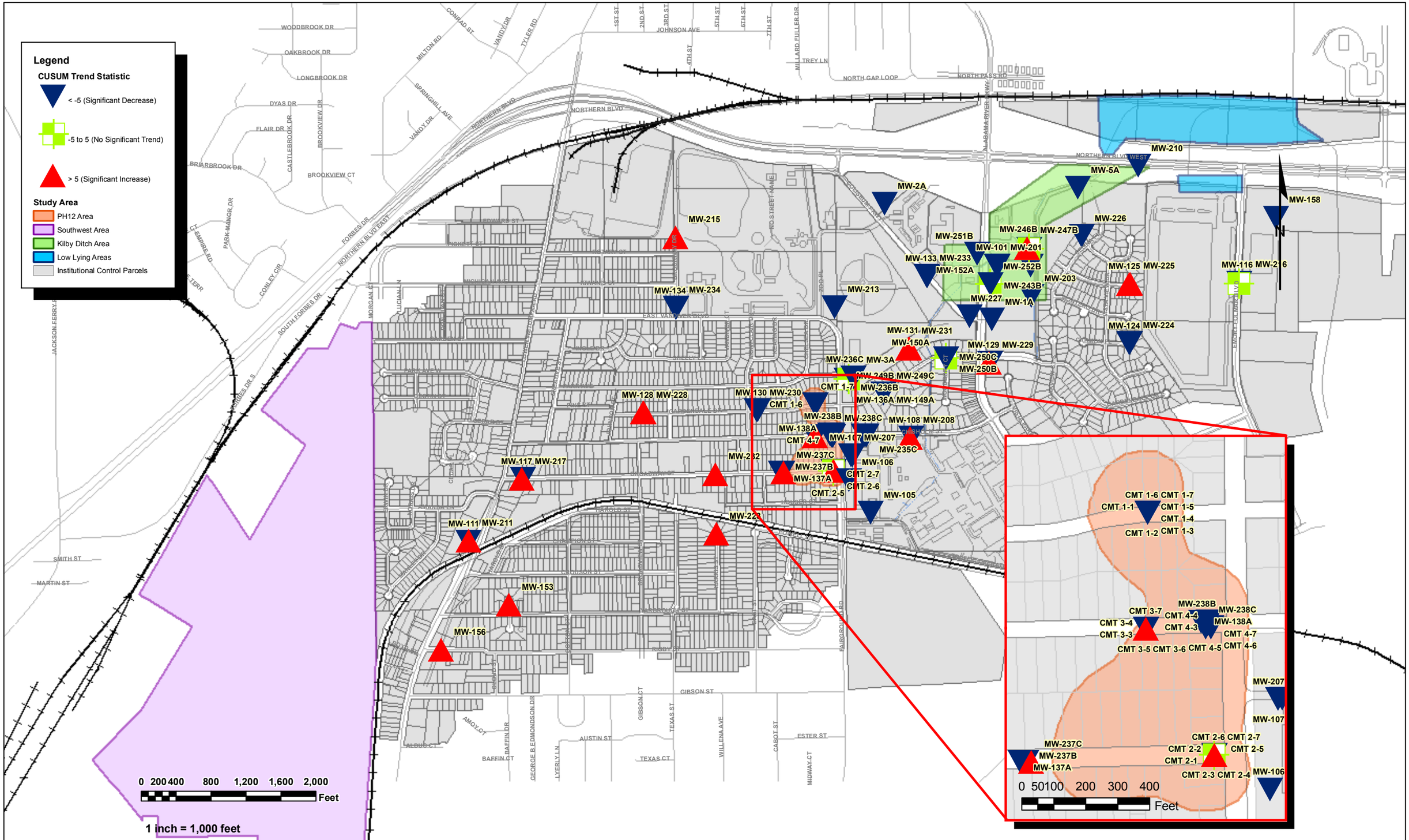
Short-Term (Shewhart) TCE Trend; All Data

FIGURE 2-2

September 2010



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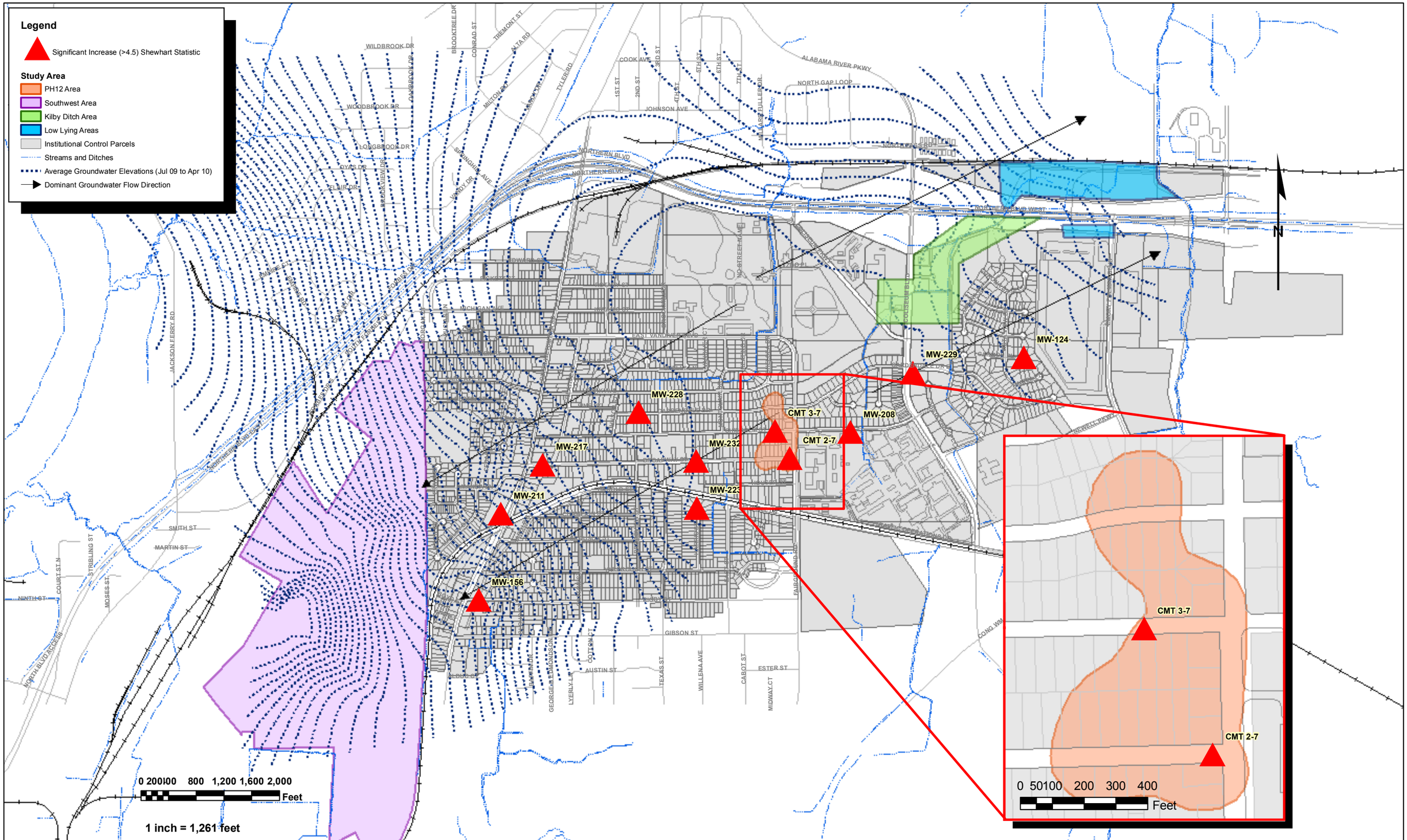
Long-Term (CUSUM) TCE Trend Summary; All Data

FIGURE 2-3

September 2010



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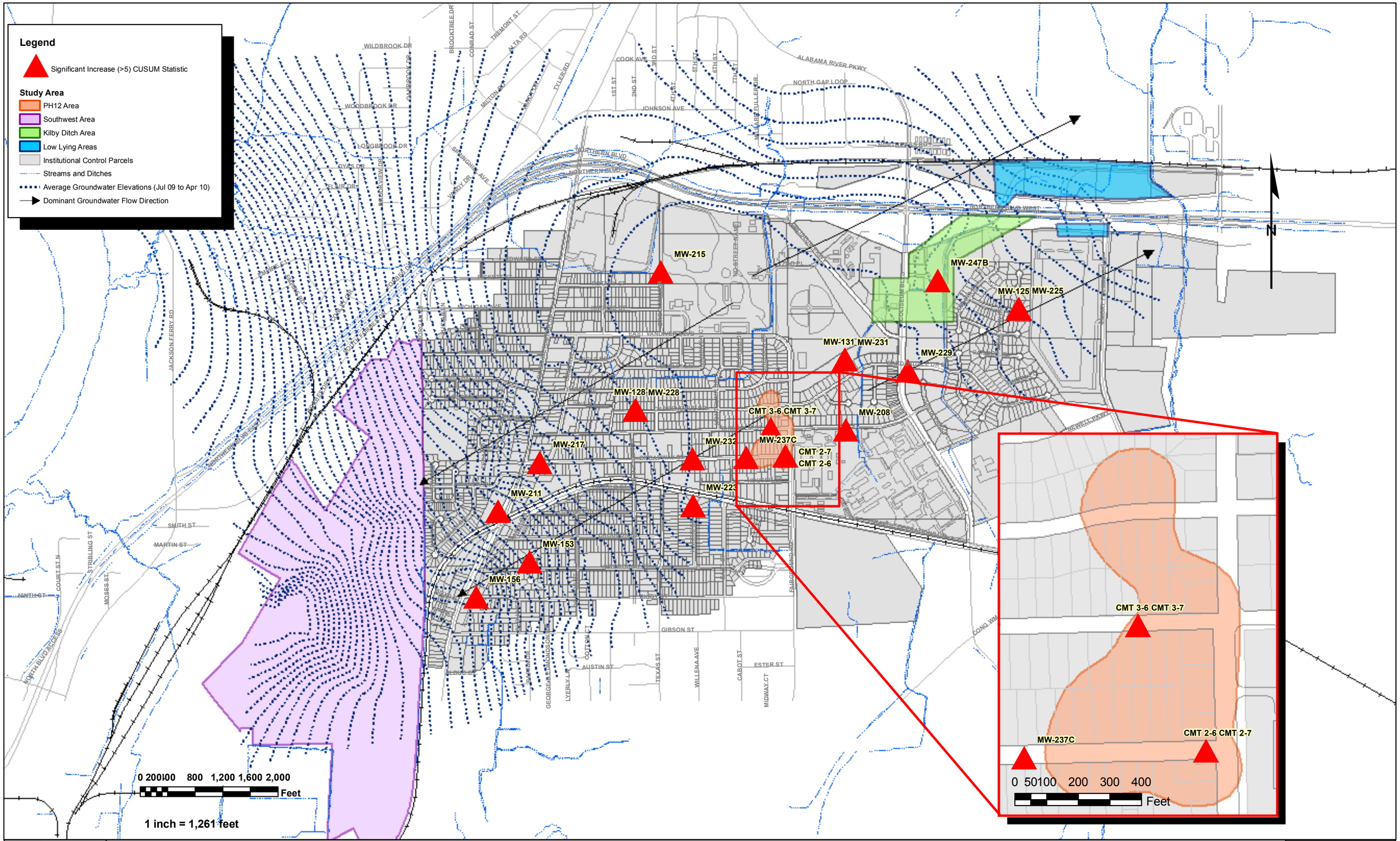
Wells with Significant Increasing Short-Term (Shewhart Statistic) TCE Trends; July 2009 through April 2010 Data

FIGURE 2-4

September 2010



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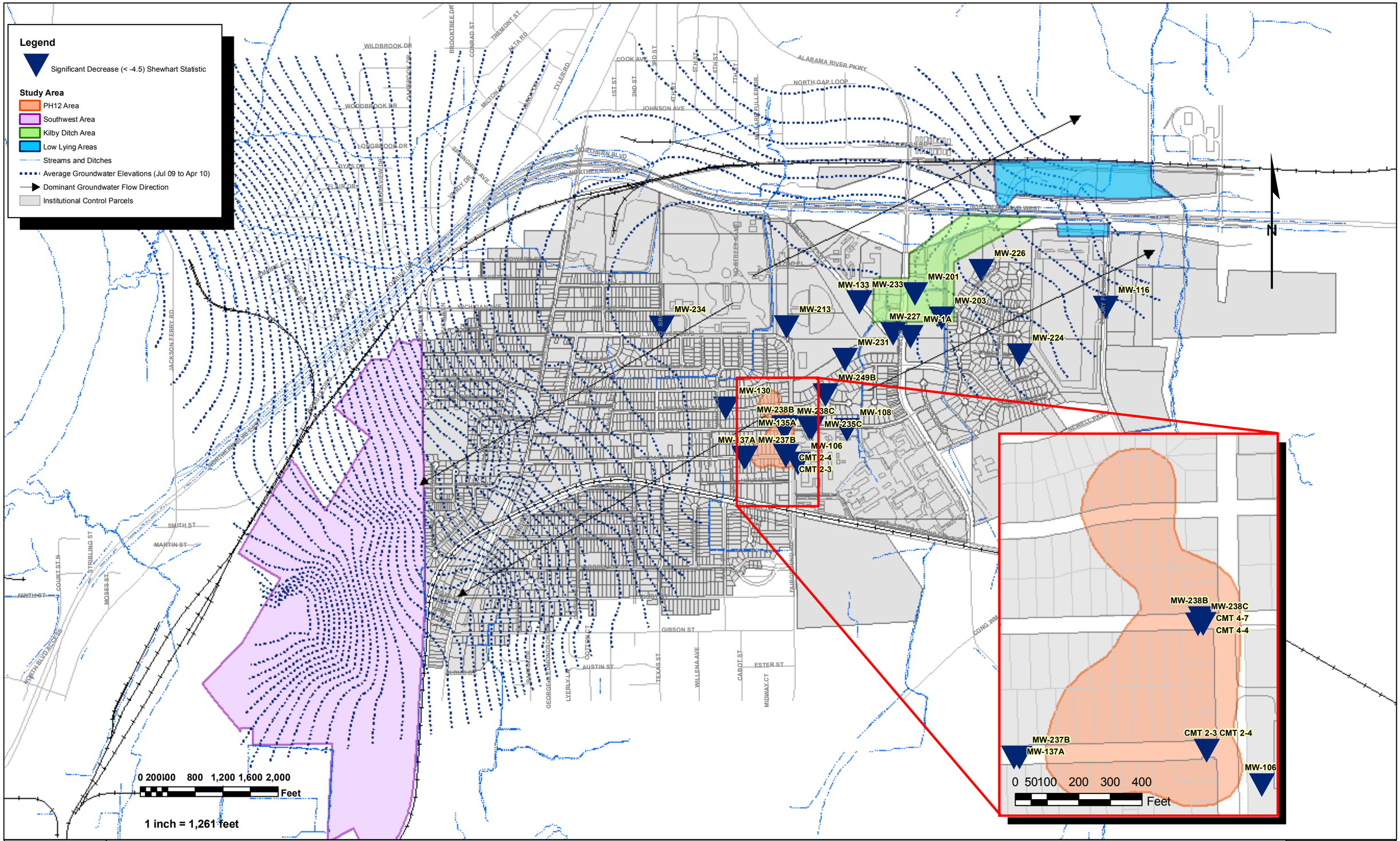
Wells with Significant Increasing Long-Term (CUSUM Statistic) TCE Trends; July 2009 through April 2010 Data

FIGURE 2-5

September 2010



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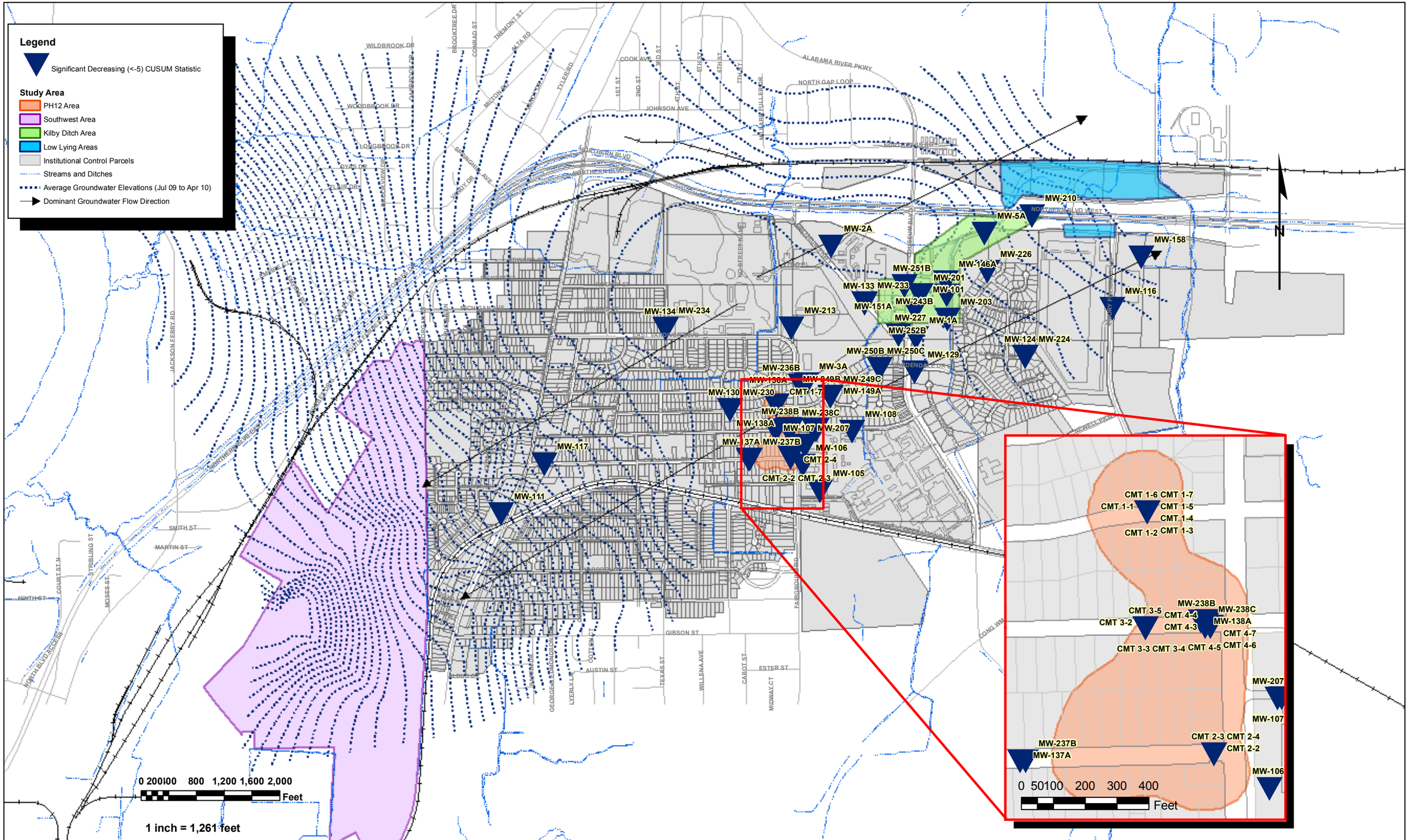
Wells with Significant Decreasing Short-Term (Shewhart Statistic) TCE Trends; July 2009 through April 2010 Data

FIGURE 2-6

September 2010



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Wells with Significant Decreasing Long-Term (CUSUM Statistic) TCE Trends; July 2009 through April 2010 Data

FIGURE 2-7

September 2010

Appendix A

Trend Plots for TCE Concentrations

SUMMARY OF SHEWHART TREND ANALYSIS METRICS FOR TCE

Significant Increase		Non-Sig. Increase		Non-Sig. Decrease		Significant Decrease	
Well	Shewhart	Well	Shewhart	Well	Shewhart	Well	Shewhart
MW-124	6.78	MW-129	0.15	MW-101	-1.54	MW-106	-8.73
MW-156	9.50	MW-131	1.34	MW-105	-2.10	MW-108	-5.83
MW-208	22.51	MW-150A	0.33	MW-107	-0.47	MW-116	-5.19
MW-211	13.61	MW-152A	1.01	MW-111	-3.37	MW-130	-7.10
MW-217	43.75	MW-153	2.73	MW-117	-3.39	MW-133	-4.63
MW-223	294.04	MW-225	1.56	MW-125	-1.70	MW-135A	-8.93
MW-228	7.45	MW-230	1.90	MW-128	-4.16	MW-137A	-12.49
MW-229	15.61	MW-236C	0.72	MW-134	-2.35	MW-1A	-5.92
MW-232	24.59	MW-237C	0.99	MW-136A	-1.04	MW-201	-6.69
CMT 2-7	**20.40**	MW-246B	1.25	**MW-138A**	**-2.23**	MW-203	-11.79
CMT 3-7	**81.05**	MW-247B	0.66	MW-146A	-1.04	MW-213	-8.15
		CMT 2-5	**3.36**	MW-149A	-0.40	MW-224	-6.58
		CMT 2-6	**2.78**	MW-151A	-2.27	MW-226	-7.46
		CMT 3-6	**1.67**	MW-158	-1.02	MW-227	-5.07
				MW-207	-0.80	MW-231	-12.48
				MW-210	-0.45	MW-233	-11.79
				MW-215	-3.45	MW-234	-4.69
				MW-216	-0.59	MW-235C	-5.10
				MW-235B	-3.34	MW-237B	-8.78
				MW-236B	-1.69	**MW-238B**	**-7.13**
				MW-243B	-3.28	**MW-238C**	**-15.62**
				MW-249C	-1.23	MW-249B	-6.99
				MW-250B	-0.81	**CMT 2-3**	**-11.37**
				MW-250C	-1.56	**CMT 2-4**	**-4.57**
				MW-251B	-2.68	**CMT 4-4**	**-8.26**
				MW-252B	-0.62	**CMT 4-7**	**-16.62**
				MW-2A	-3.76		
				MW-3A	-0.35		
				MW-5A	-3.28		
				CMT 1-1	**-2.00**		
				CMT 1-2	**-1.53**		
				CMT 1-3	**-3.72**		
				CMT 1-4	**-0.73**		
				CMT 1-5	**-0.90**		
				CMT 1-6	**-2.59**		
				CMT 1-7	**-1.27**		
				CMT 2-1	**-0.31**		
				CMT 2-2	**-0.97**		
				CMT 3-2	**-1.79**		
				CMT 3-3	**-2.02**		
				CMT 3-4	**-1.66**		
				CMT 3-5	**-1.90**		
				CMT 4-2	**-1.66**		
				CMT 4-3	**-1.29**		
				CMT 4-5	**-1.74**		

SUMMARY OF SHEWHART TREND ANALYSIS METRICS FOR TCE

Significant Increase		Non-Sig. Increase		Non-Sig. Decrease		Significant Decrease	
Well	Shewhart	Well	Shewhart	Well	Shewhart	Well	Shewhart
				CMT 4-6	-2.44		

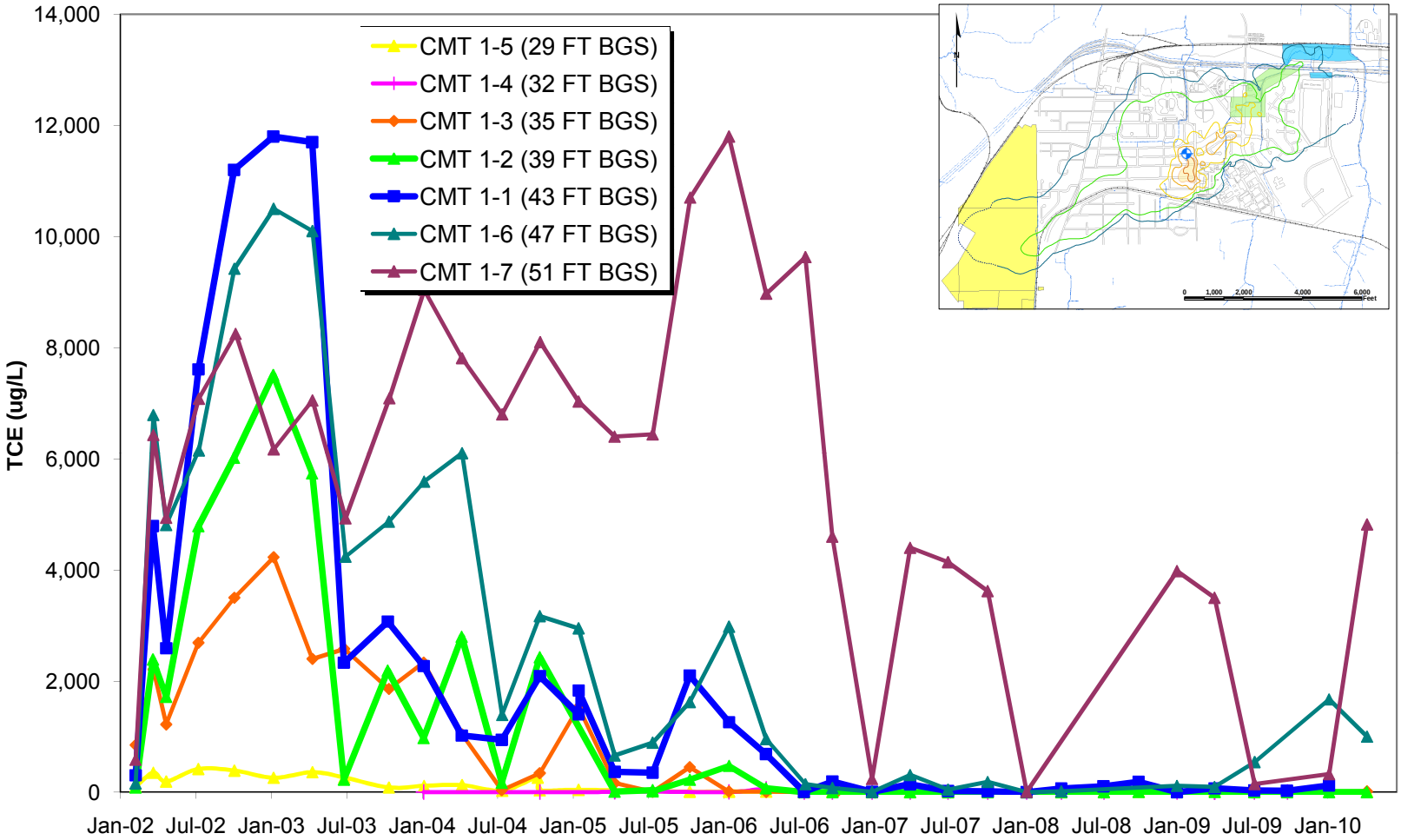
SUMMARY OF CUSUM TREND ANALYSIS METRICS FOR TCE

Significant Increase		Non-Sig. Increase		Non-Sig. Decrease		Significant Decrease	
Well	CUSUM	Well	CUSUM	Well	CUSUM	Well	CUSUM
MW-125	347.55	MW-152A	4.71	MW-150A	-2.38	MW-101	-77.90
MW-128	27.45	**CMT 2-1**	**0.55**	MW-216	-3.01	MW-105	-37.20
MW-131	114.39			MW-236C	-4.69	MW-106	-328.02
MW-153	50.82			MW-246B	-4.36	MW-107	-29.00
MW-156	51.06			**CMT 2-5**	**-2.34**	MW-108	-106.99
MW-208	581.16					MW-111	-12.83
MW-211	195.54					MW-116	-102.90
MW-215	19.33					MW-117	-40.77
MW-217	584.76					MW-124	-54.60
MW-223	1586.40					MW-129	-44.77
MW-225	30.83					MW-130	-116.56
MW-228	30.85					MW-133	-123.03
MW-229	397.51					MW-134	-78.84
MW-231	316.18					MW-135A	-81.89
MW-232	686.32					MW-136A	-23.52
MW-237C	152.00					MW-137A	-235.86
MW-247B	28.13					**MW-138A**	**-73.54**
CMT 2-6	**24.39**					MW-146A	-32.29
CMT 2-7	**165.86**					MW-149A	-15.91
CMT 3-6	**92.18**					MW-151A	-15.72
CMT 3-7	**401.54**					MW-158	-10.40
						MW-1A	-73.71
						MW-201	-167.12
						MW-203	-205.63
						MW-207	-6.53
						MW-210	-15.75
						MW-213	-105.85
						MW-224	-162.14
						MW-226	-67.42
						MW-227	-30.92
						MW-230	-19.60
						MW-233	-281.20
						MW-234	-68.70
						MW-235B	-34.65
						MW-235C	-38.80
						MW-236B	-15.91
						MW-237B	-215.33
						MW-238B	**-133.24**
						MW-238C	**-178.51**
						MW-243B	-34.21
						MW-249B	-63.83
						MW-249C	-25.42
						MW-250B	-11.29
						MW-250C	-6.01
						MW-251B	-6.23

SUMMARY OF CUSUM TREND ANALYSIS METRICS FOR TCE

Significant Increase		Non-Sig. Increase		Non-Sig. Decrease		Significant Decrease	
Well	CUSUM	Well	CUSUM	Well	CUSUM	Well	CUSUM
						MW-252B	-21.72
						MW-2A	-61.55
						MW-3A	-20.41
						MW-5A	-70.21
						CMT 1-1	**-78.09**
						CMT 1-2	**-63.35**
						CMT 1-3	**-113.84**
						CMT 1-4	**-18.25**
						CMT 1-5	**-45.39**
						CMT 1-6	**-82.32**
						CMT 1-7	**-38.84**
						CMT 2-2	**-41.37**
						CMT 2-3	**-187.52**
						CMT 2-4	**-130.33**
						CMT 3-2	**-36.97**
						CMT 3-3	**-68.49**
						CMT 3-4	**-61.20**
						CMT 3-5	**-39.59**
						CMT 4-2	**-37.64**
						CMT 4-3	**-54.37**
						CMT 4-4	**-160.07**
						CMT 4-5	**-65.57**
						CMT 4-6	**-54.81**
						CMT 4-7	**-215.21**

Time Series Plots
CMT 1-1 - CMT 1-7



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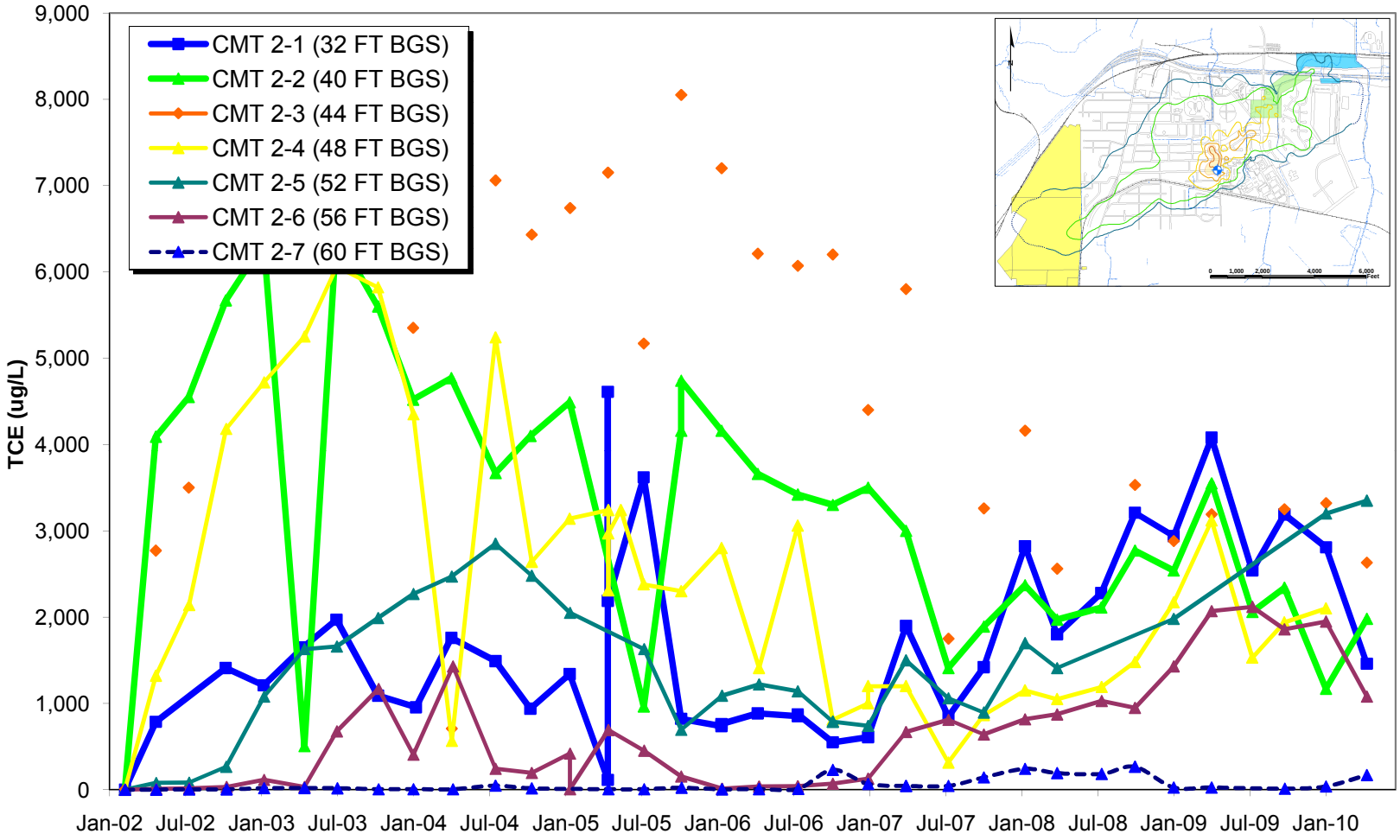
CMT 2-1 - CMT 2-7



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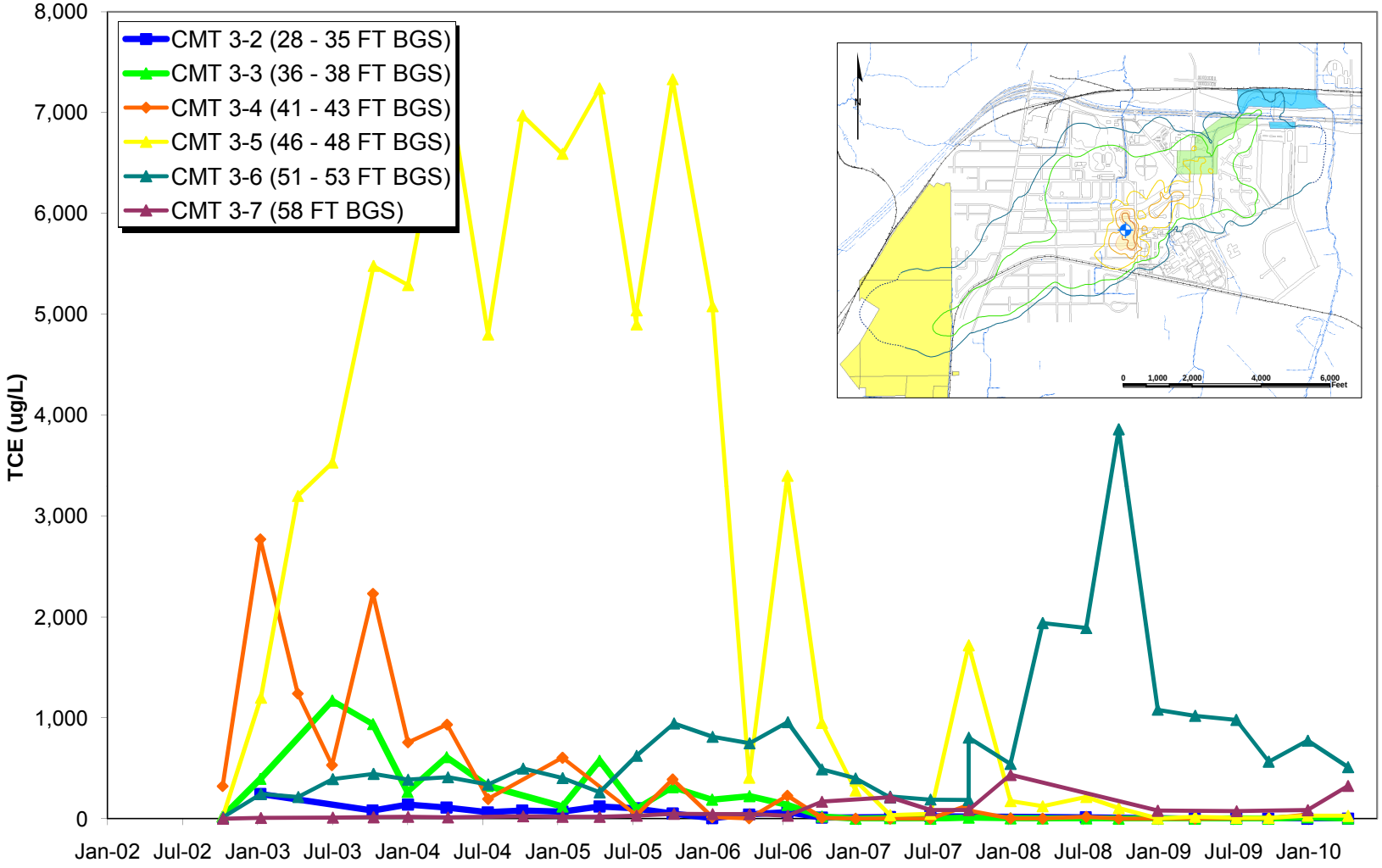
CMT 3-2 - CMT 3-7



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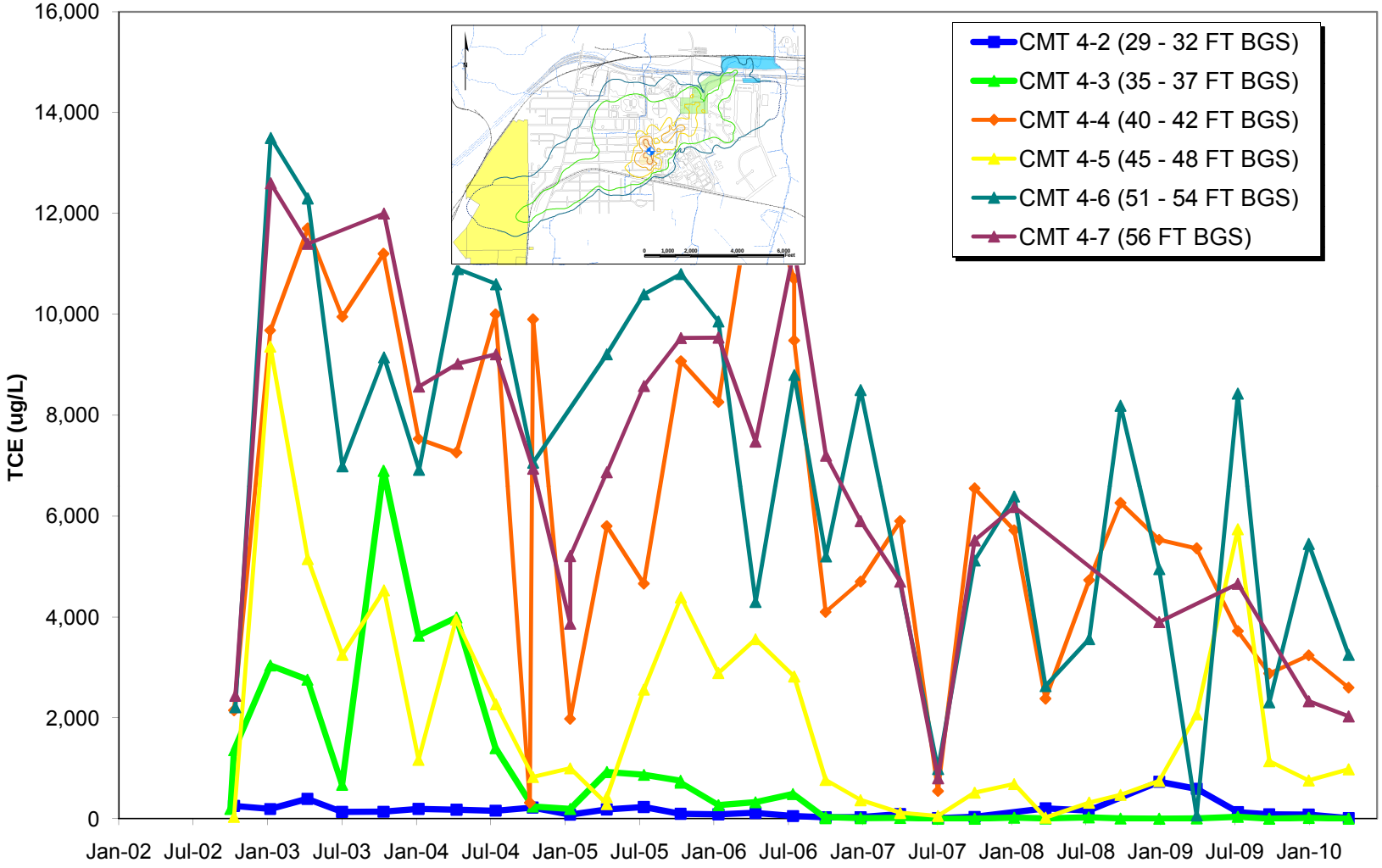
CMT 4-2 - CMT 4-7



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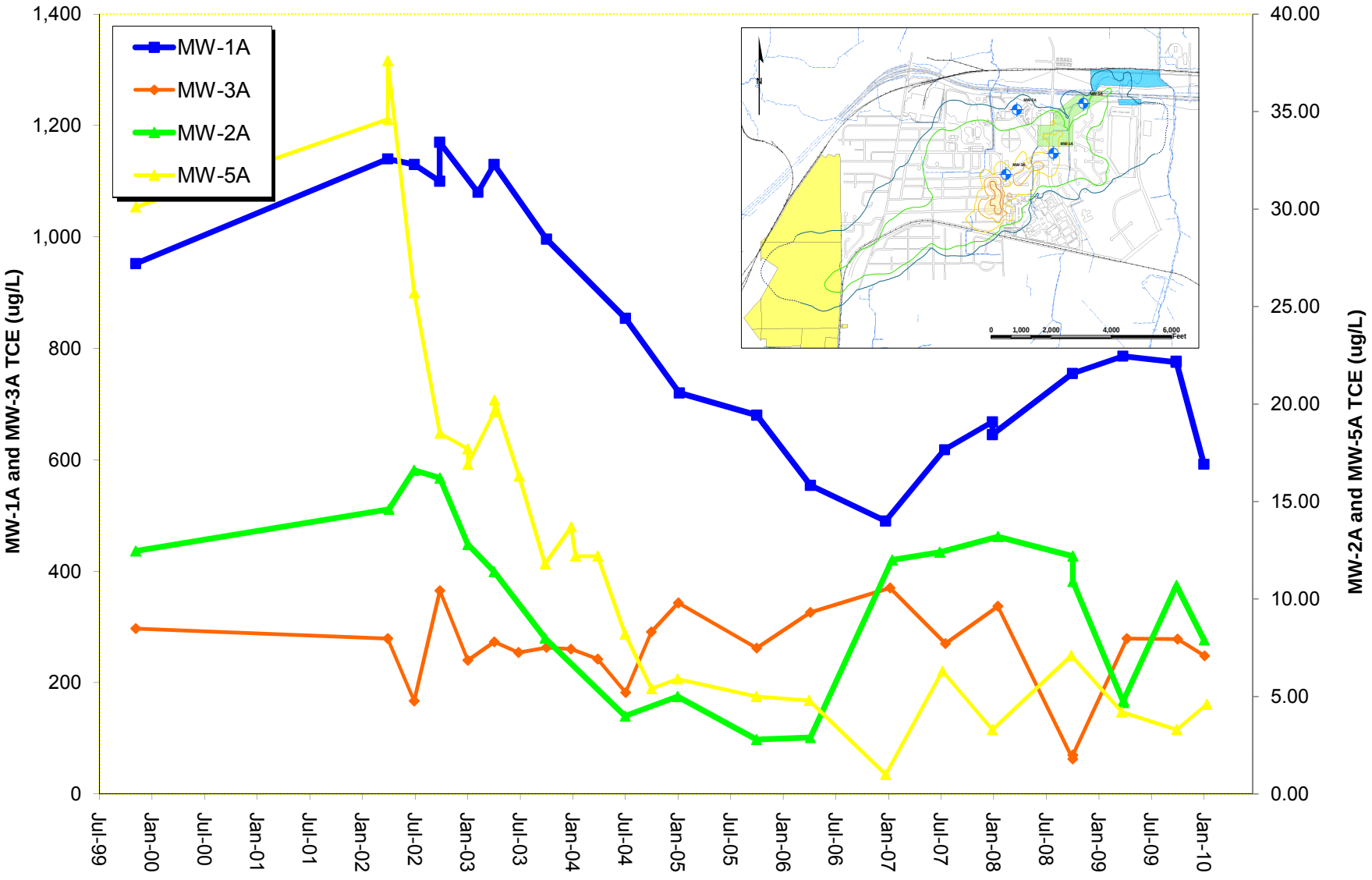
MW-1A - MW-5A



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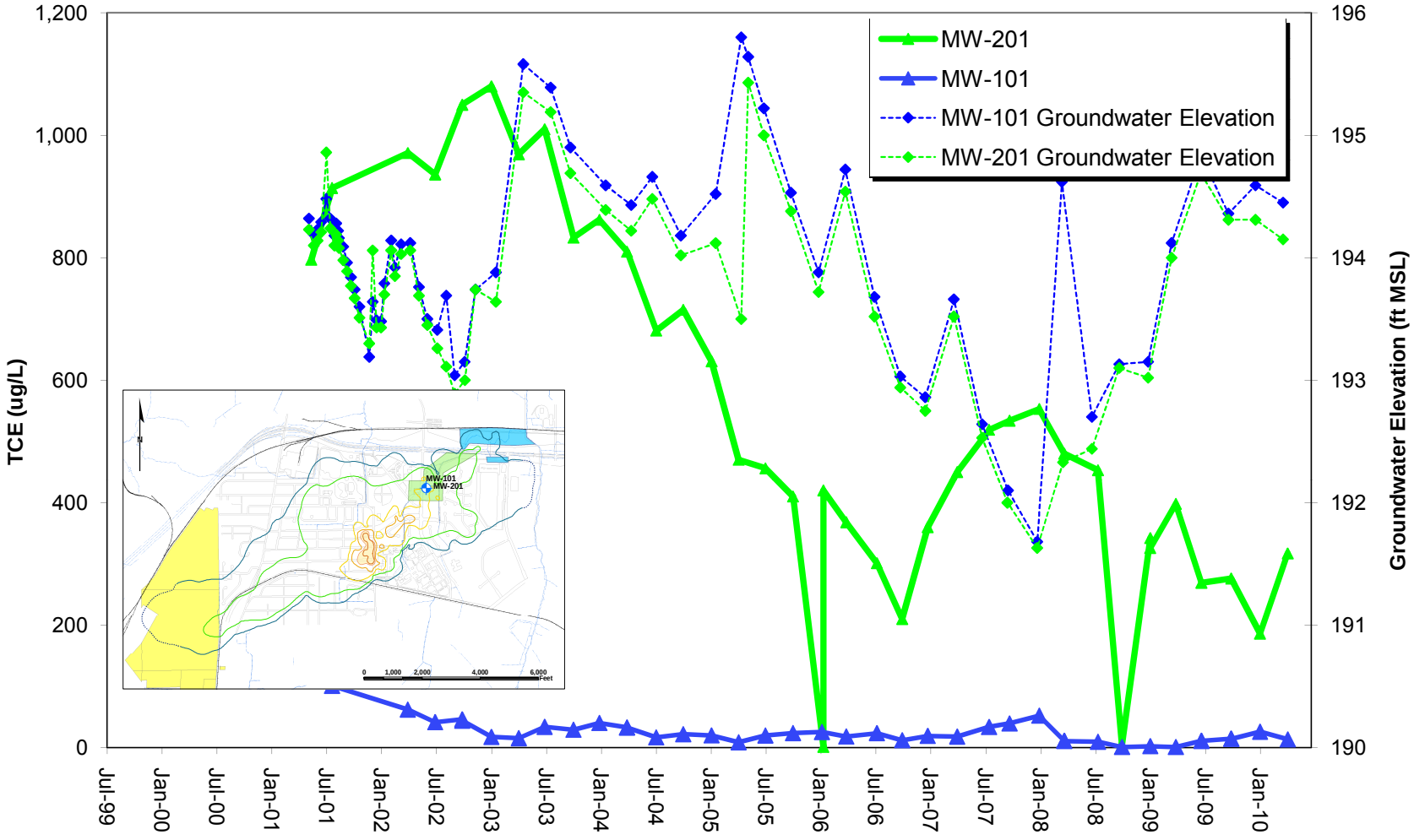
MW-101 - MW-201



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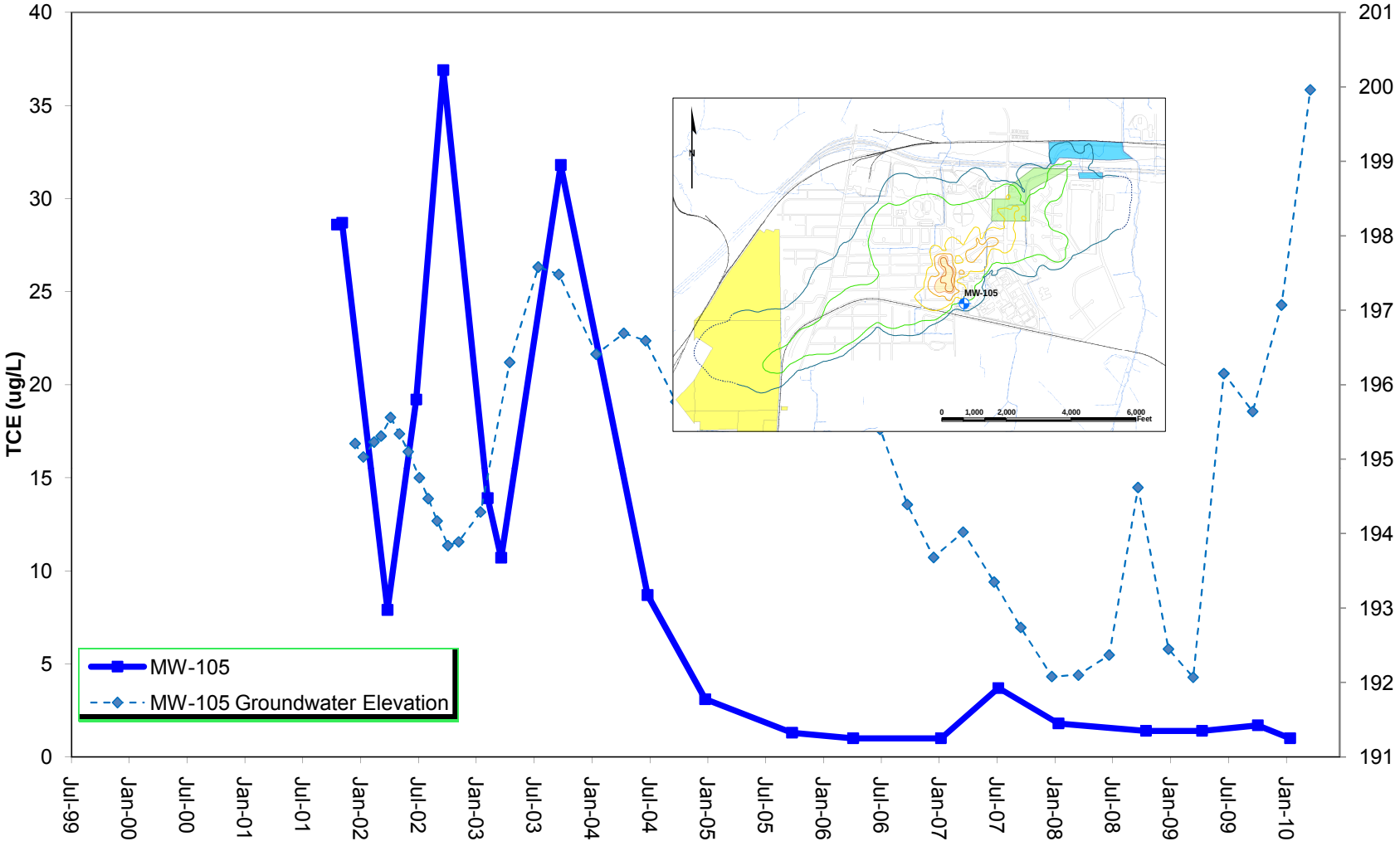
MW-105



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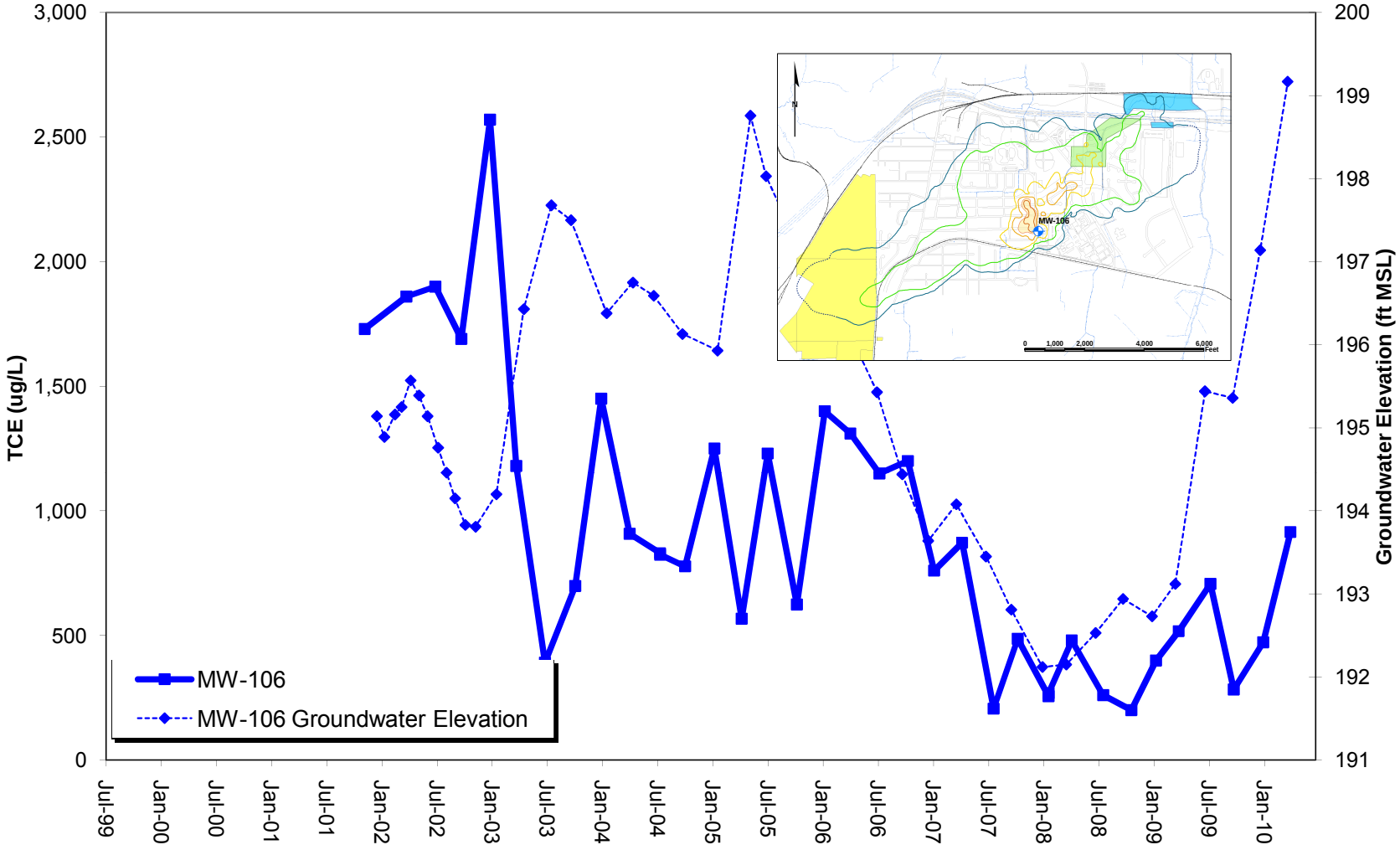

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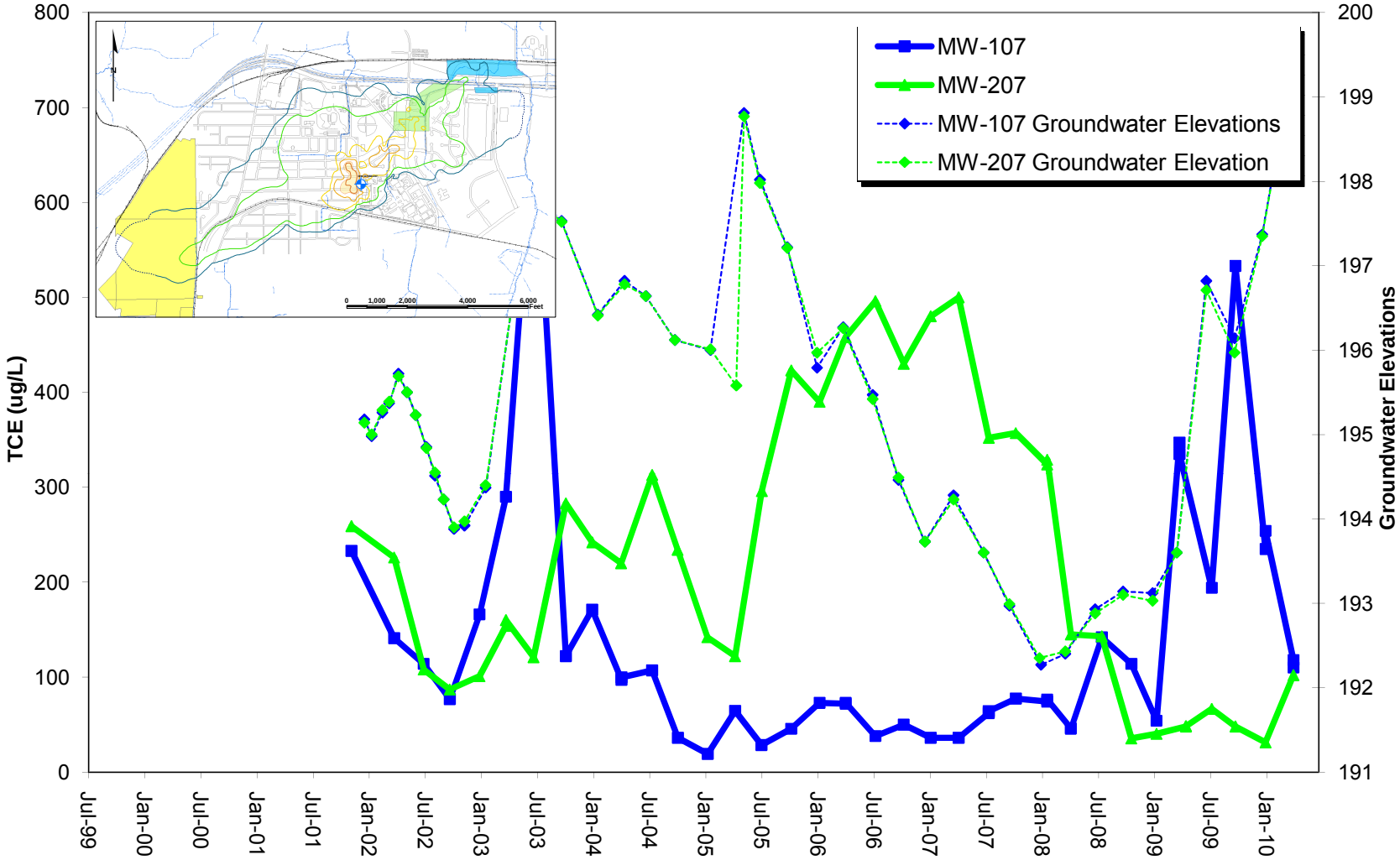
MW-107 - MW-207



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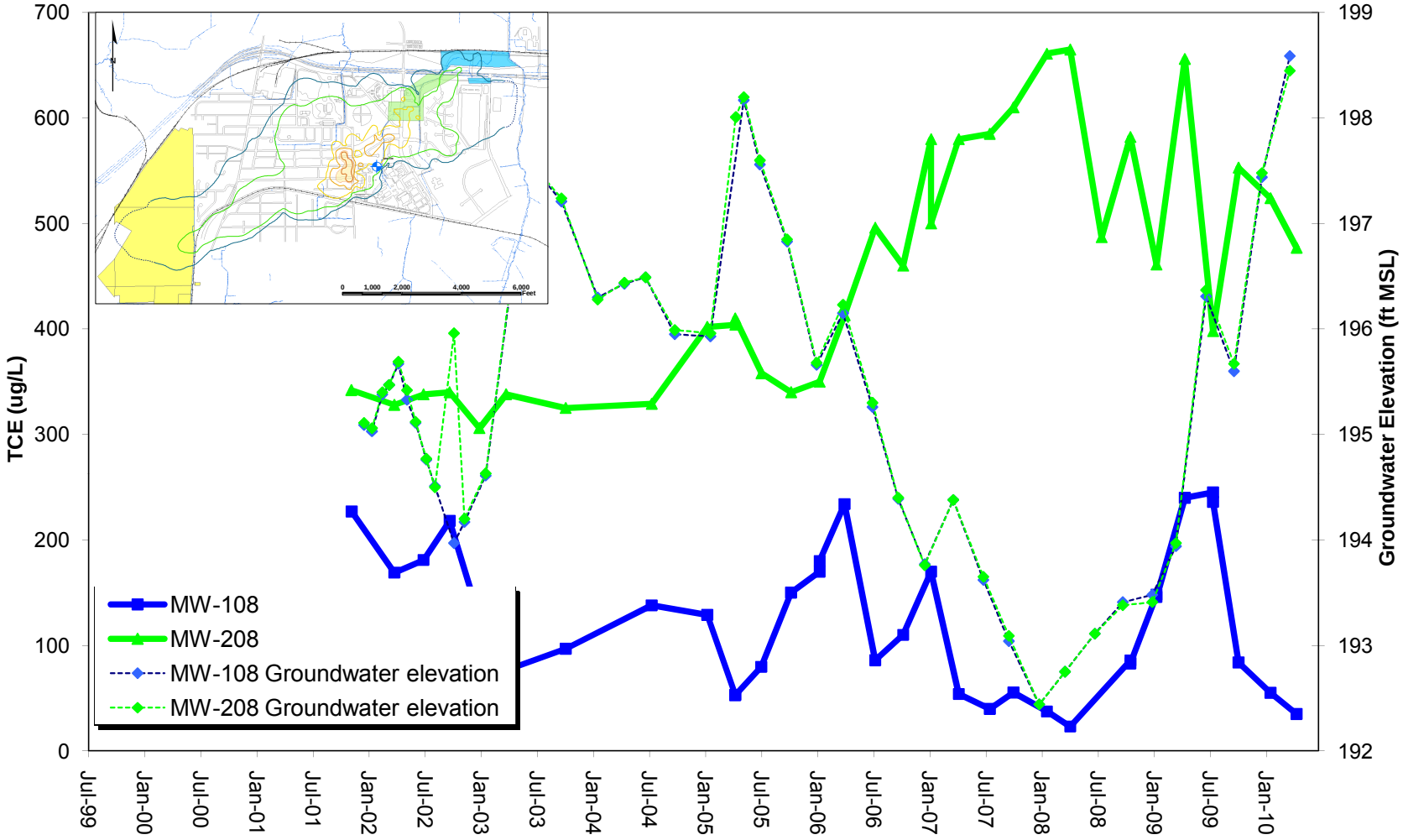
MW-108 - MW-208



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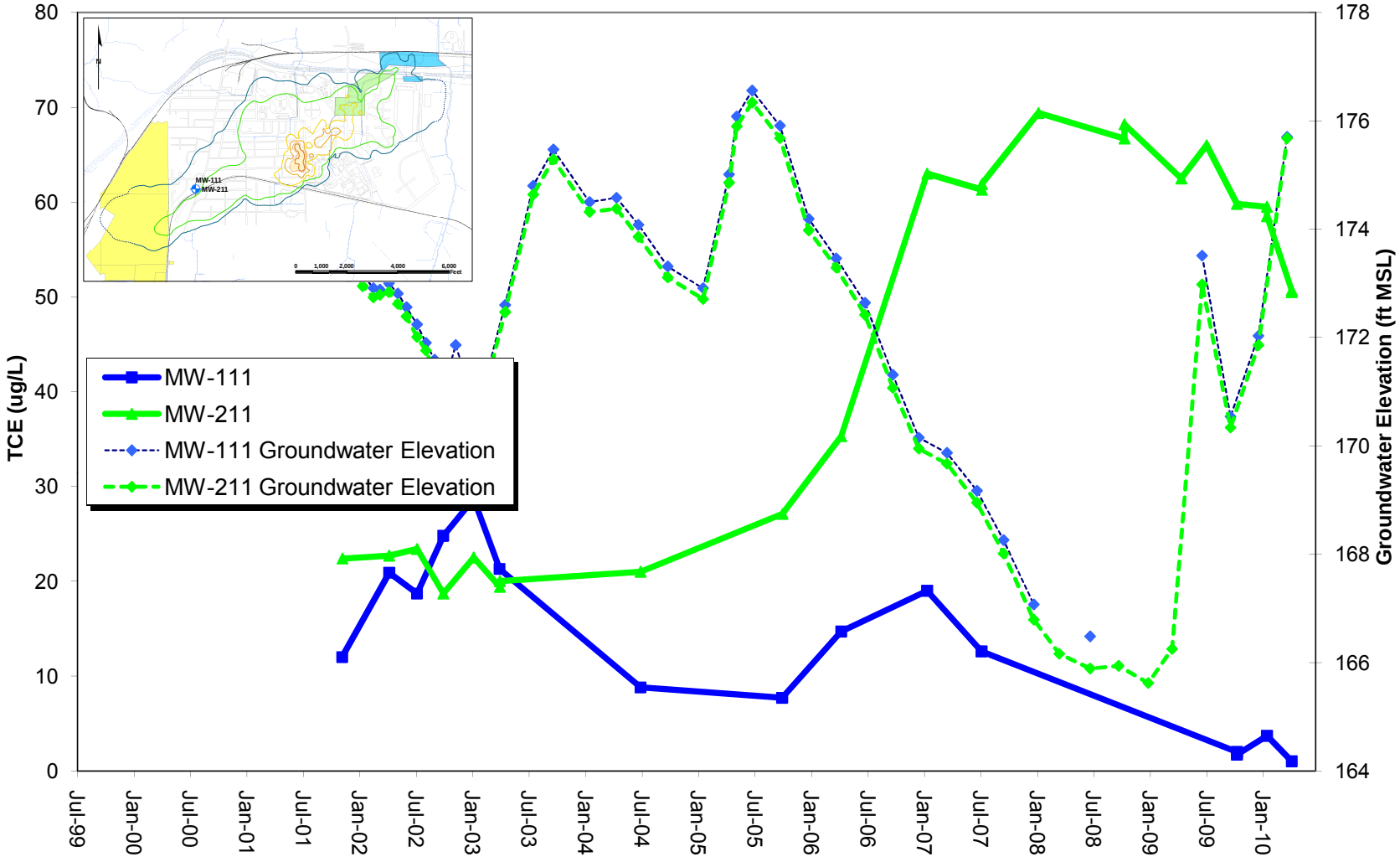
MW-111 - MW-211



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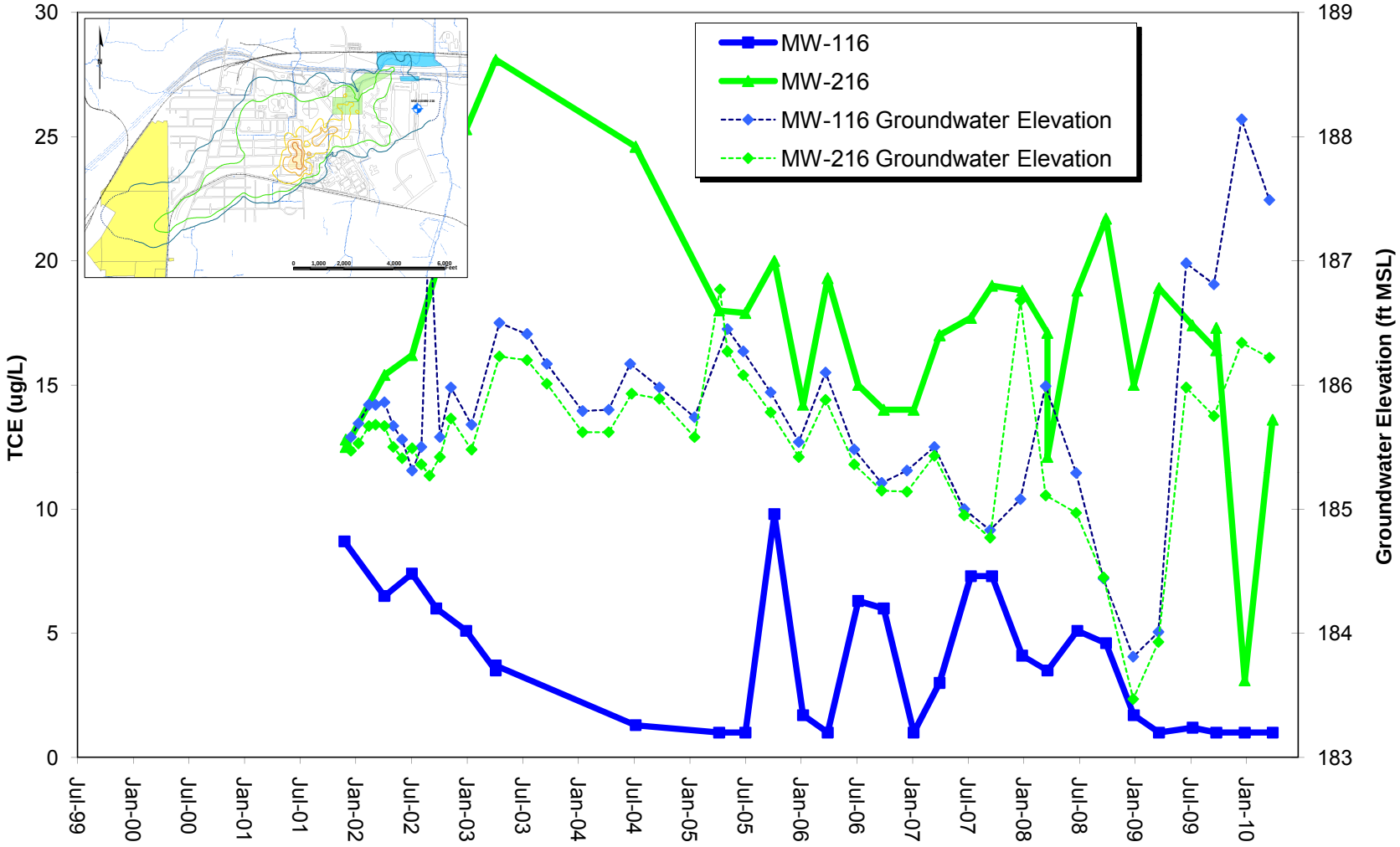
MW-116 - MW-216



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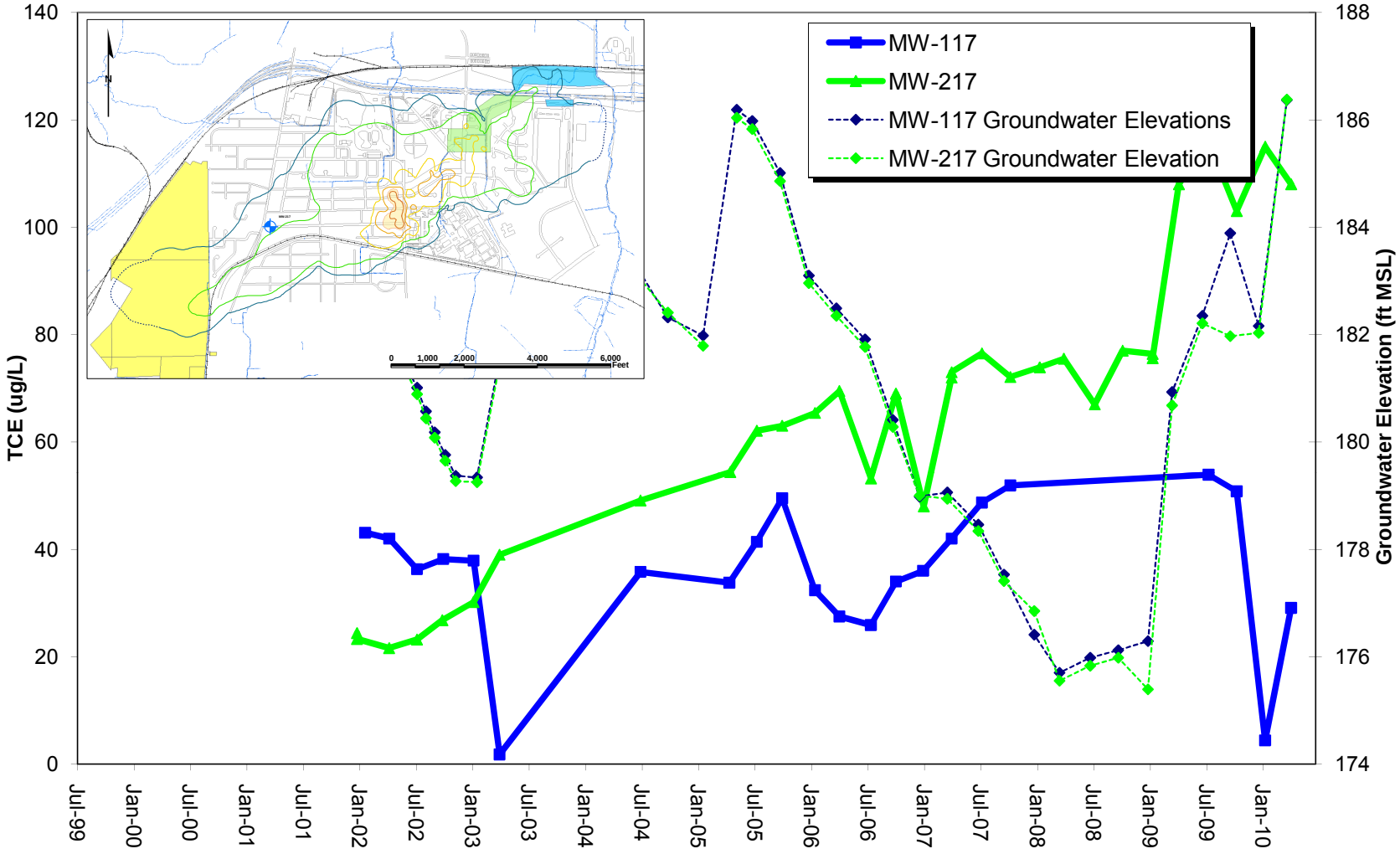
MW-117 - MW-217



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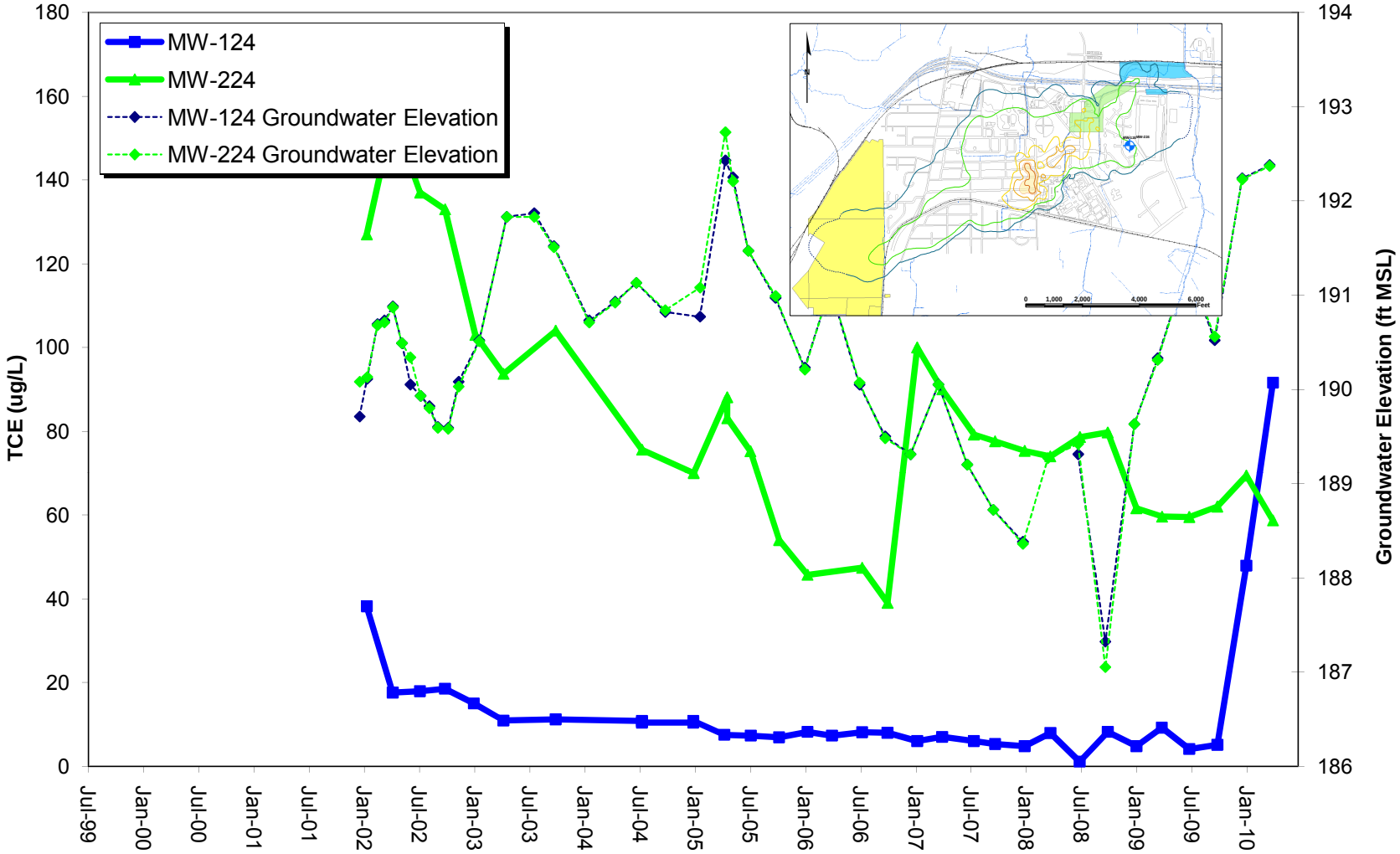
MW-124 - MW-224



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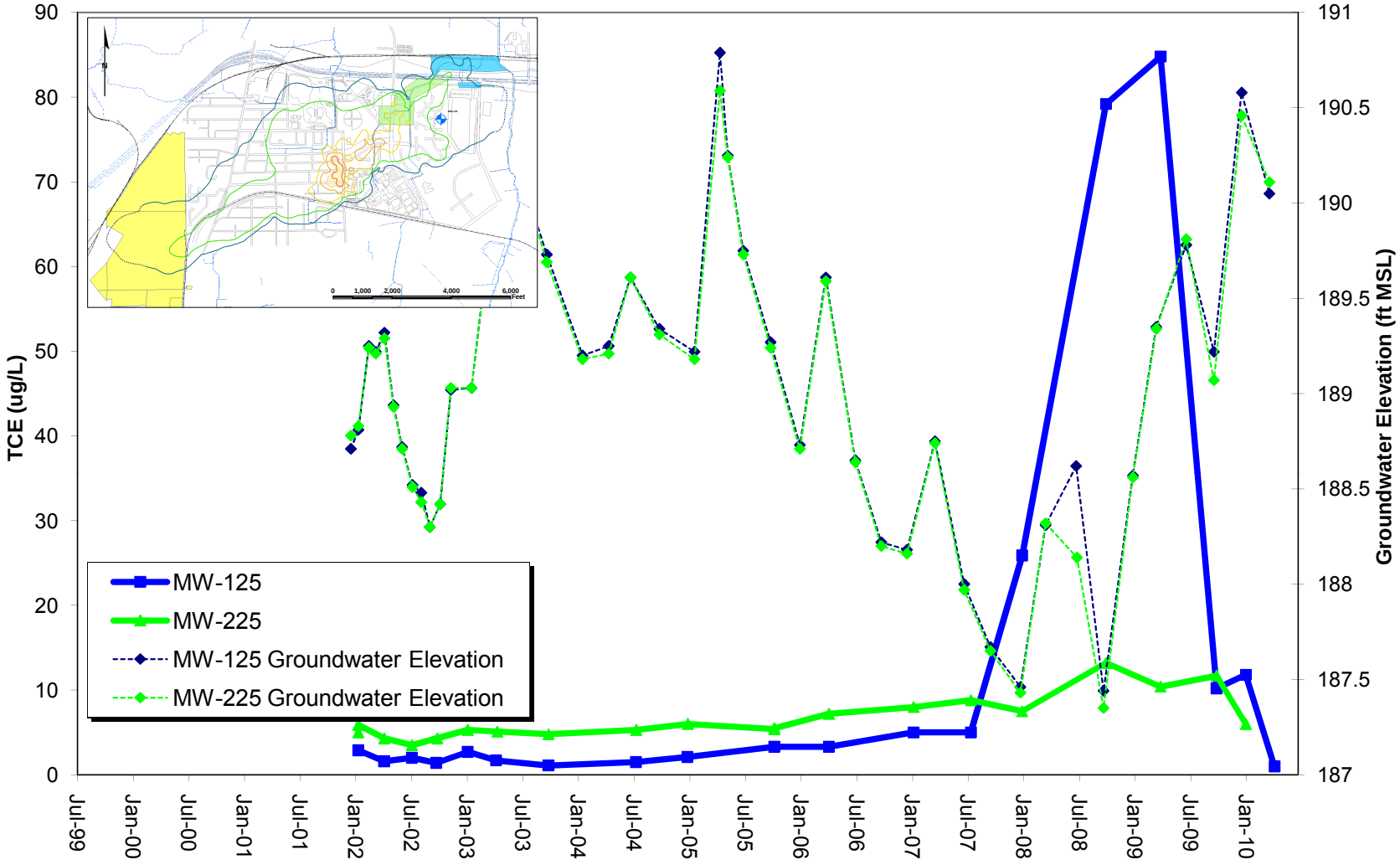
MW-125 - MW-225



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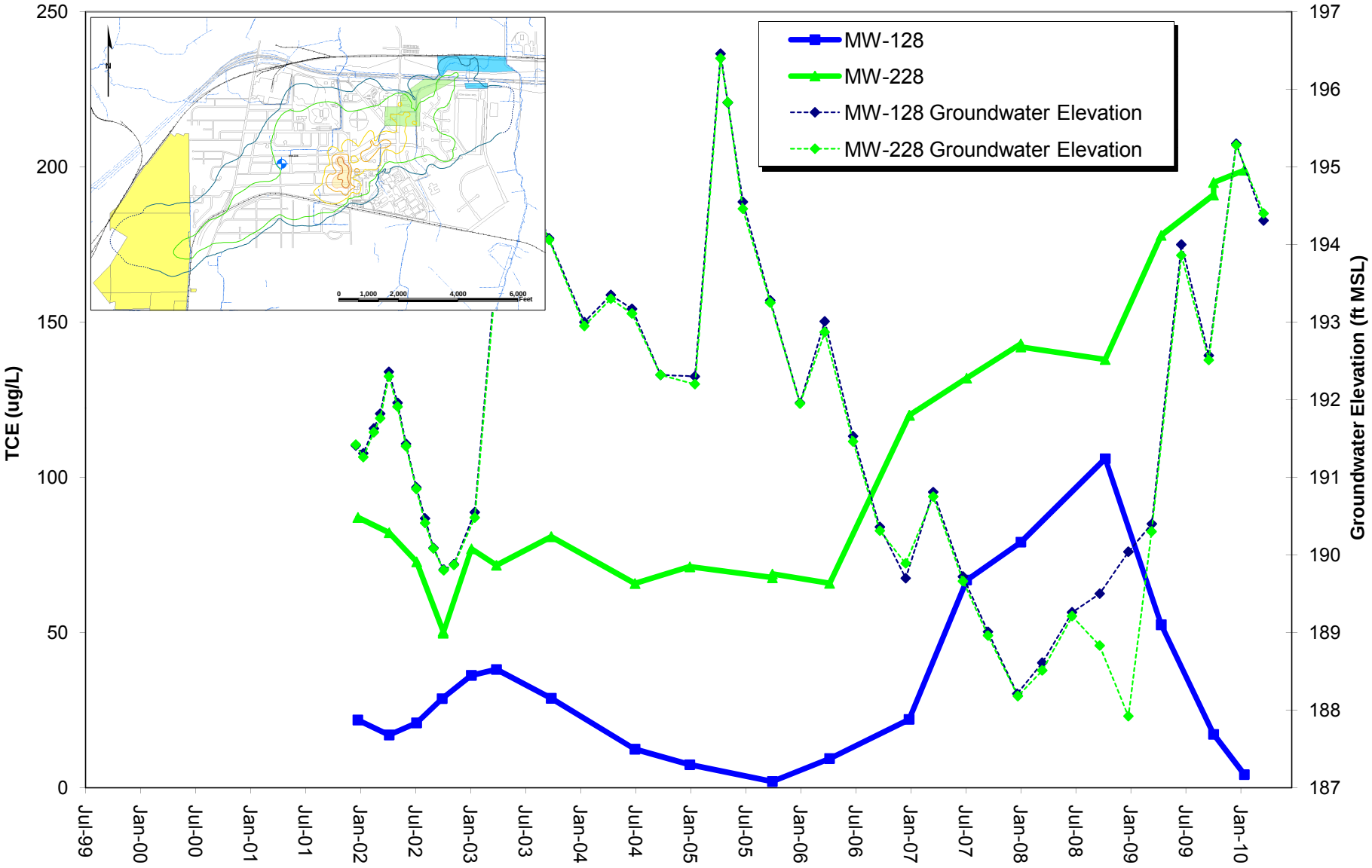
MW-128 - MW-228



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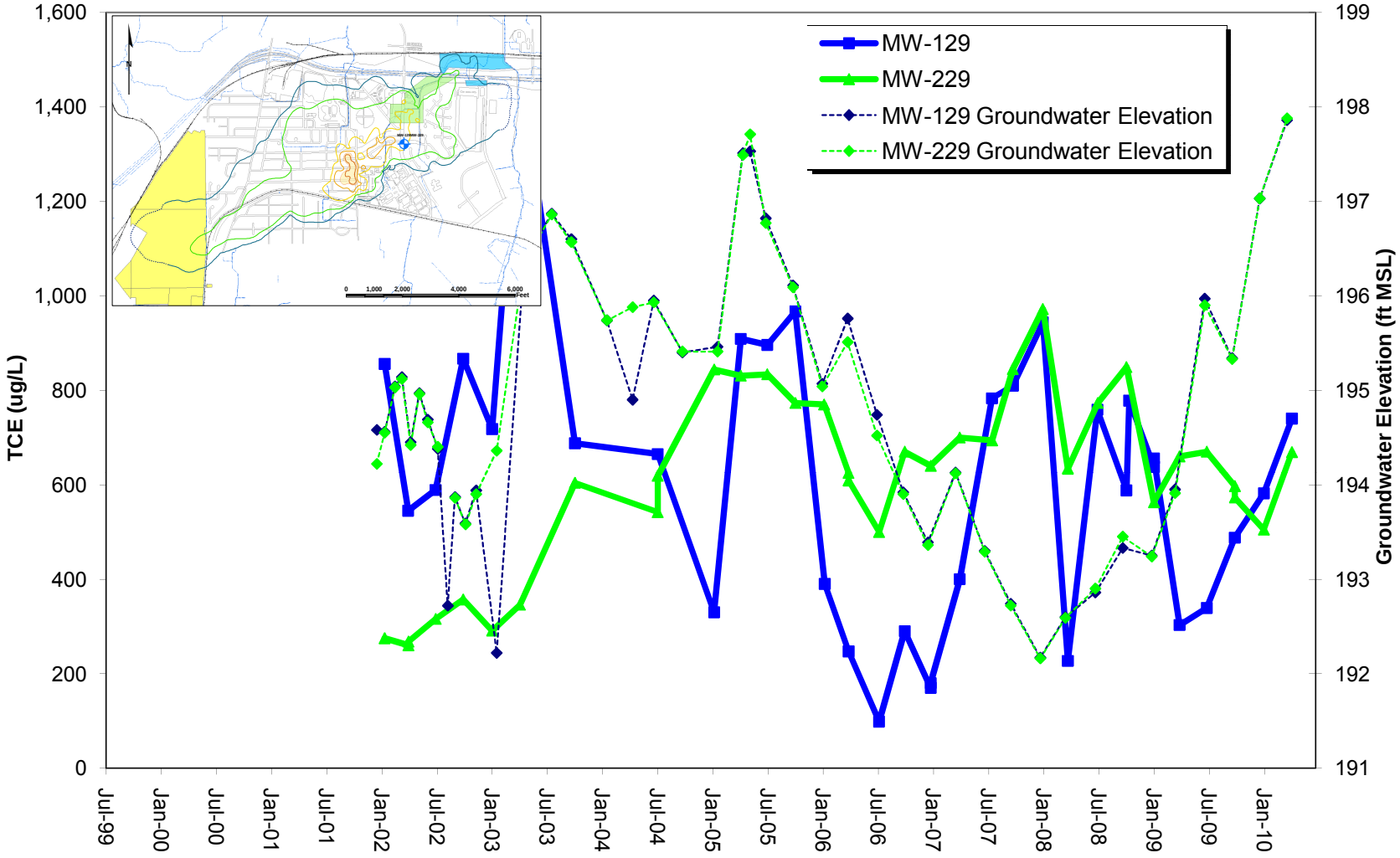
MW-129 - MW-229



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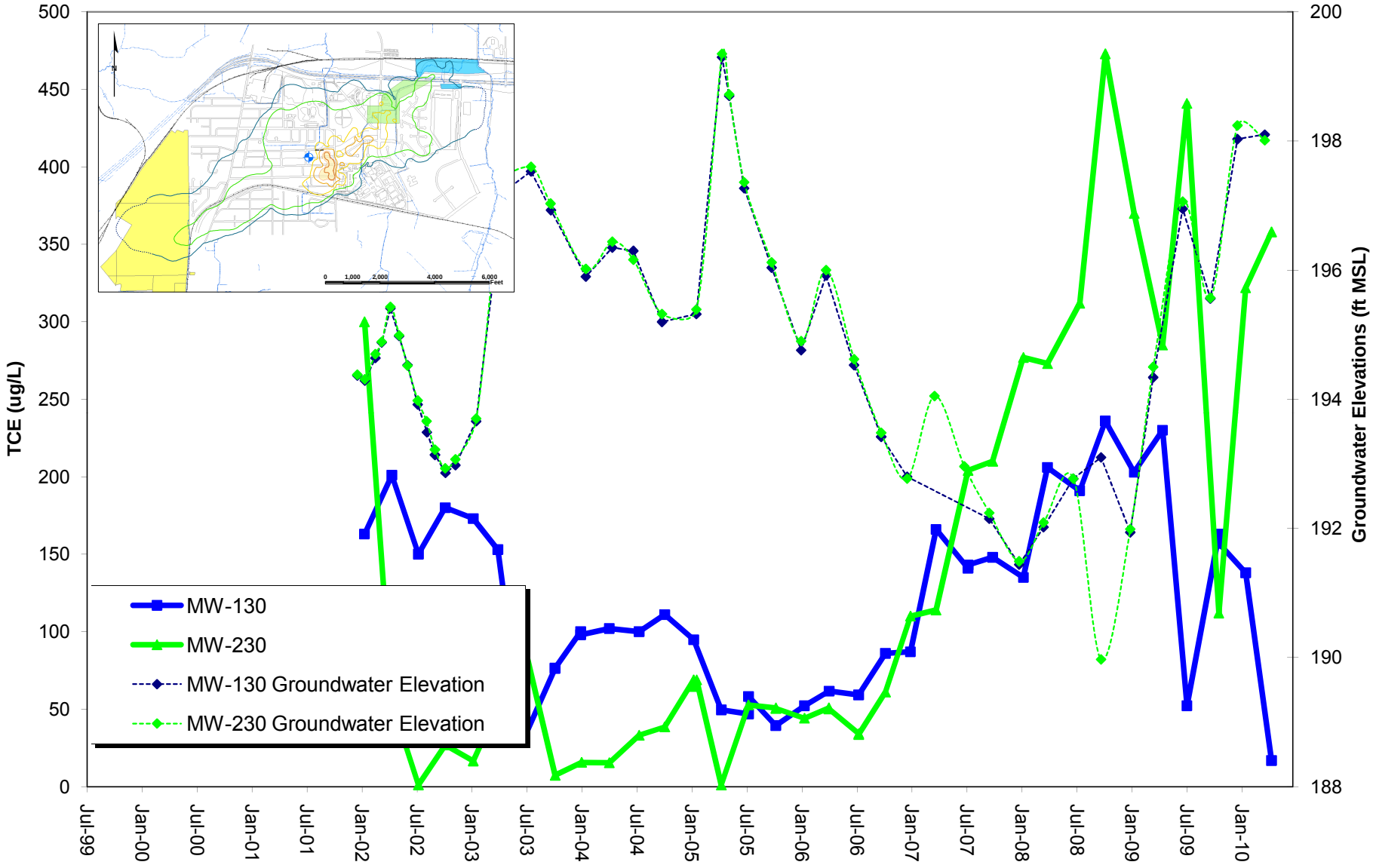

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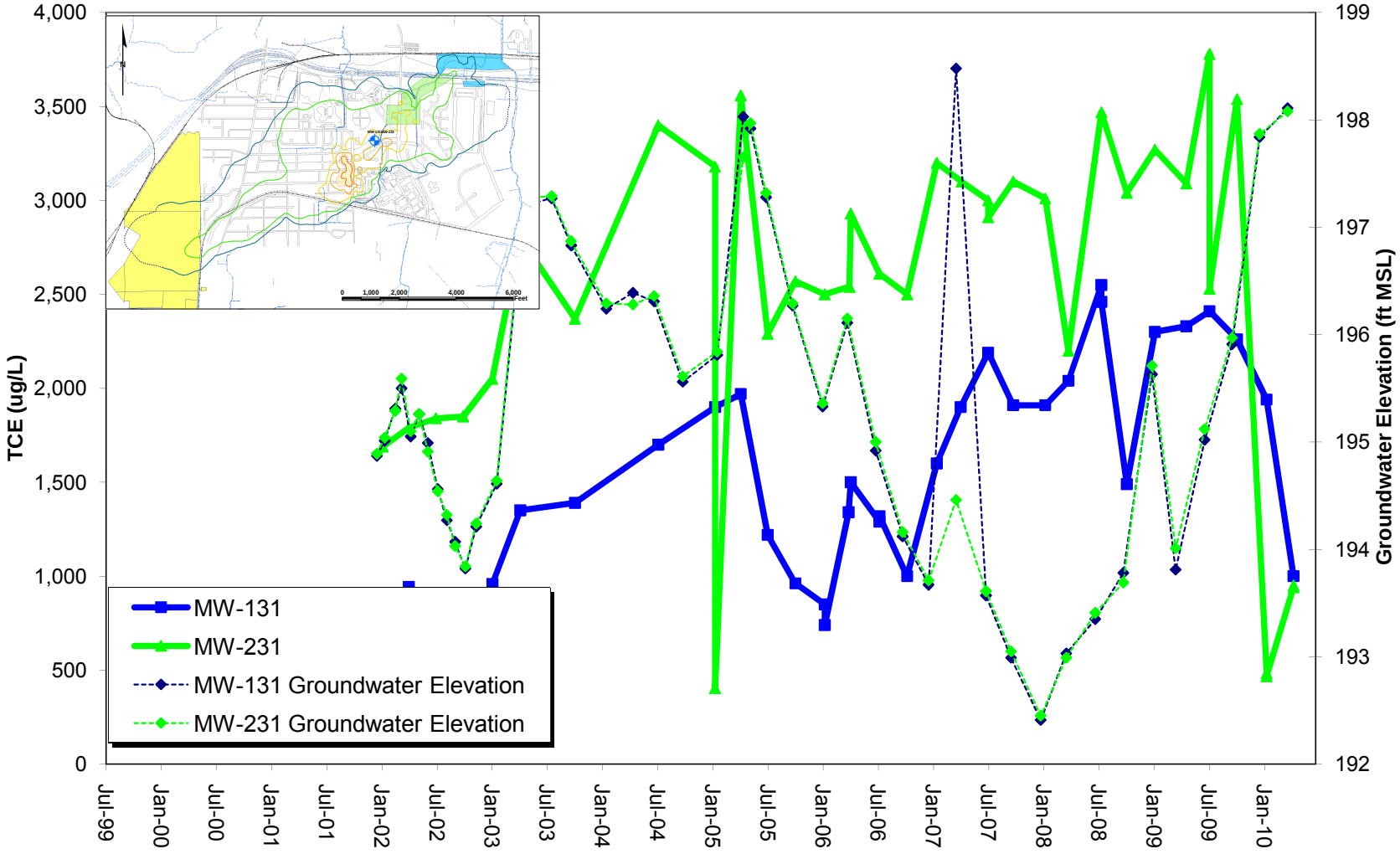

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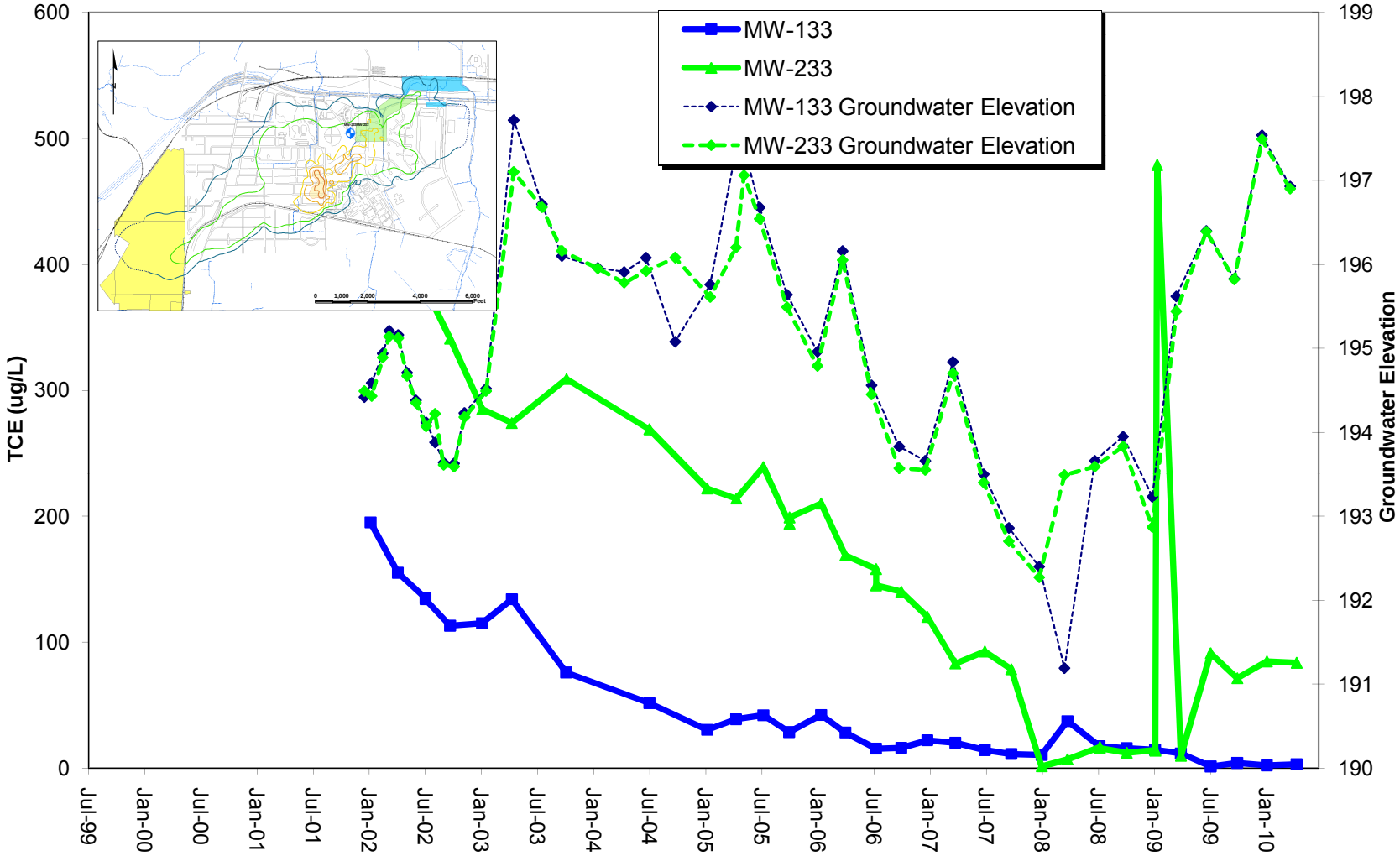

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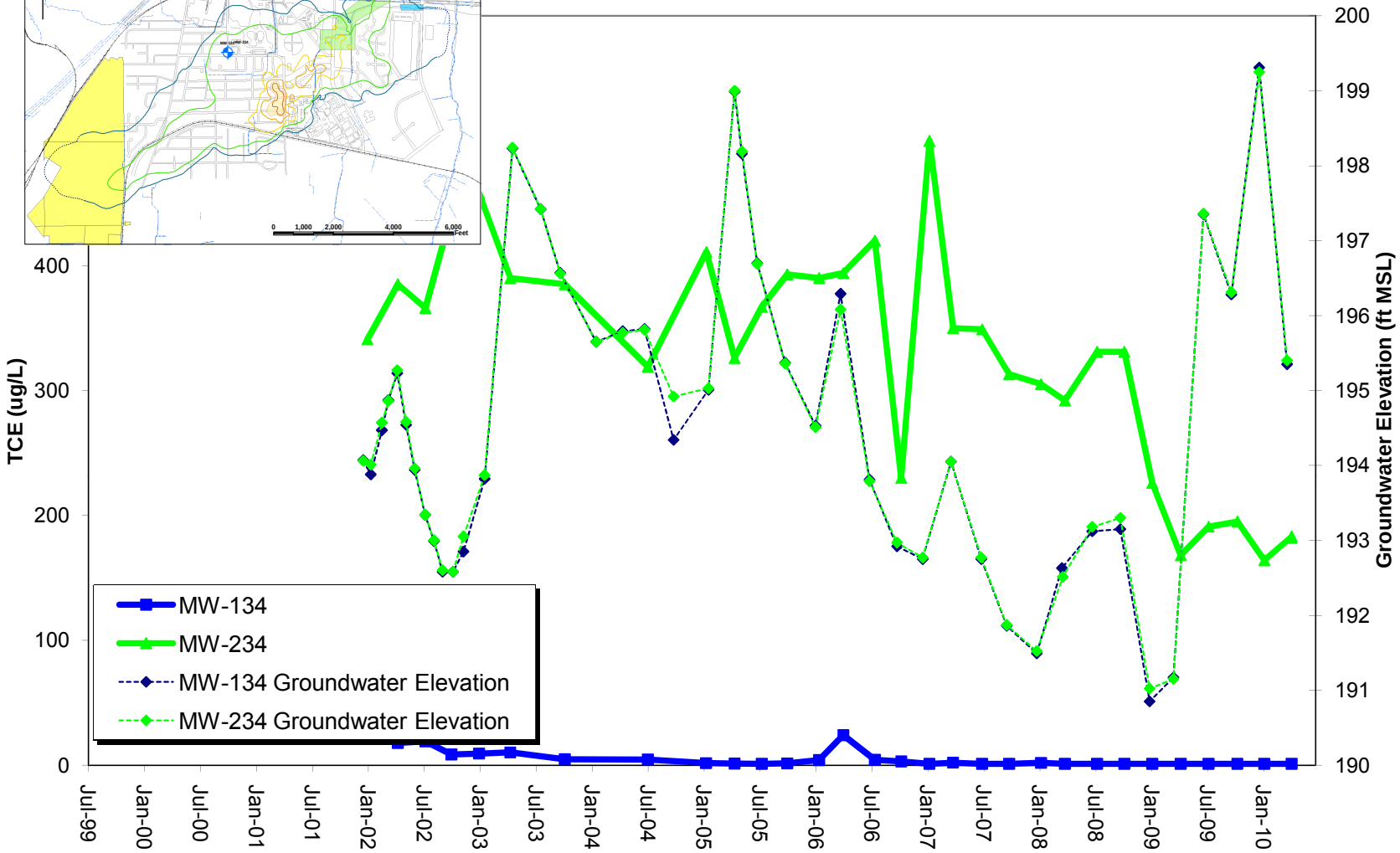

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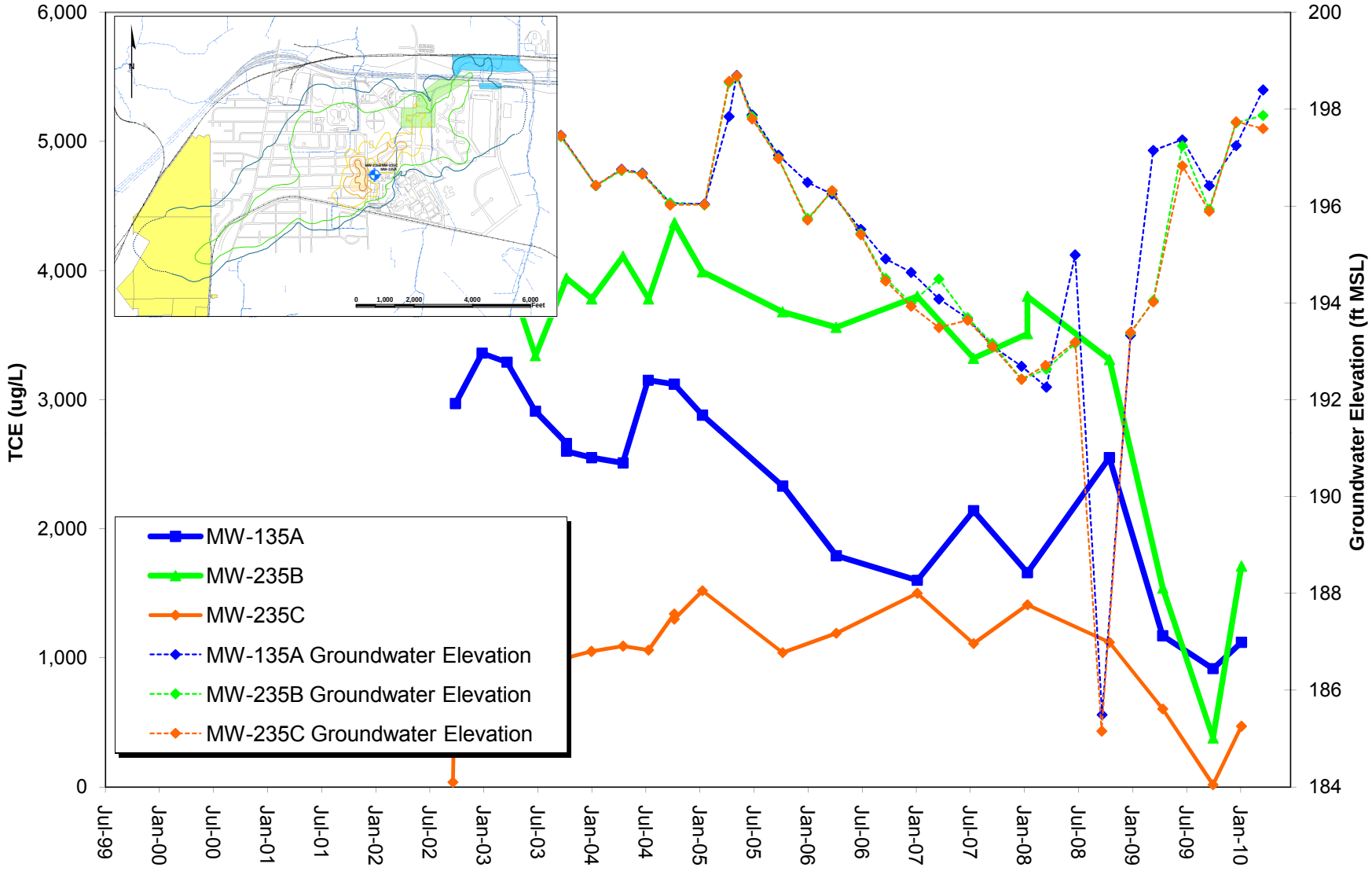

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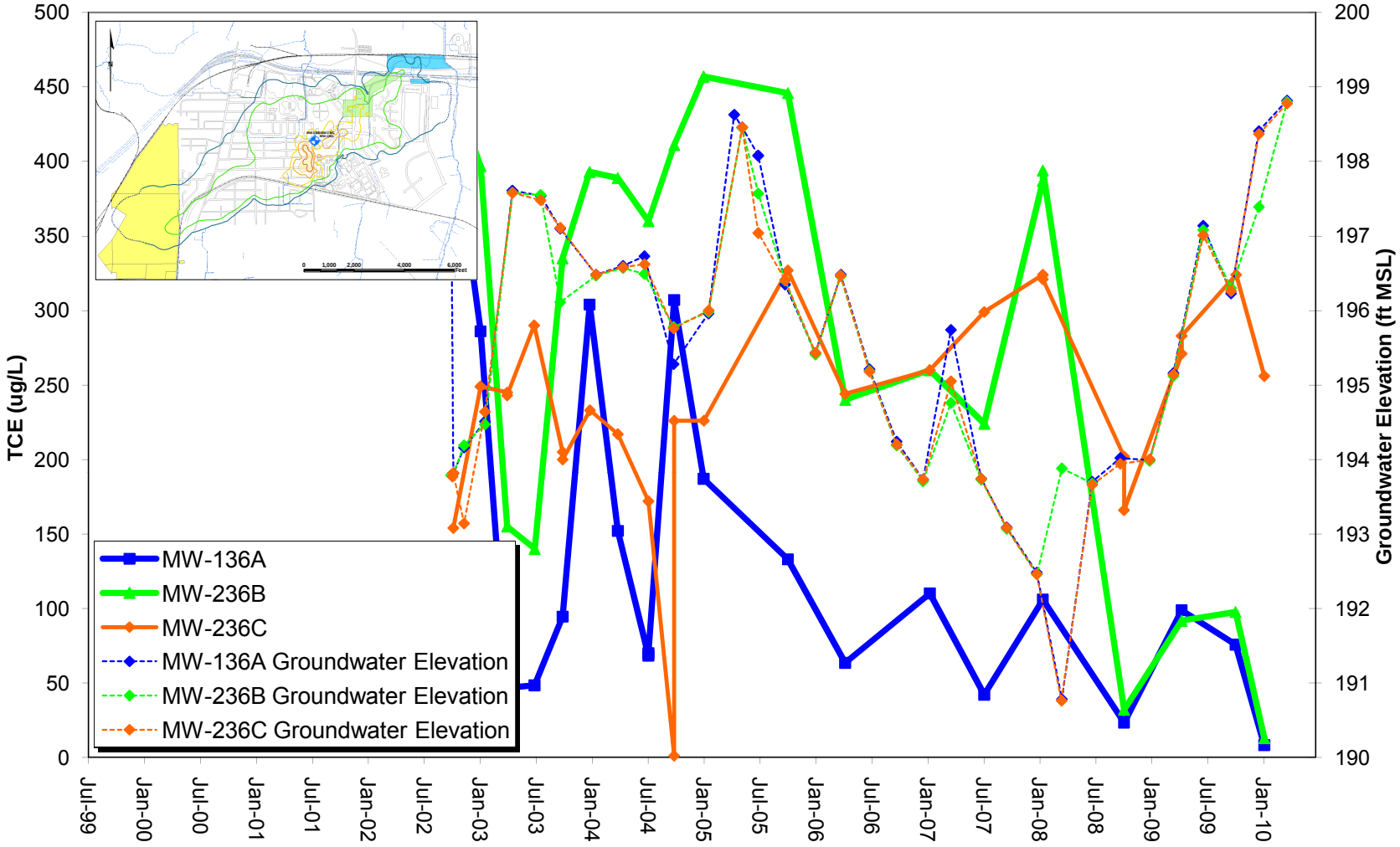

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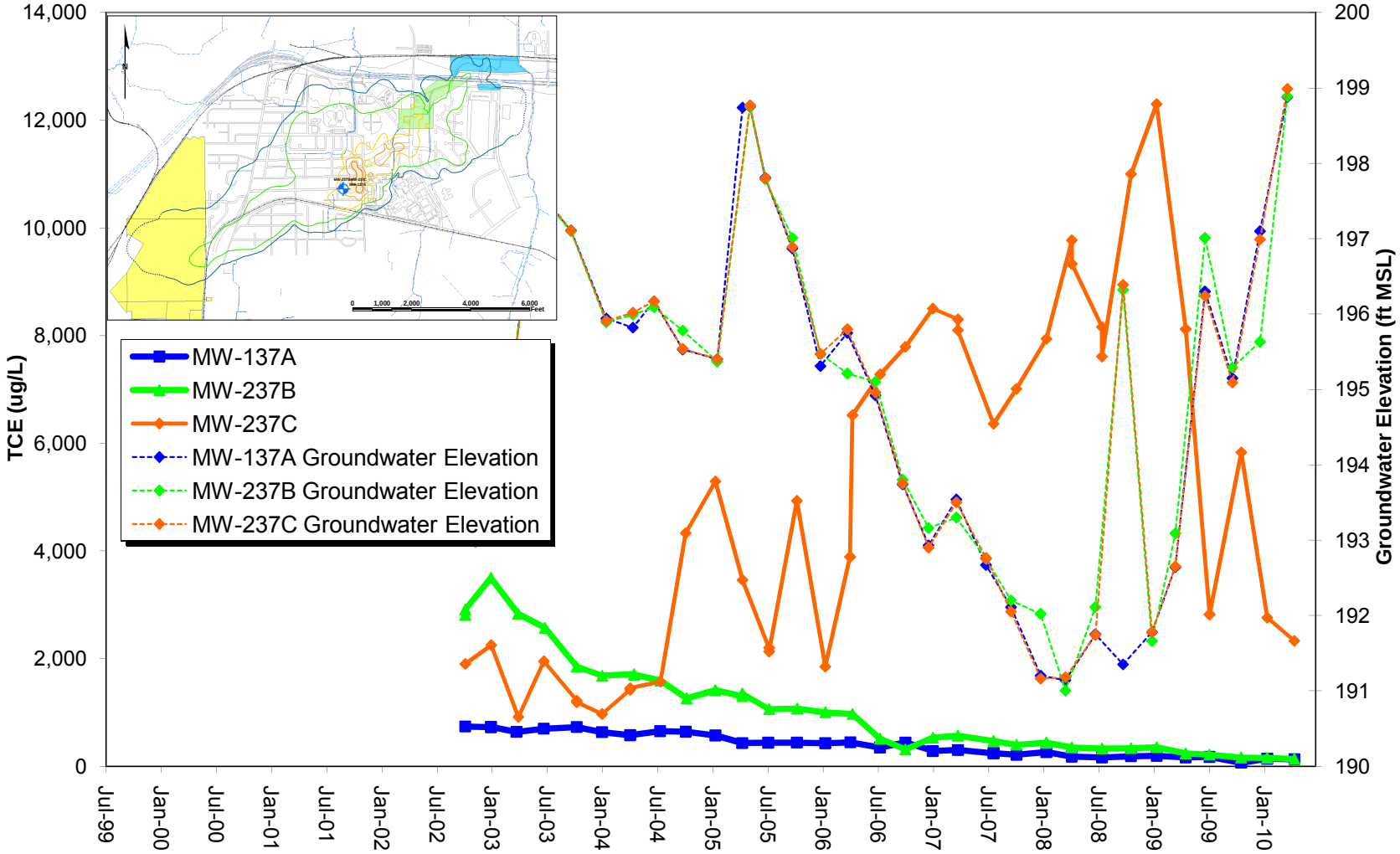

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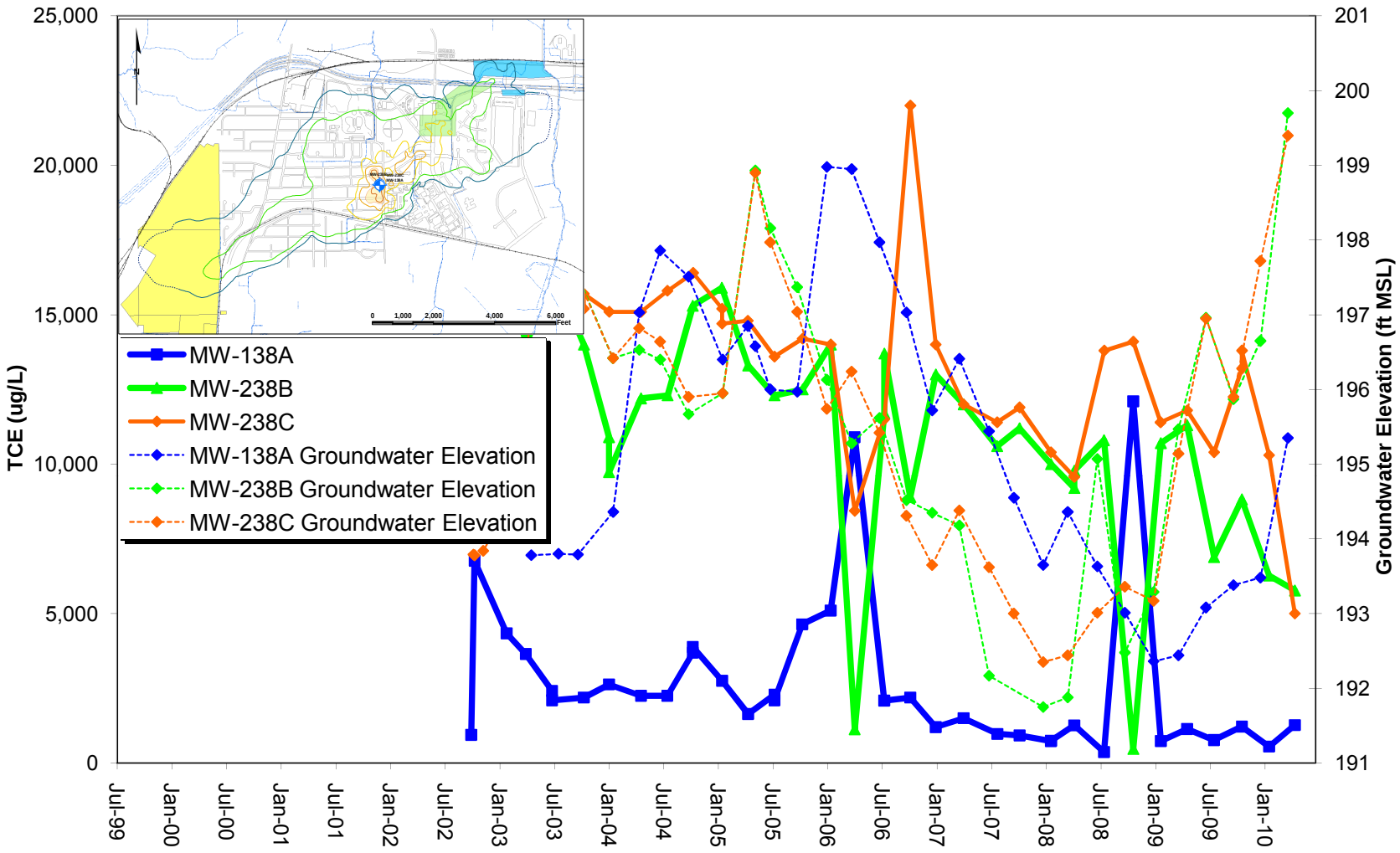

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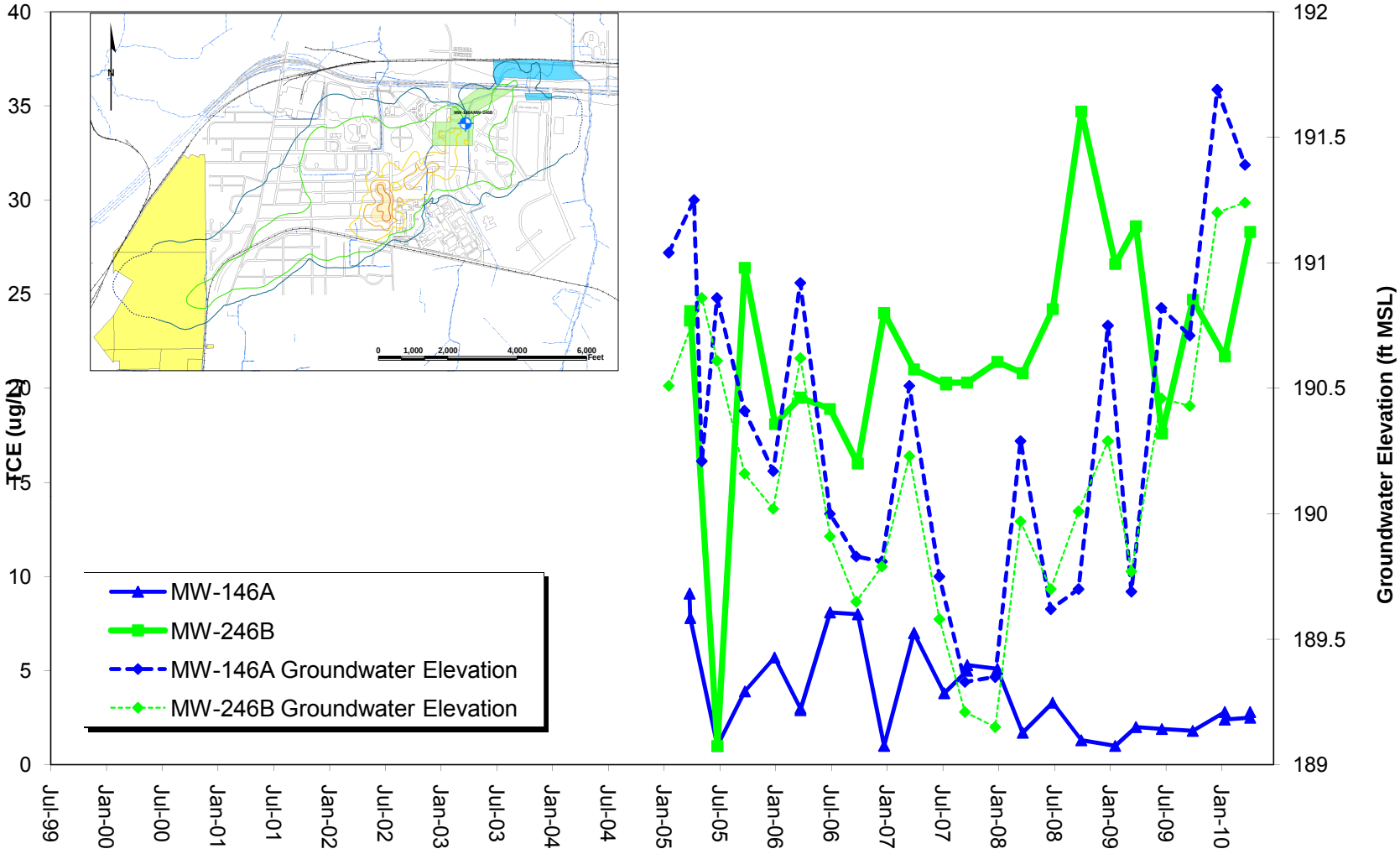
MW-146A - MW-246B



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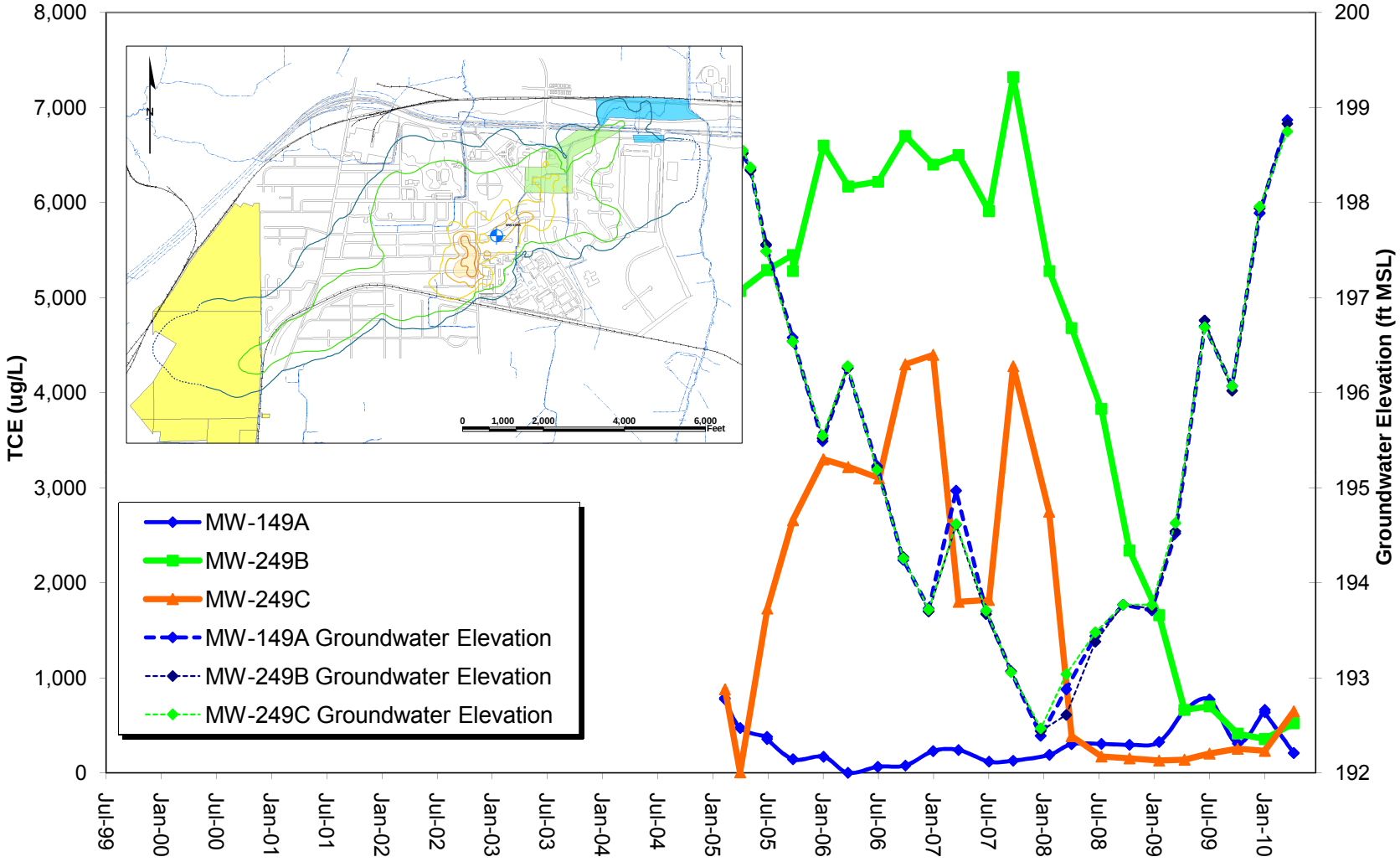

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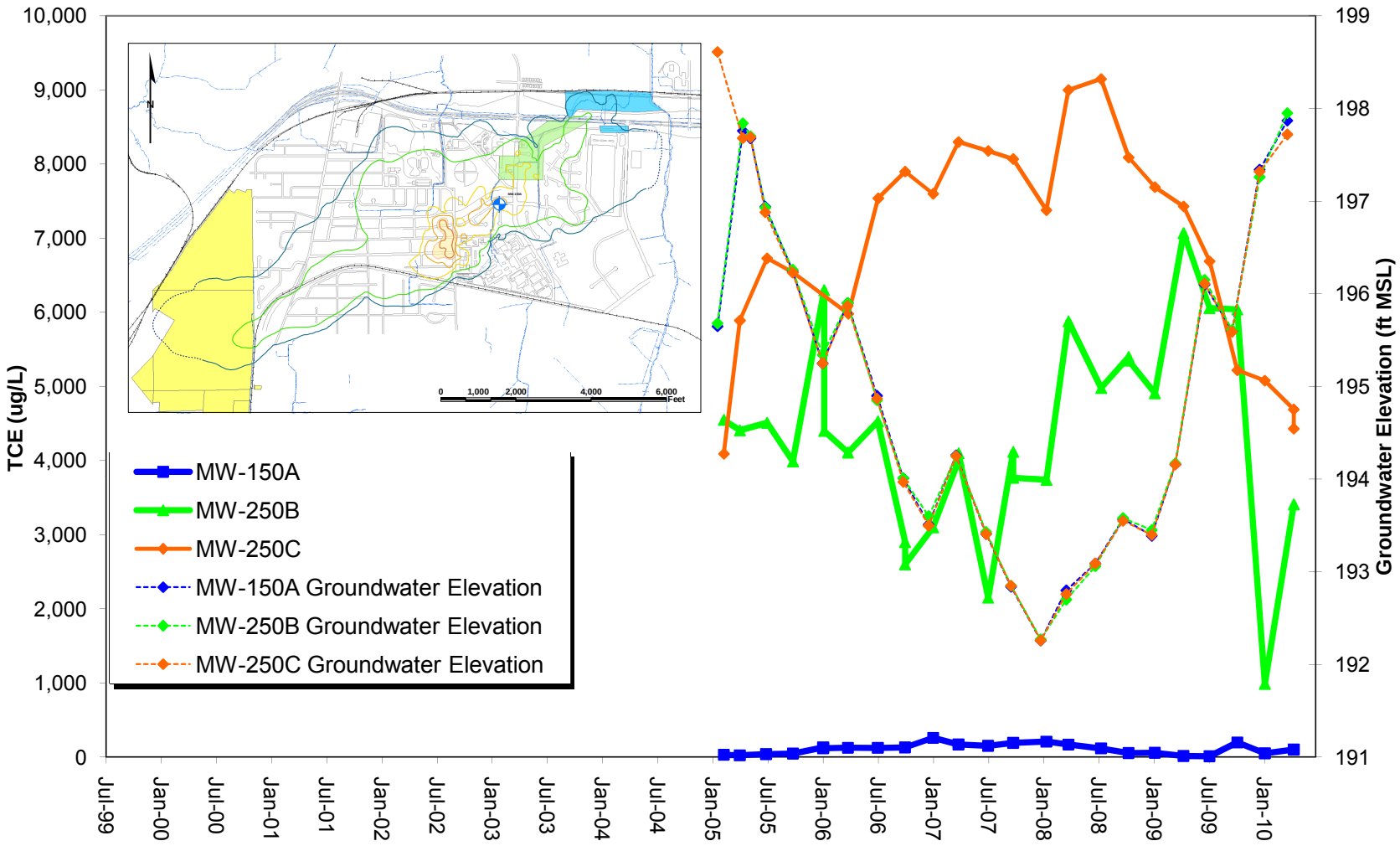

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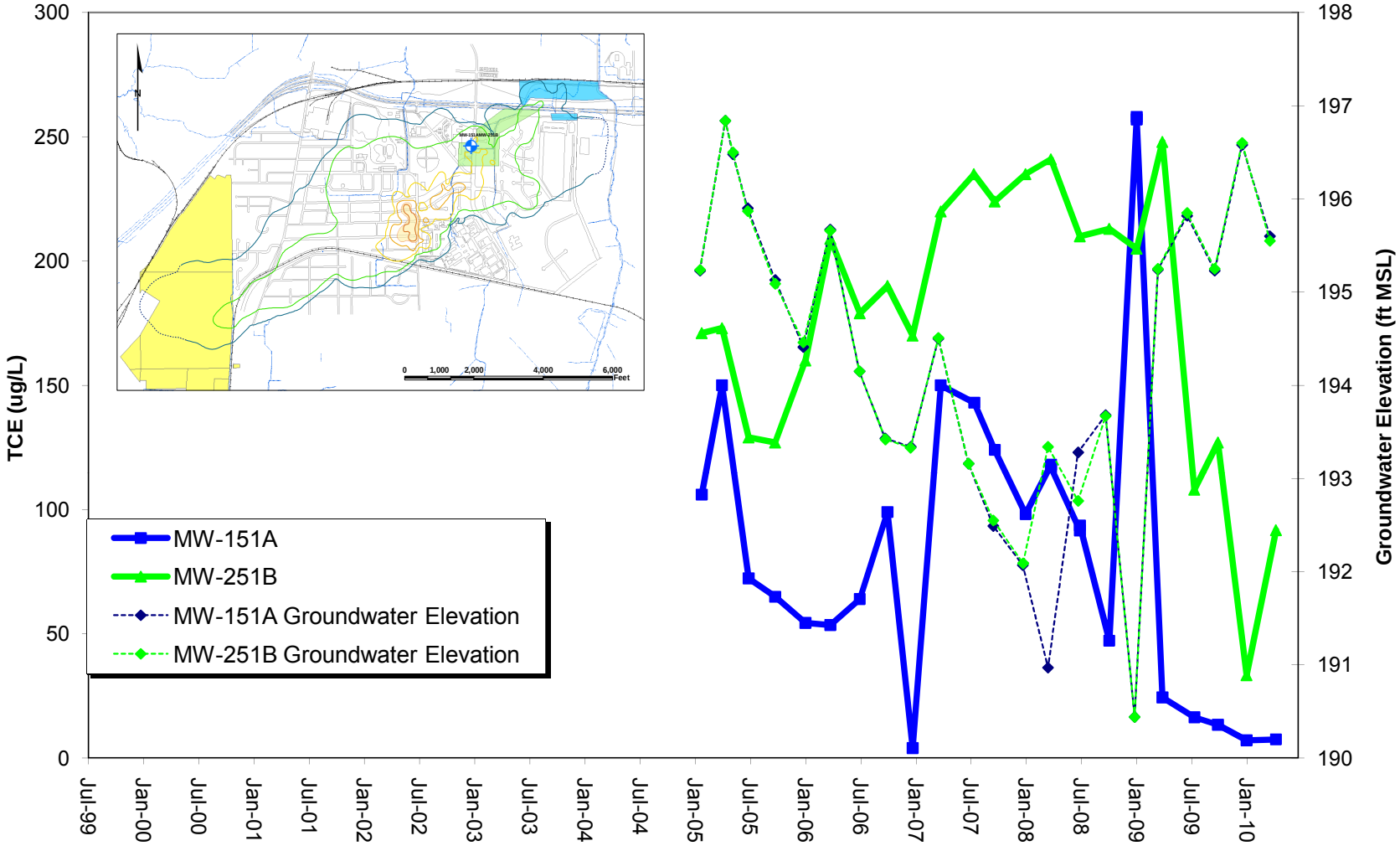

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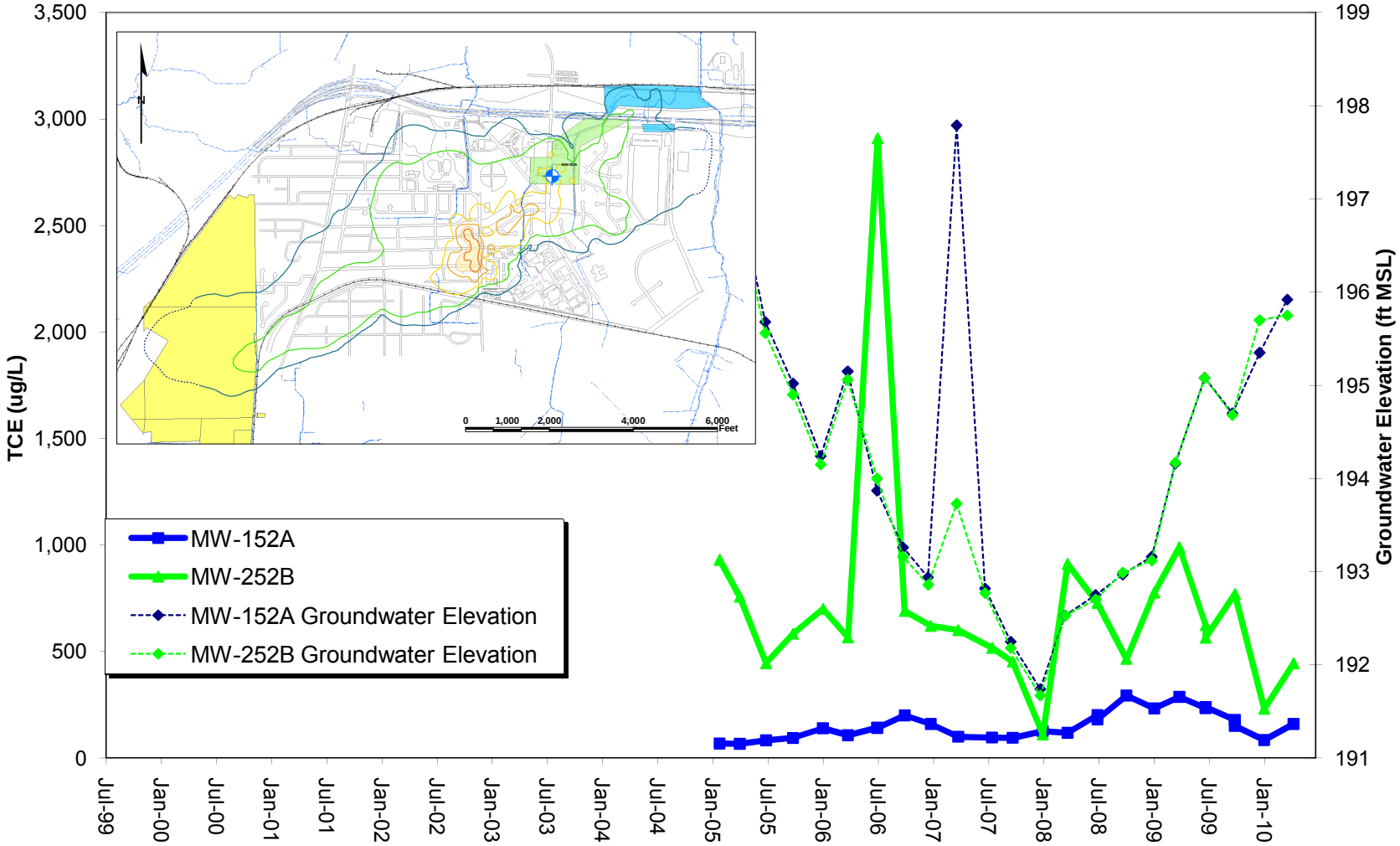

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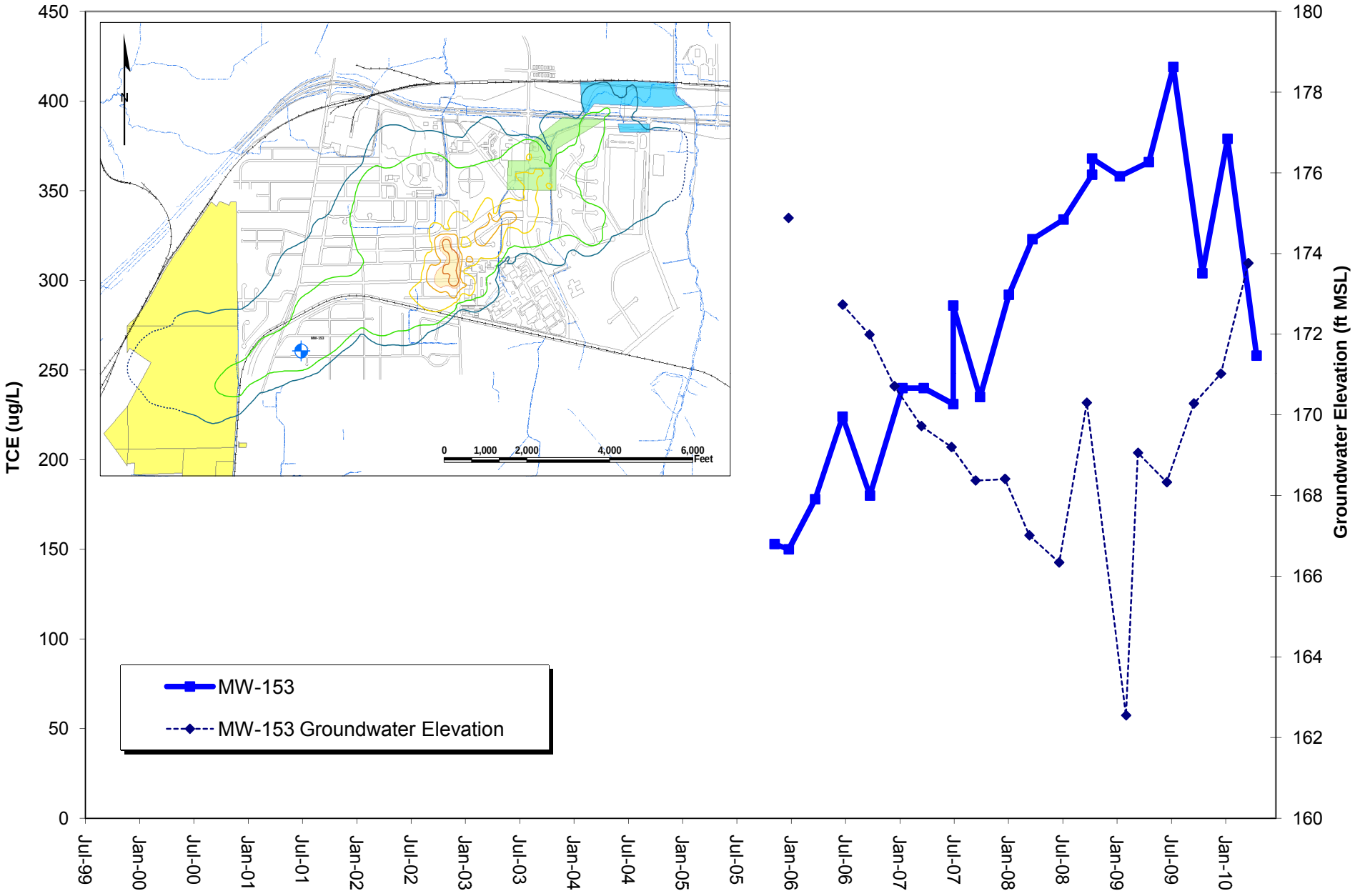

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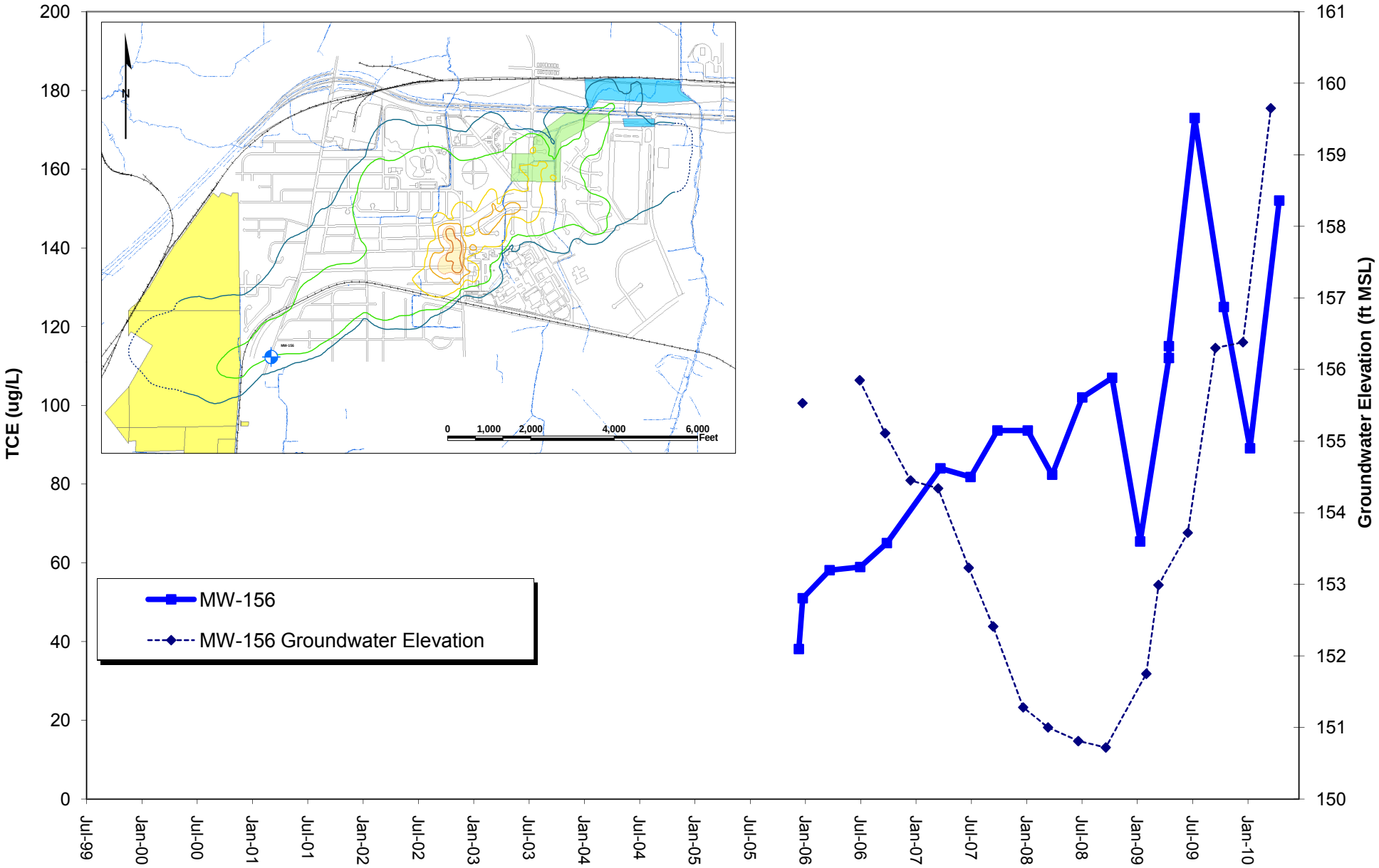

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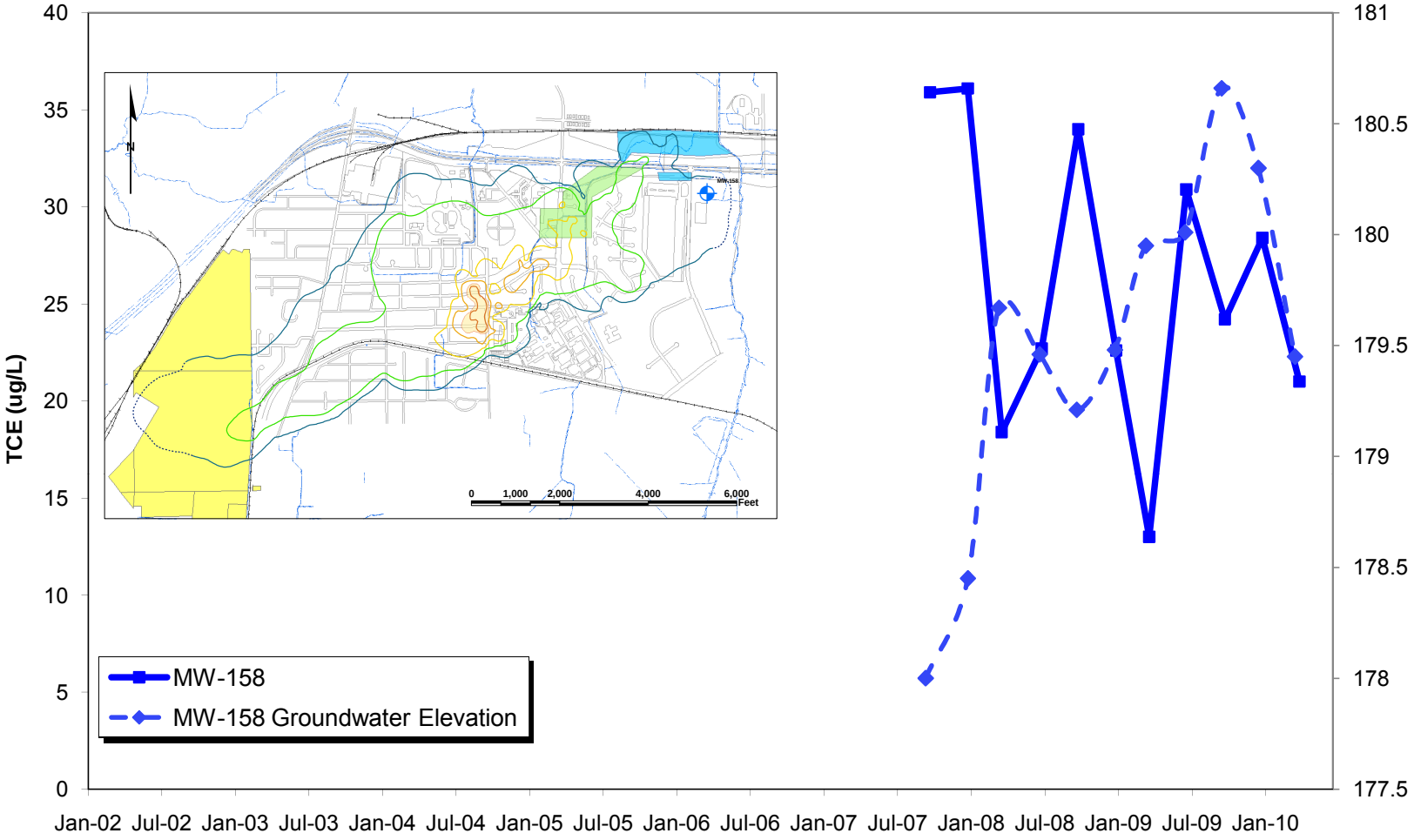

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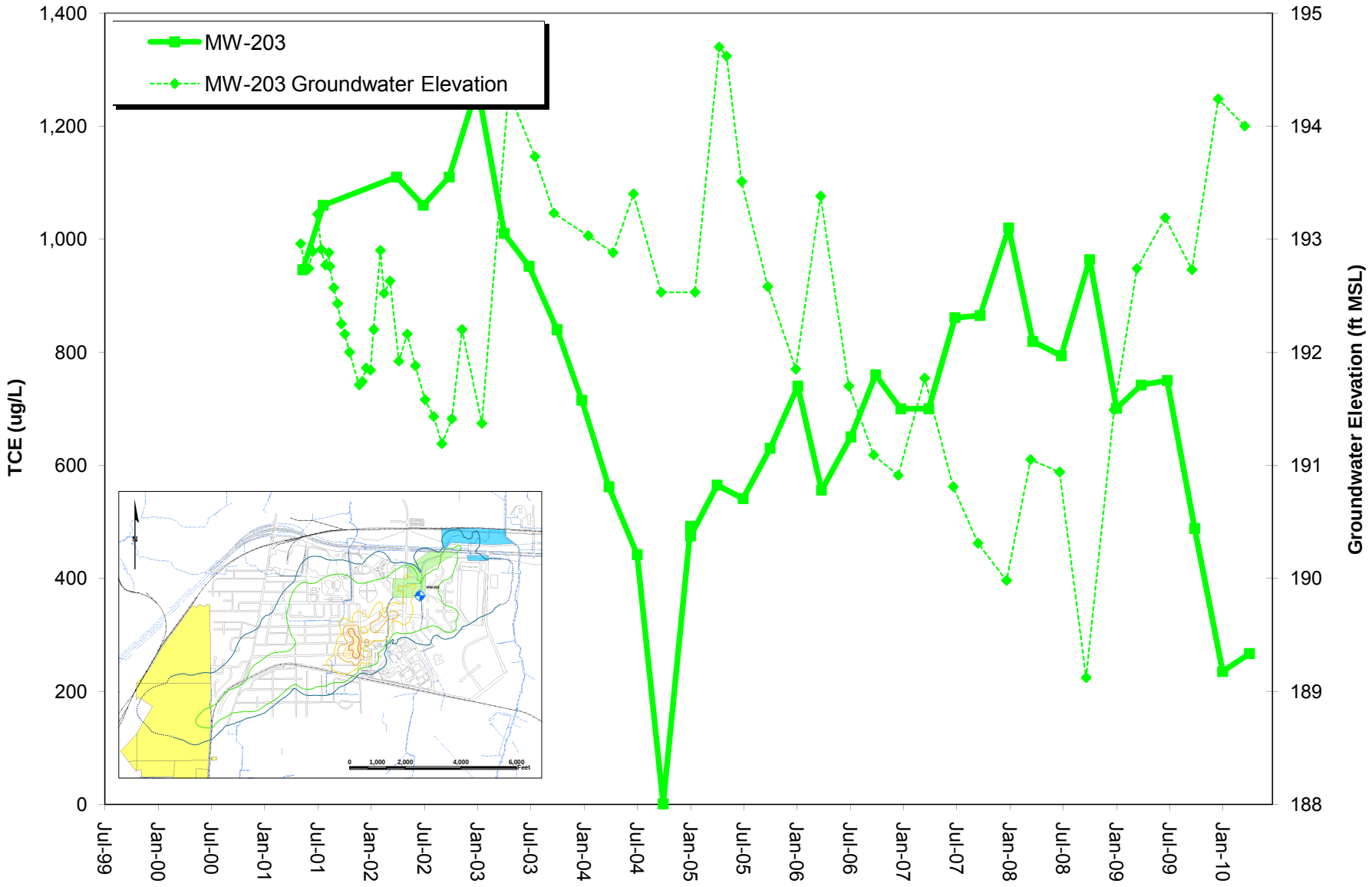

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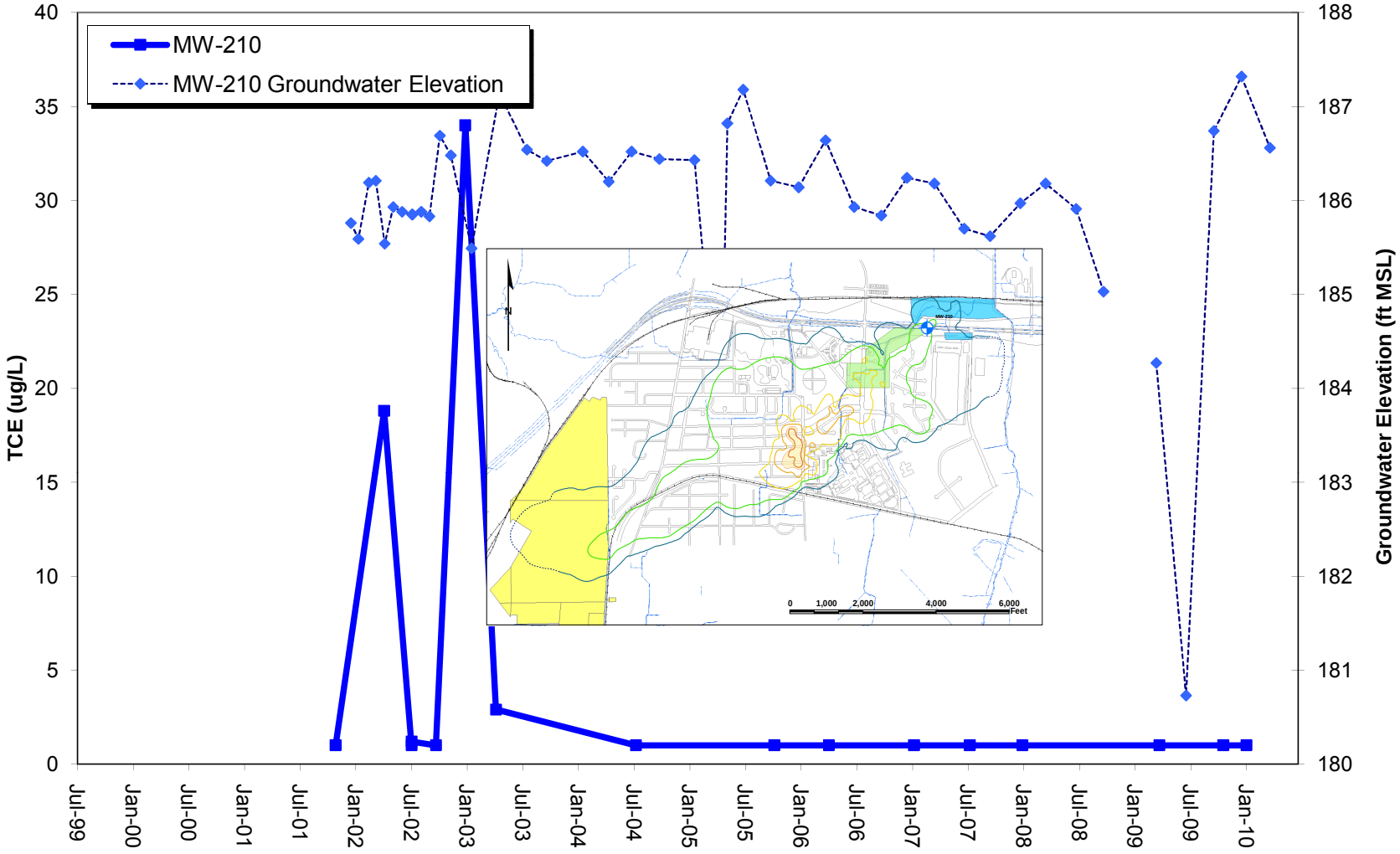

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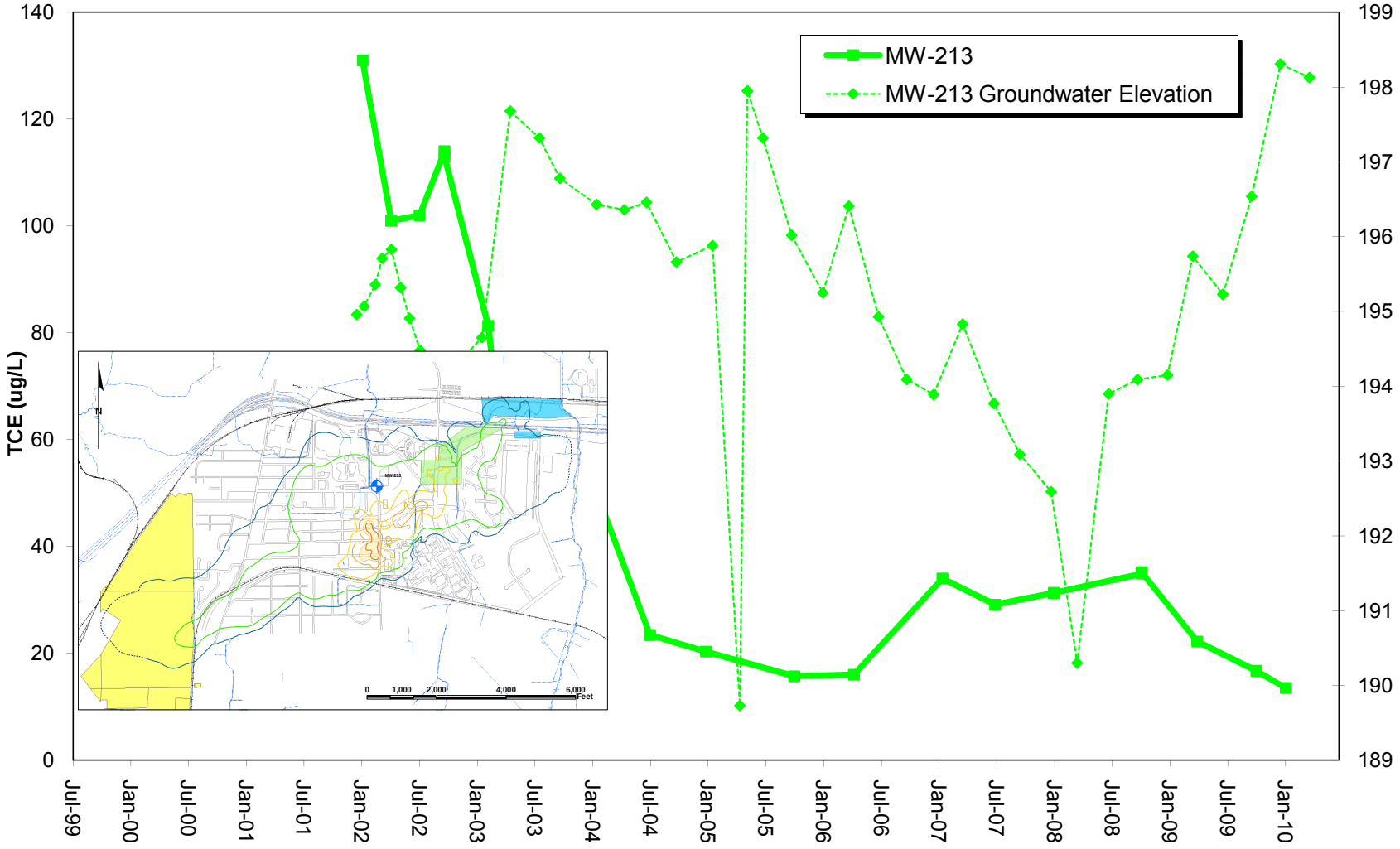

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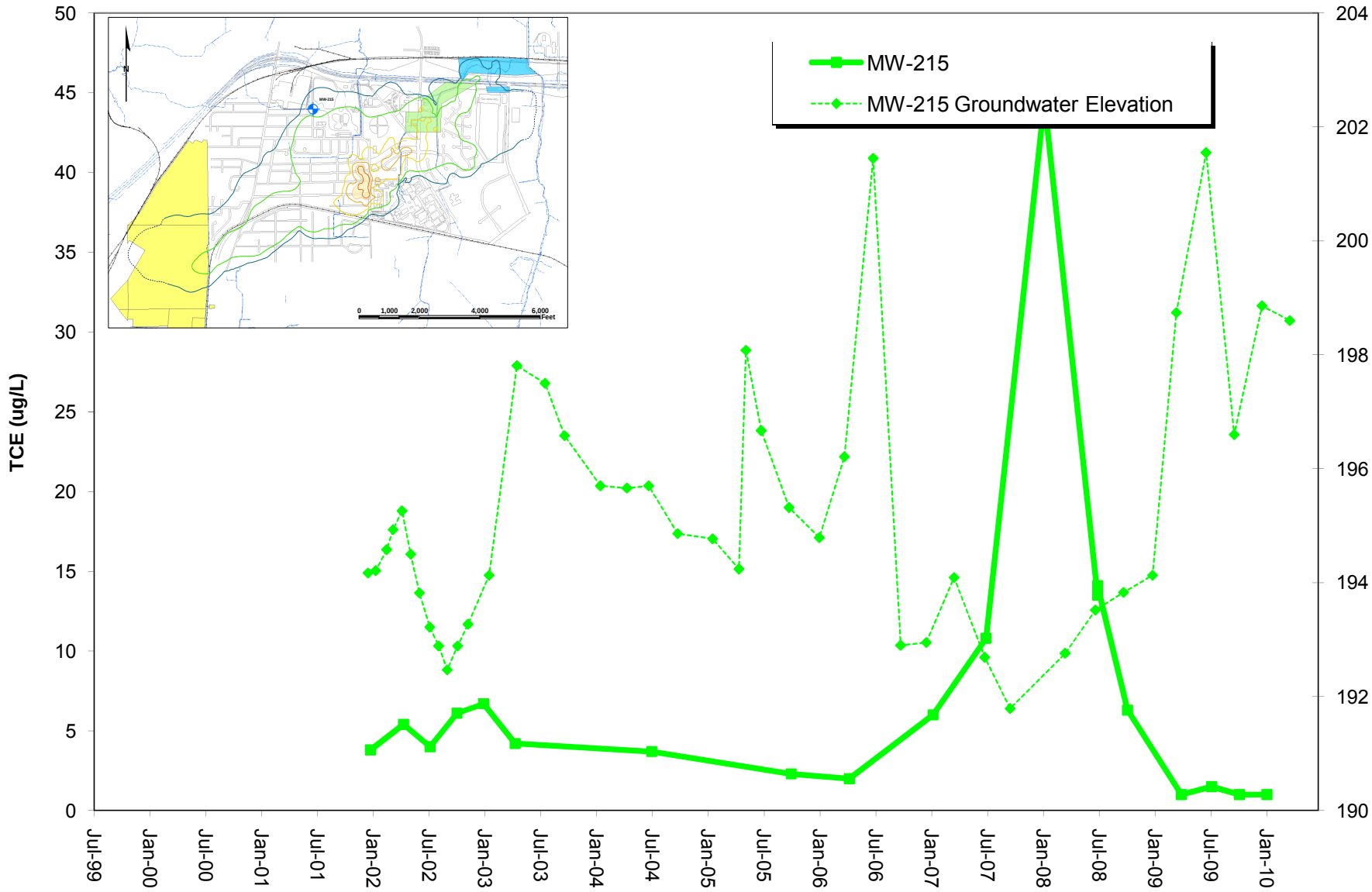

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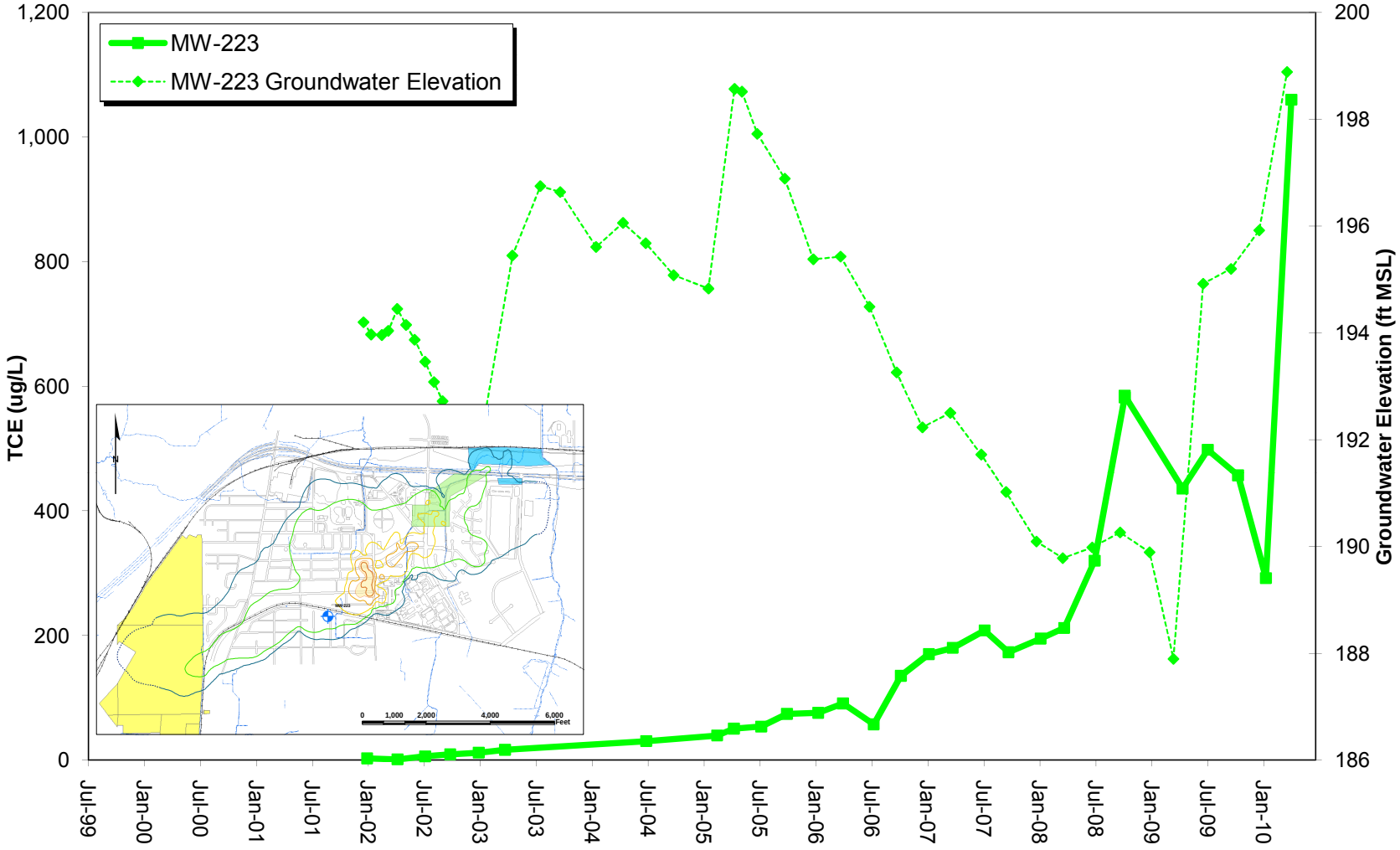

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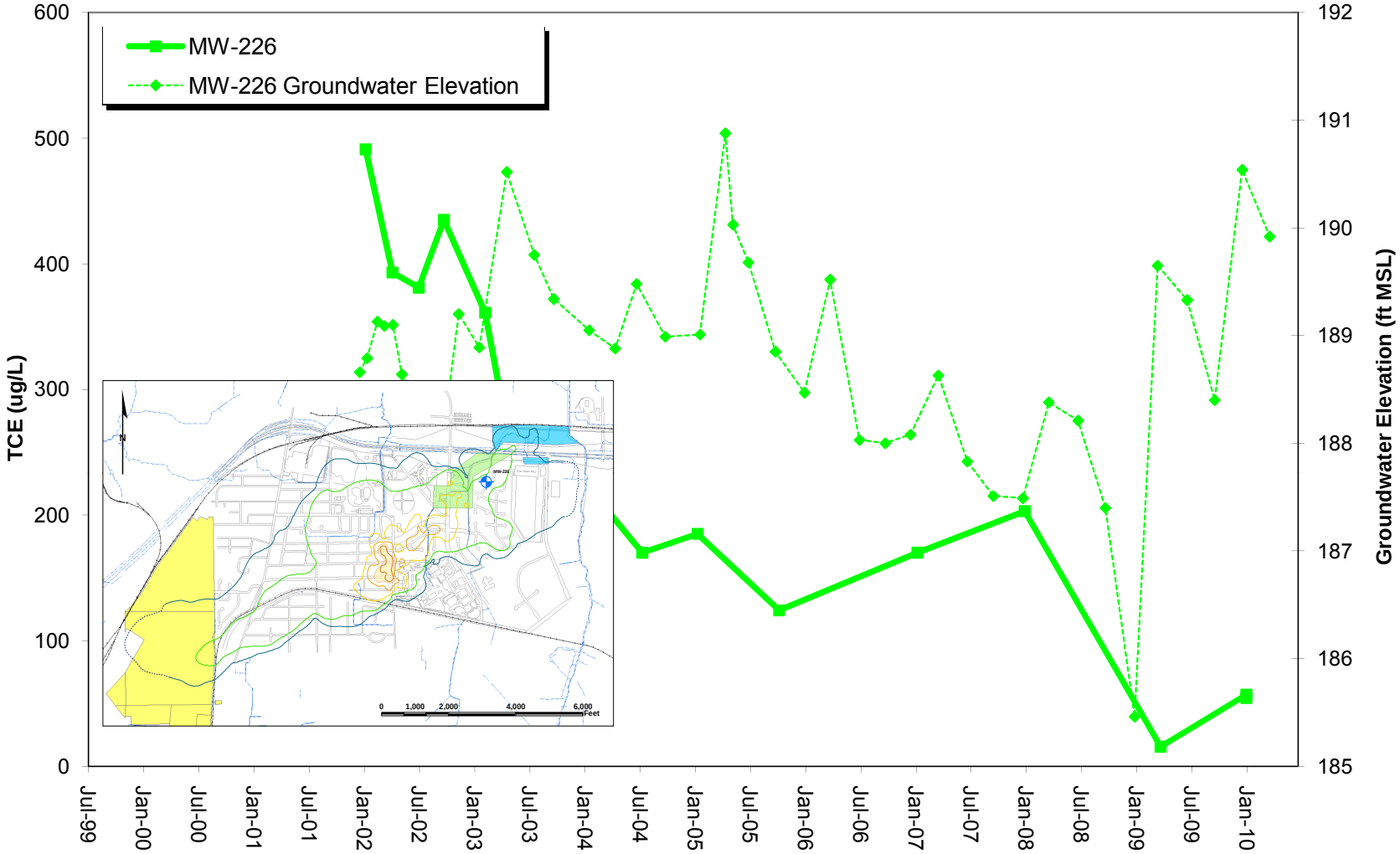

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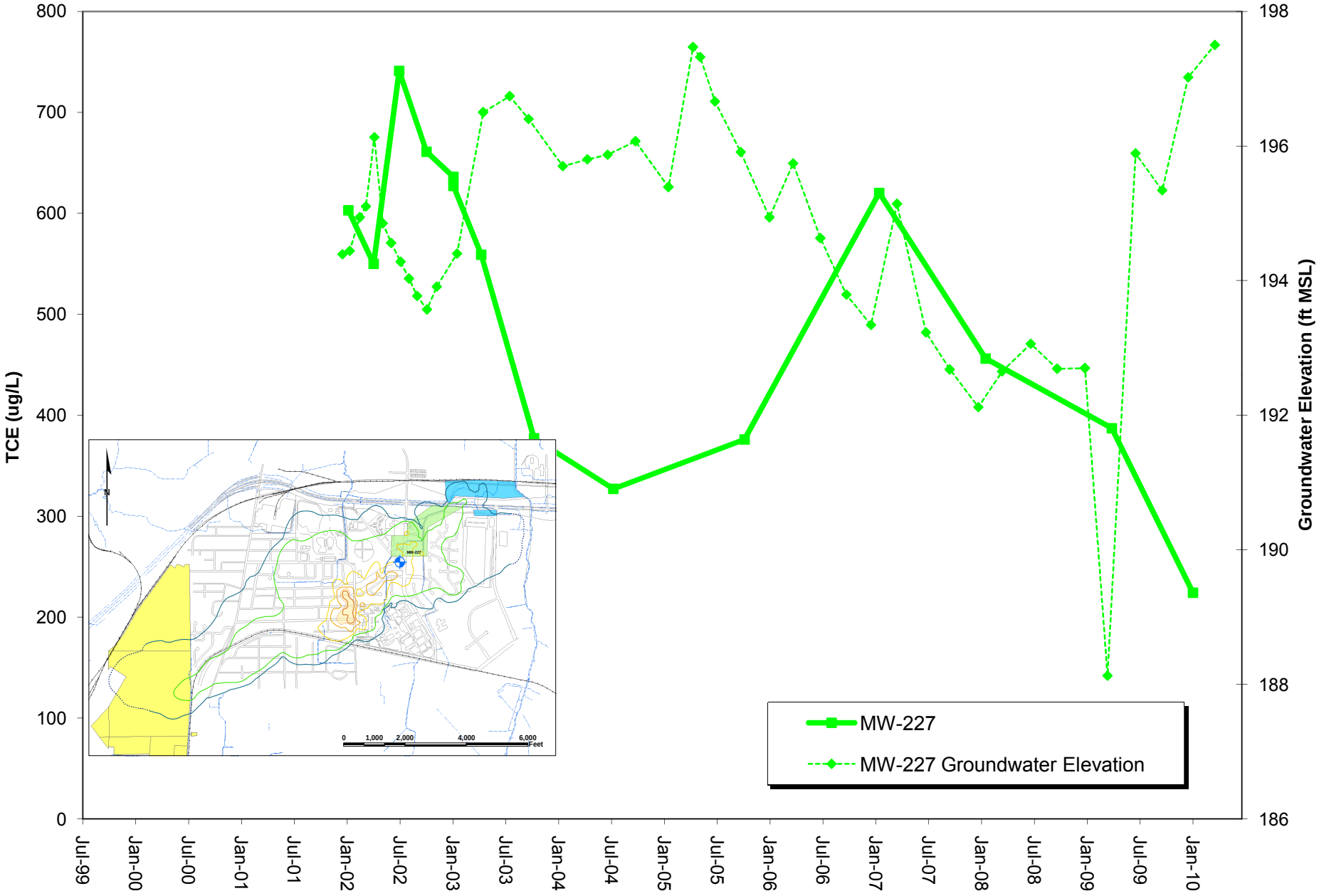

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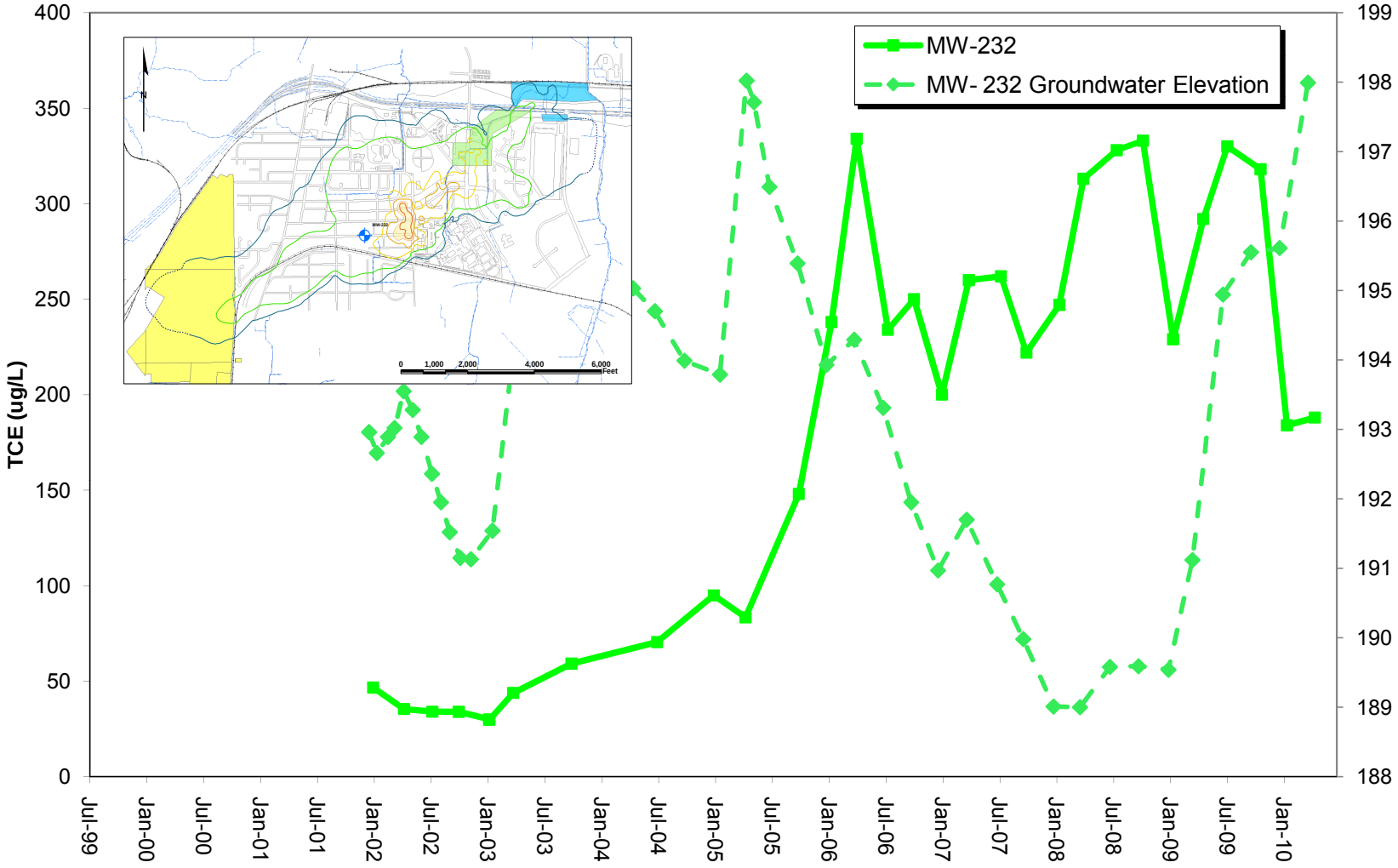

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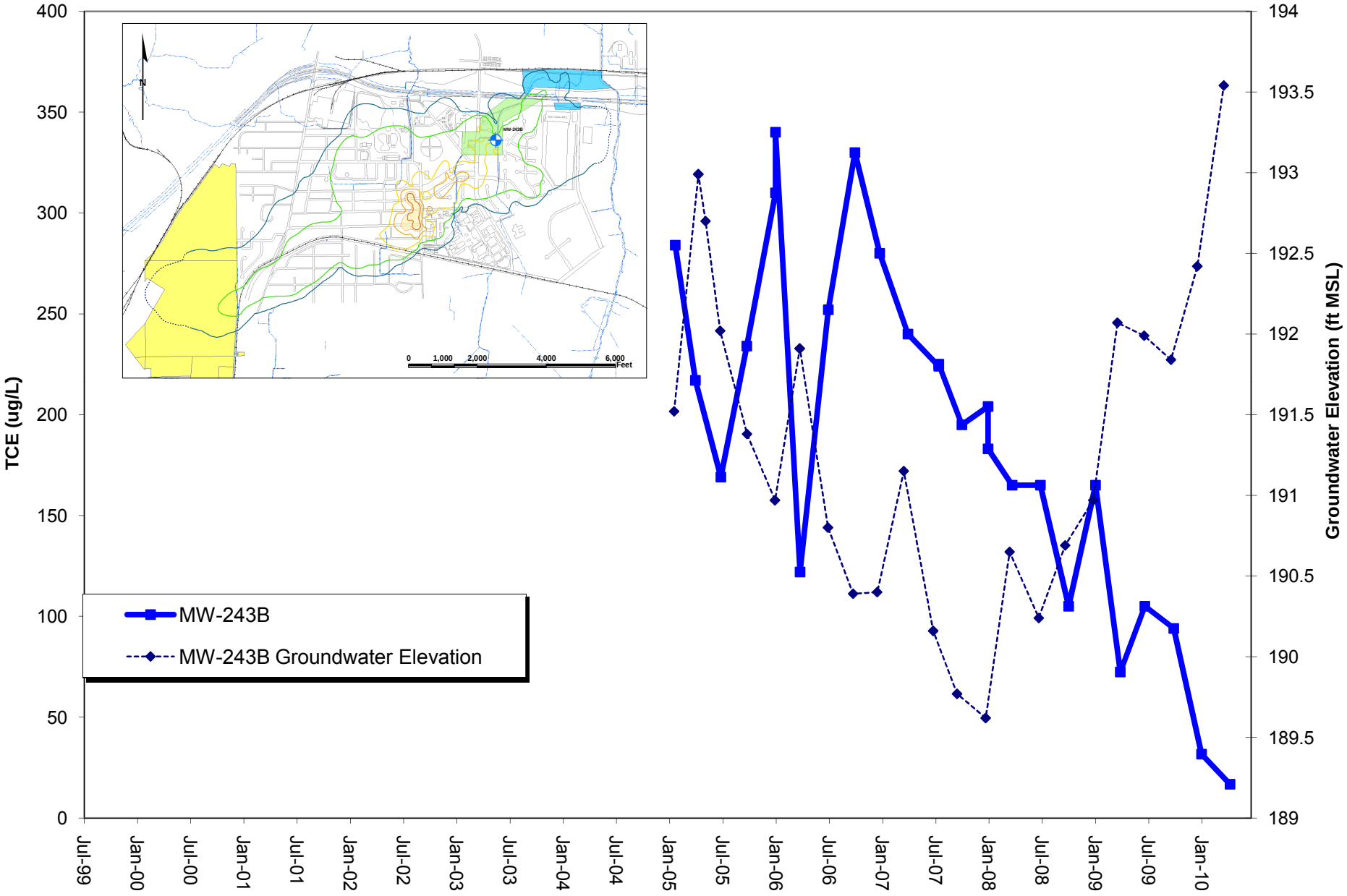

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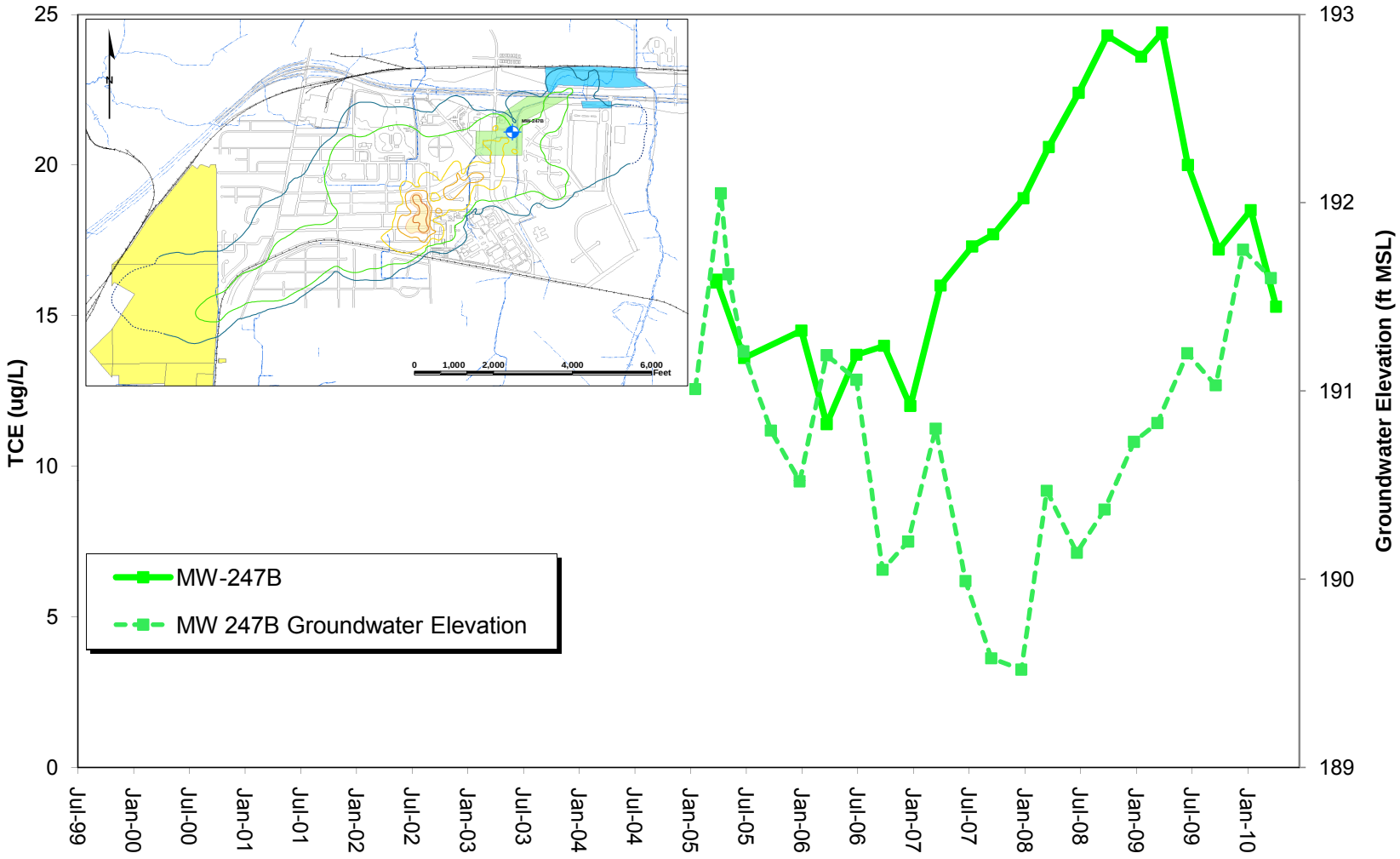
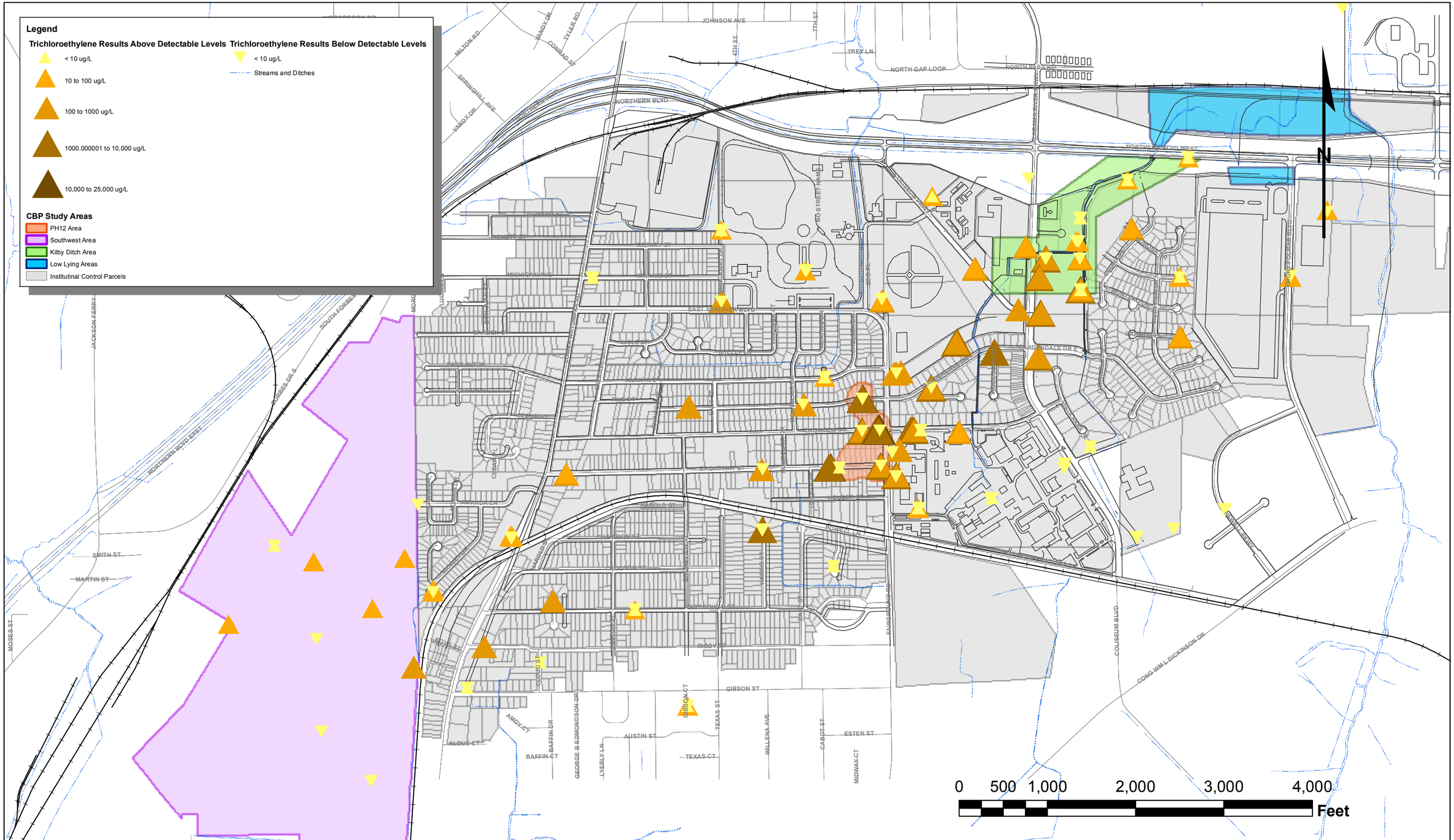


Appendix B

TCE Degradation Product Trend Plots
And
TCE Degradation Indicator Parameters

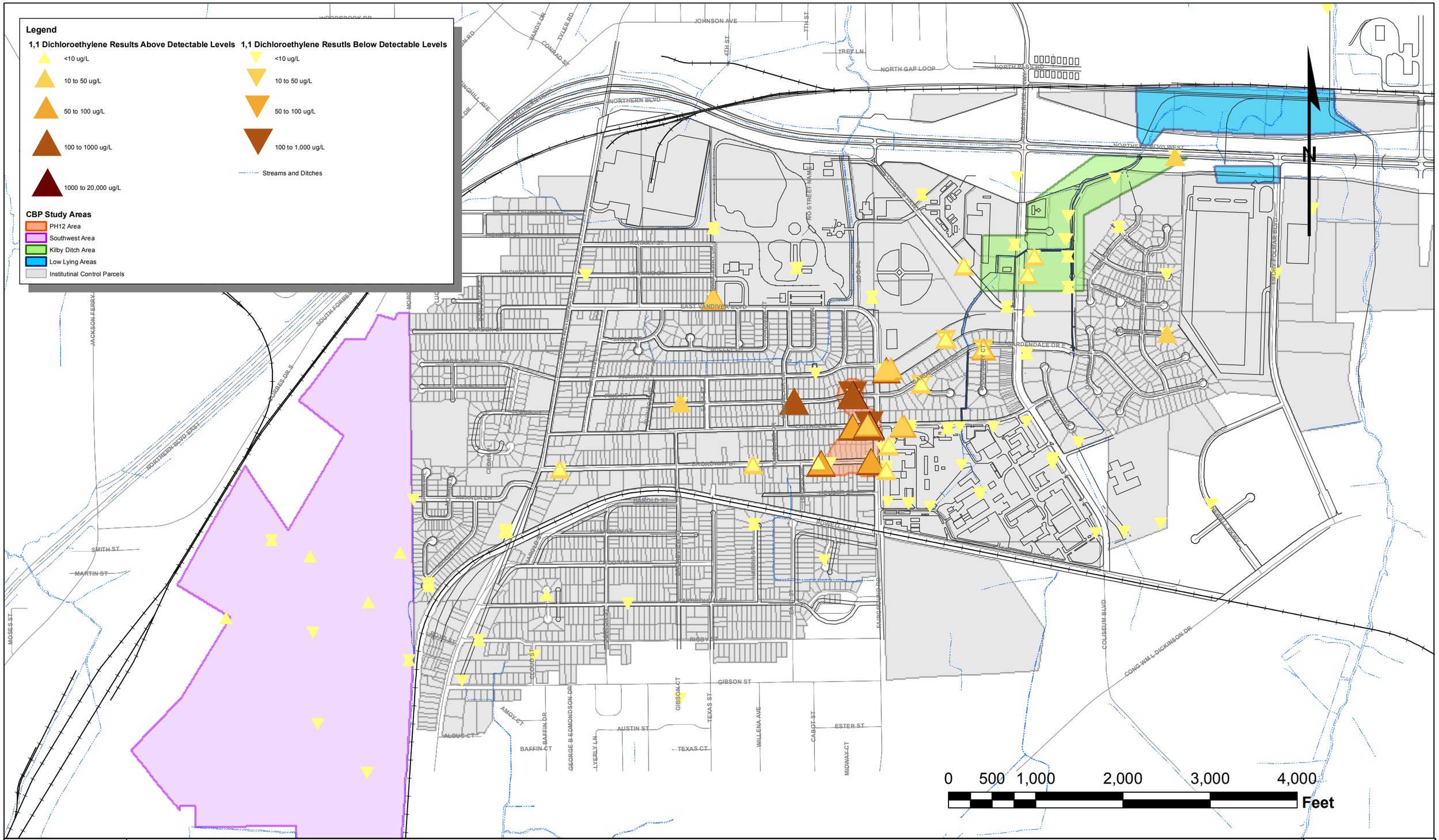


Alabama Department of Transportation
Coliseum Boulevard Project

Maximum TCE Concentration in Groundwater (May 2001 - April 2010)

FIGURE B-1

September 2010

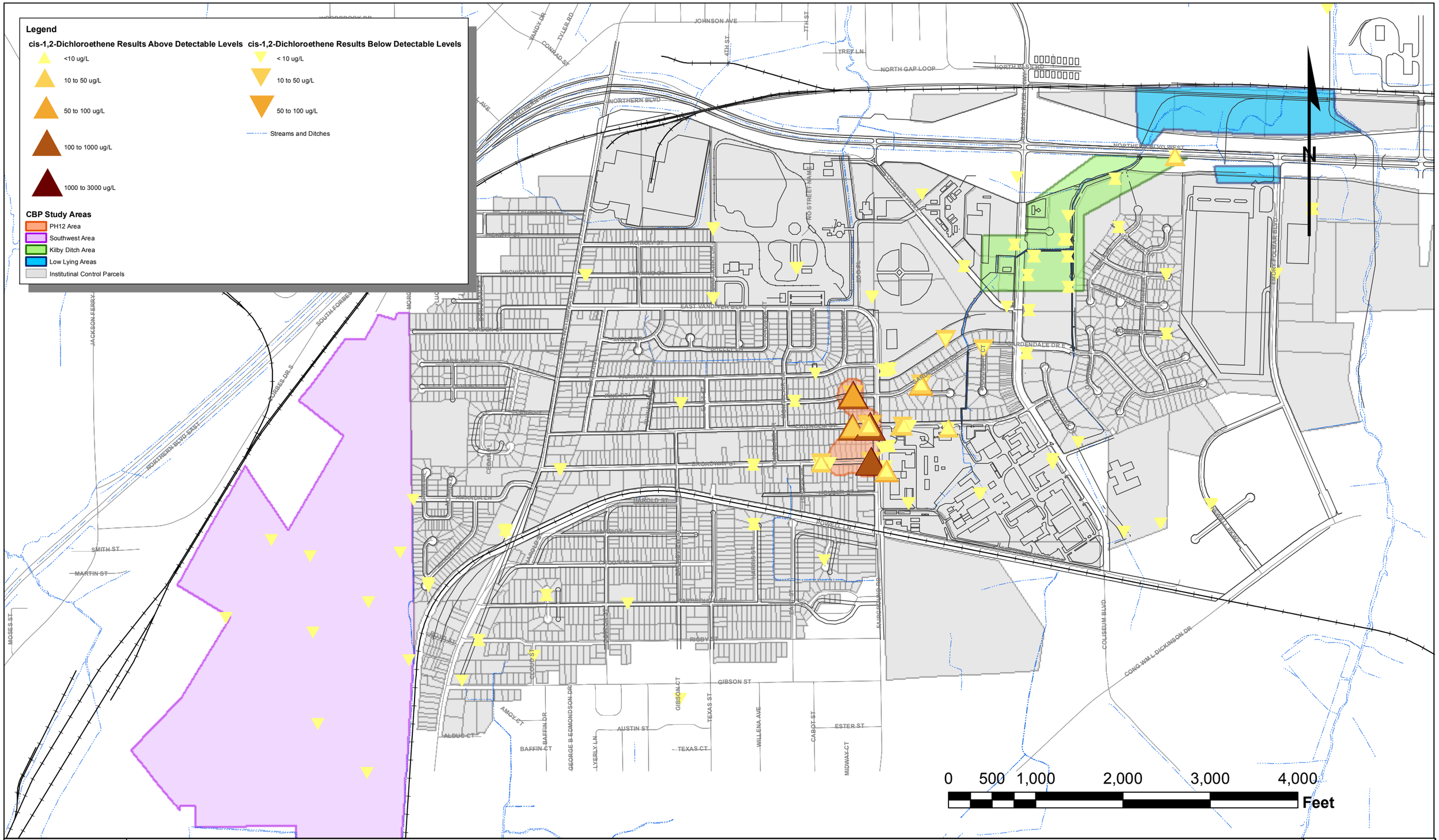


Alabama Department of Transportation
Coliseum Boulevard Project

Maximum 1,1-Dichloroethene Concentration in Groundwater (May 2001 - April 2010)

FIGURE B-2

September 2010

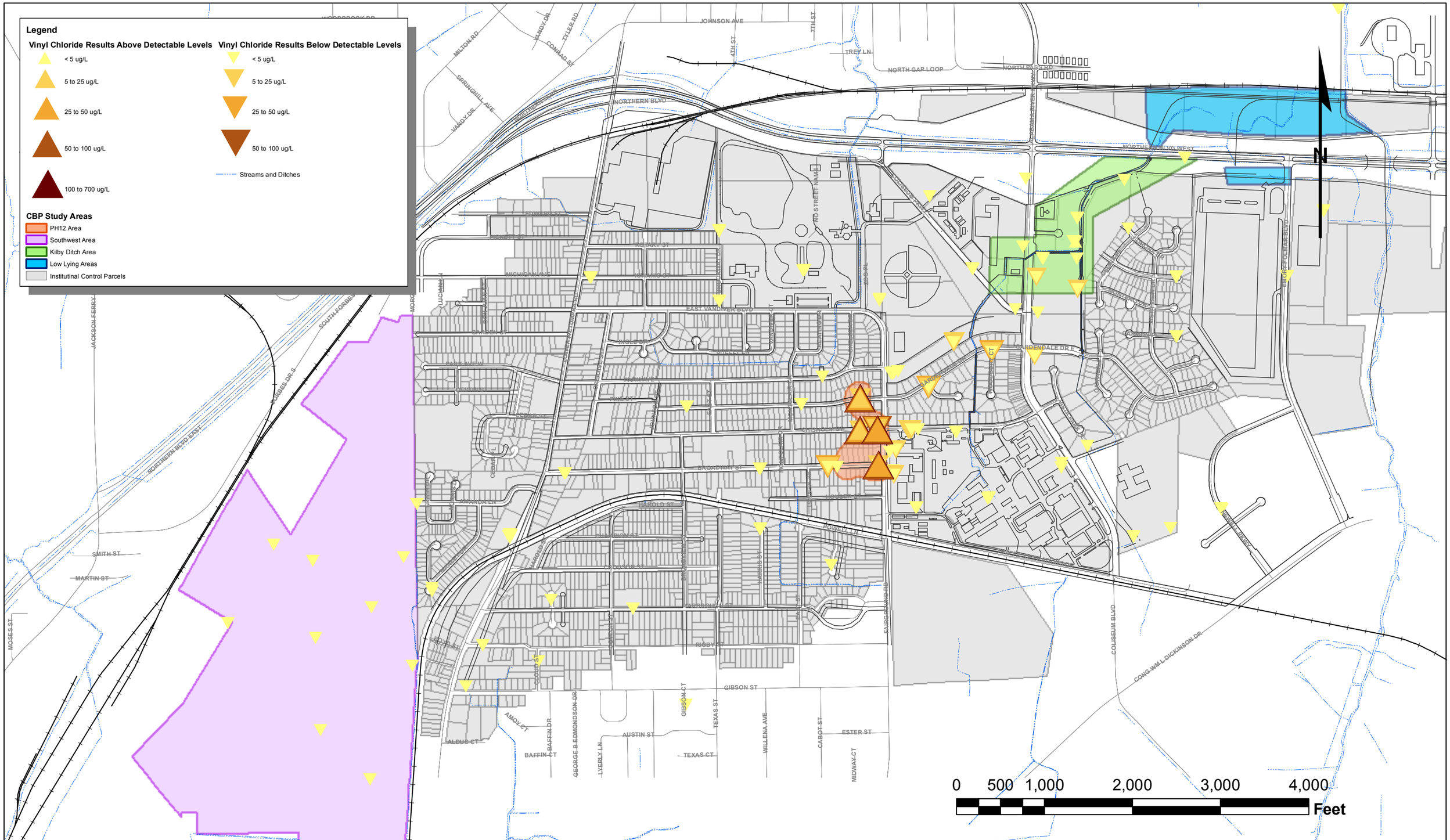


Alabama Department of Transportation
Coliseum Boulevard Project

Maximum Cis-1,2-Dichloroethene Concentration in Groundwater (May 2001 - April 2010)

FIGURE B-3

September 2010

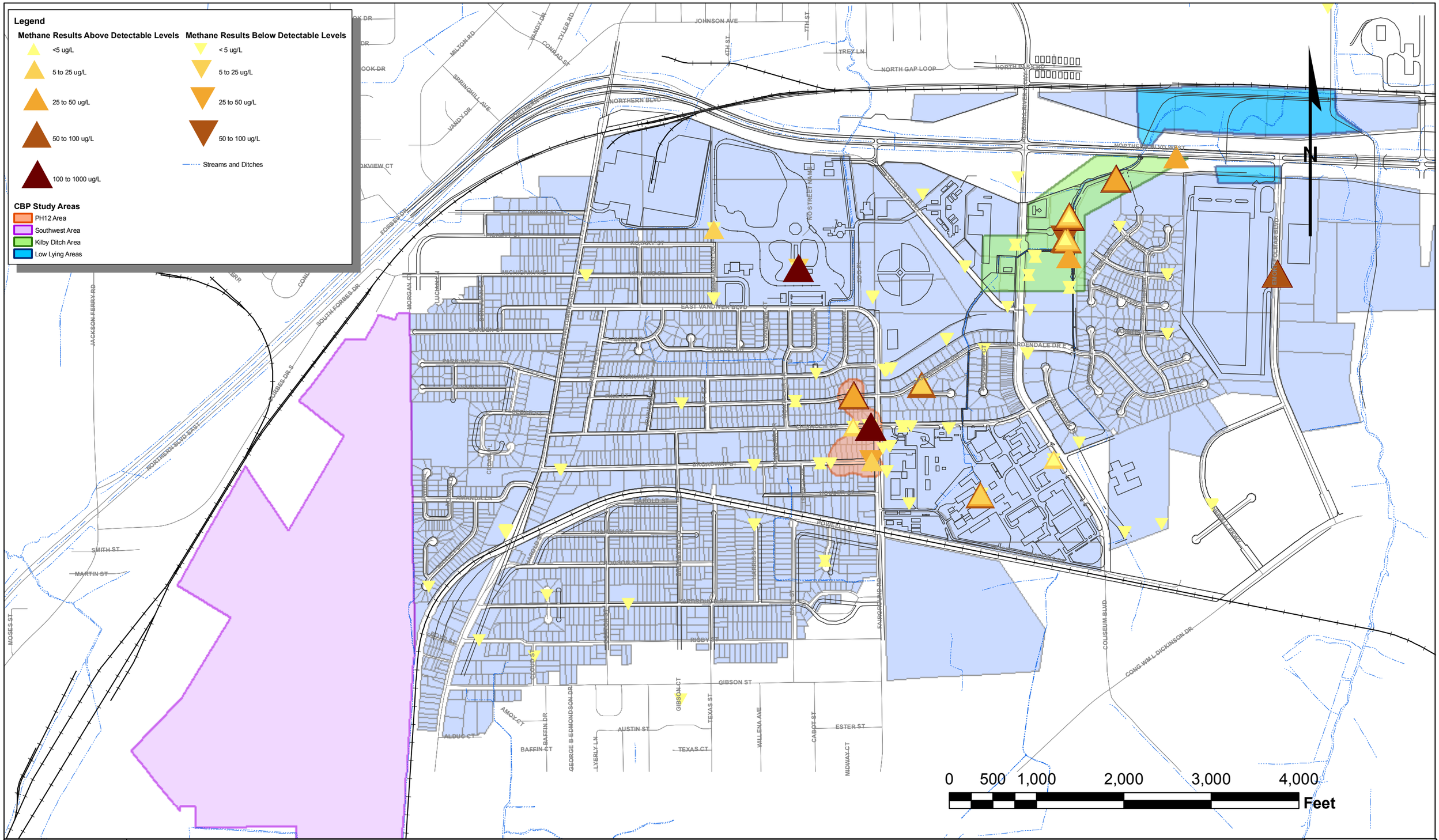


Alabama Department of Transportation
Coliseum Boulevard Project

Maximum Vinyl Chloride Concentration in Groundwater (May 2001 - April 2010)

FIGURE B-4

September 2010



Alabama Department of Transportation
Coliseum Boulevard Project

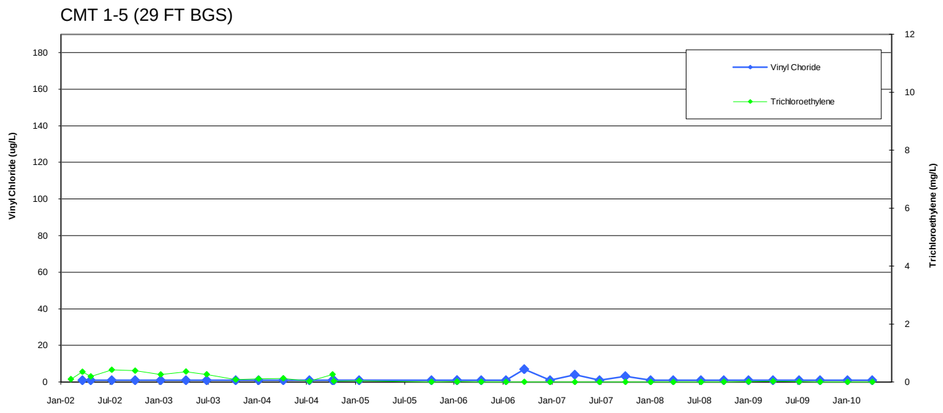
Maximum Methane Concentration in Groundwater (May 2001 - April 2010)

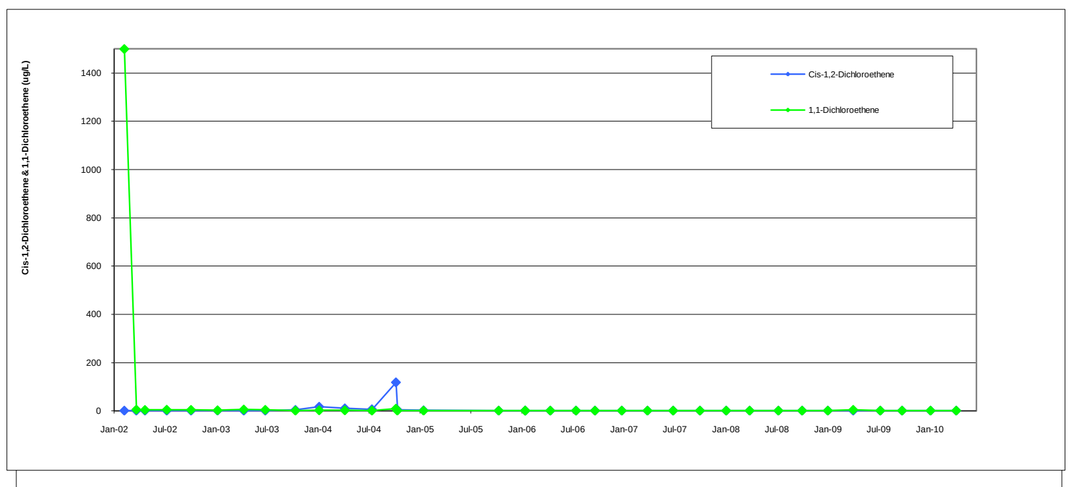
FIGURE B-5

September 2010

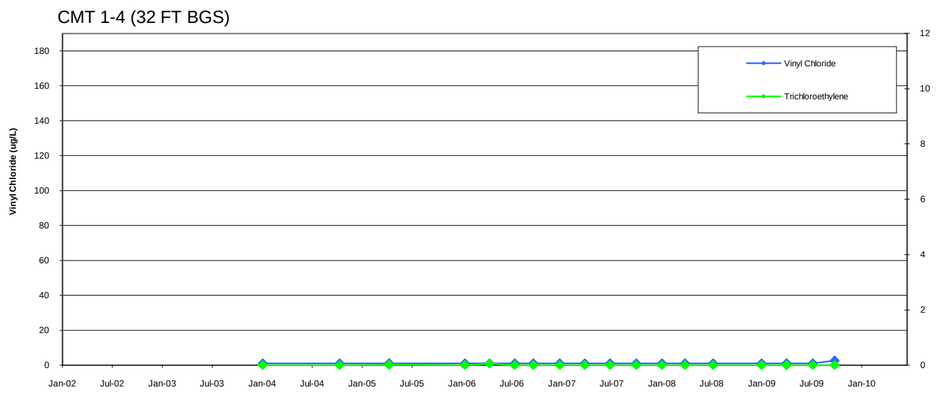
COLISEUM BOULEVARD PLUME
CMT 1 CONSTITUENT CONCENTRATION TRENDS

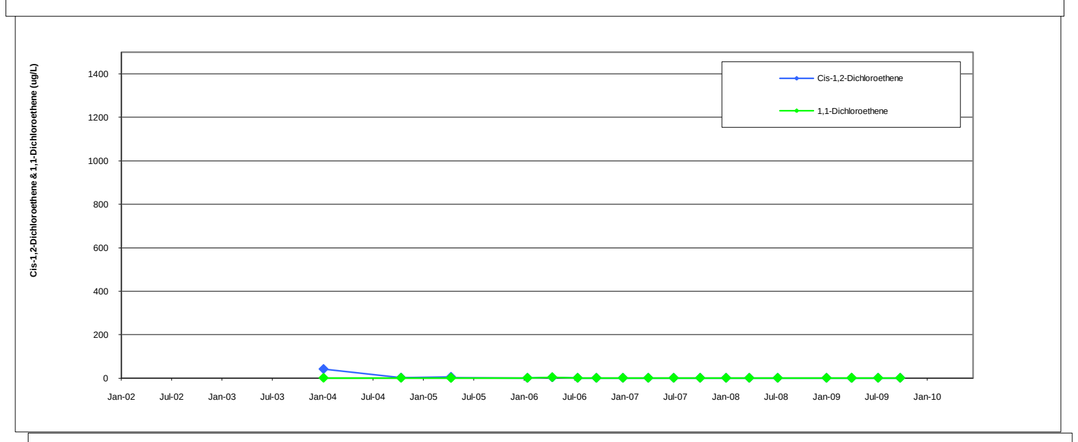
CMT 1-5 (29 FT BGS)



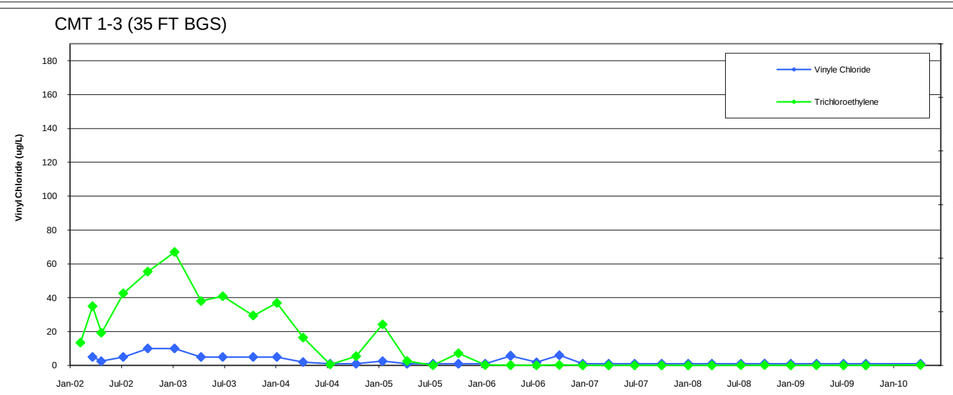


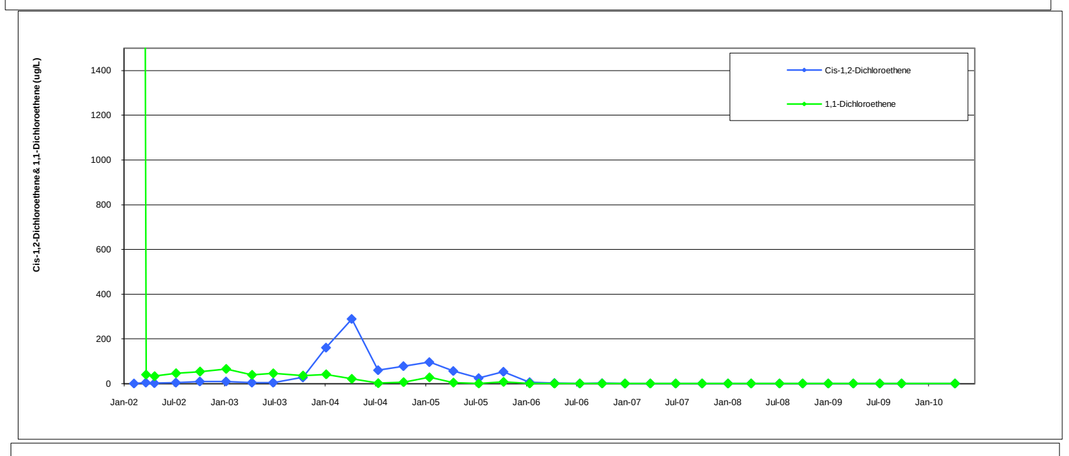
CMT 1-4 (32 FT BGS)



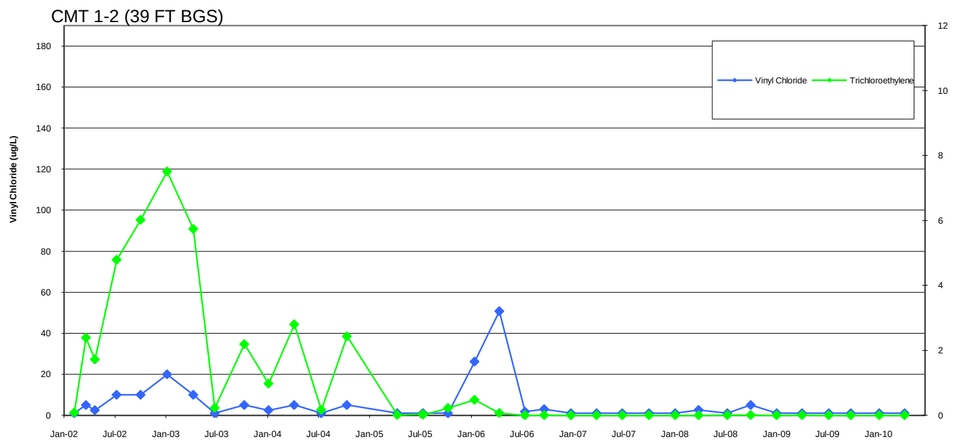


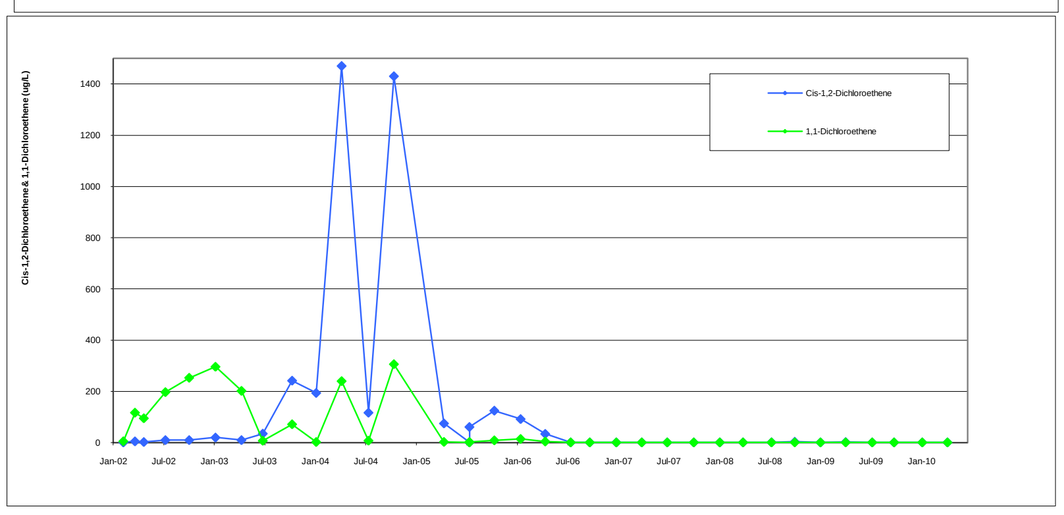
CMT 1-3 (35 FT BGS)



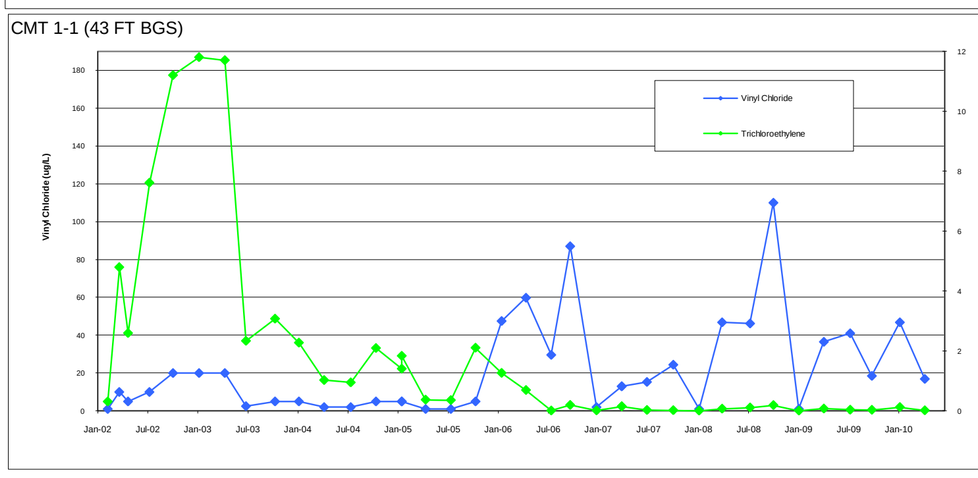


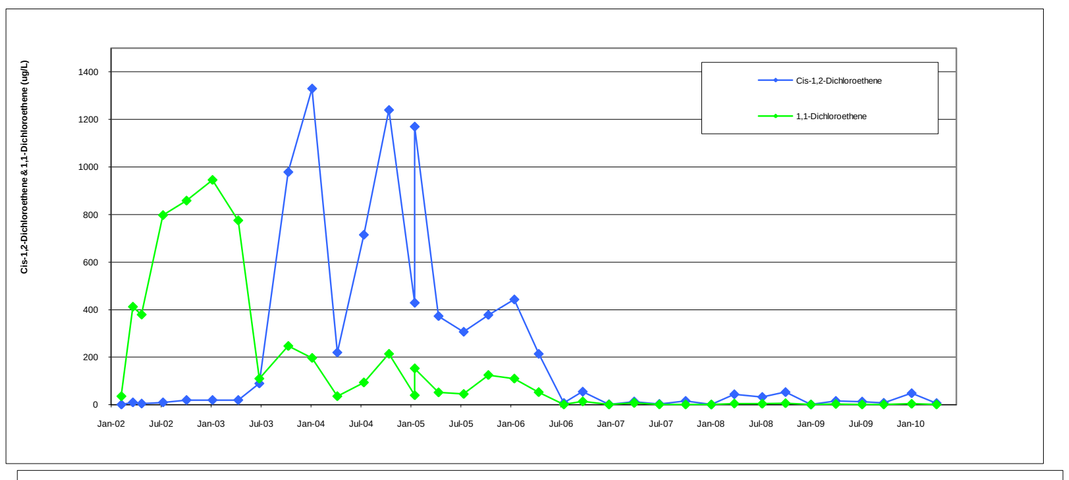
CMT 1-2 (39 FT BGS)





CMT 1-1 (43 FT BGS)





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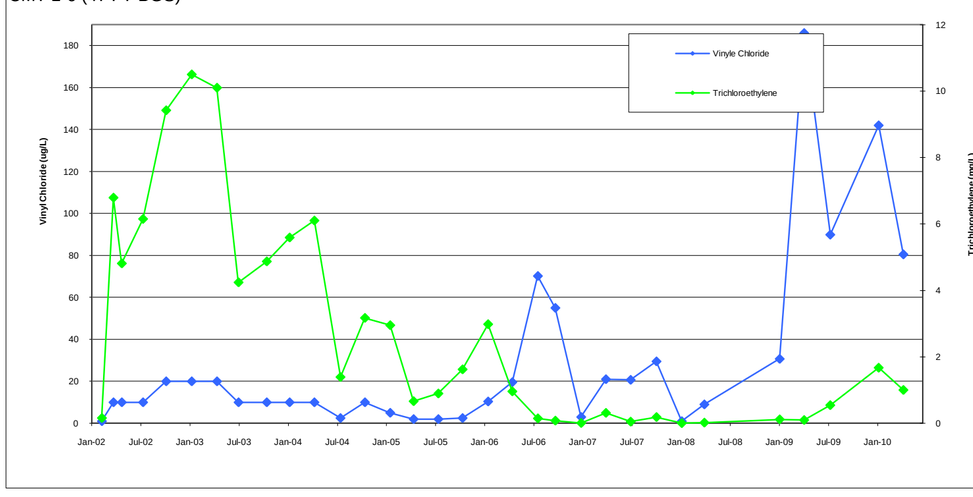

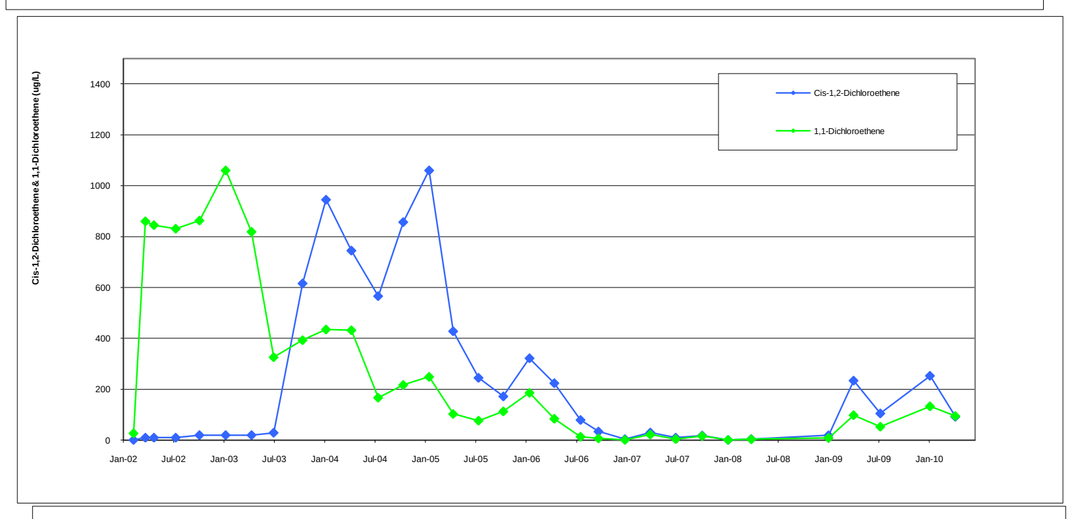

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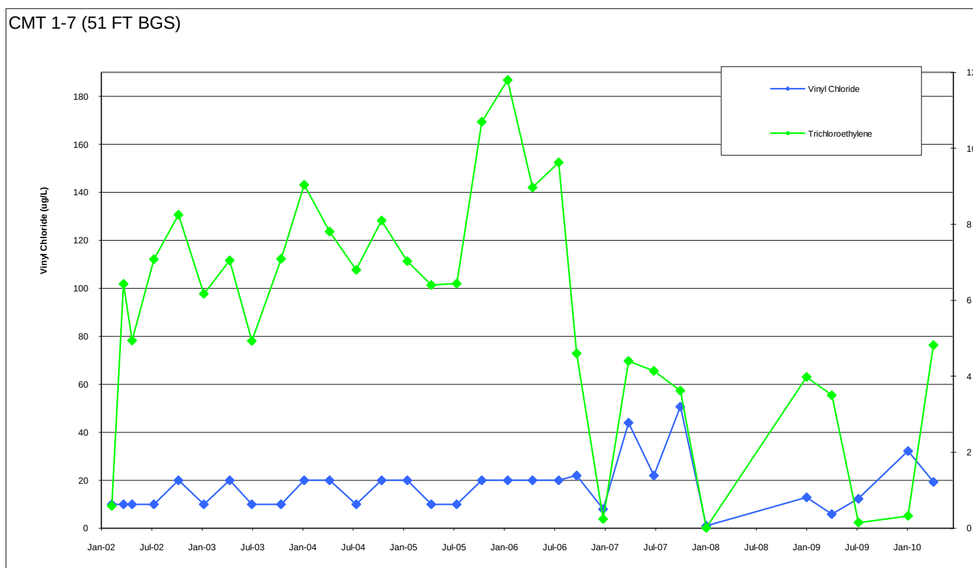
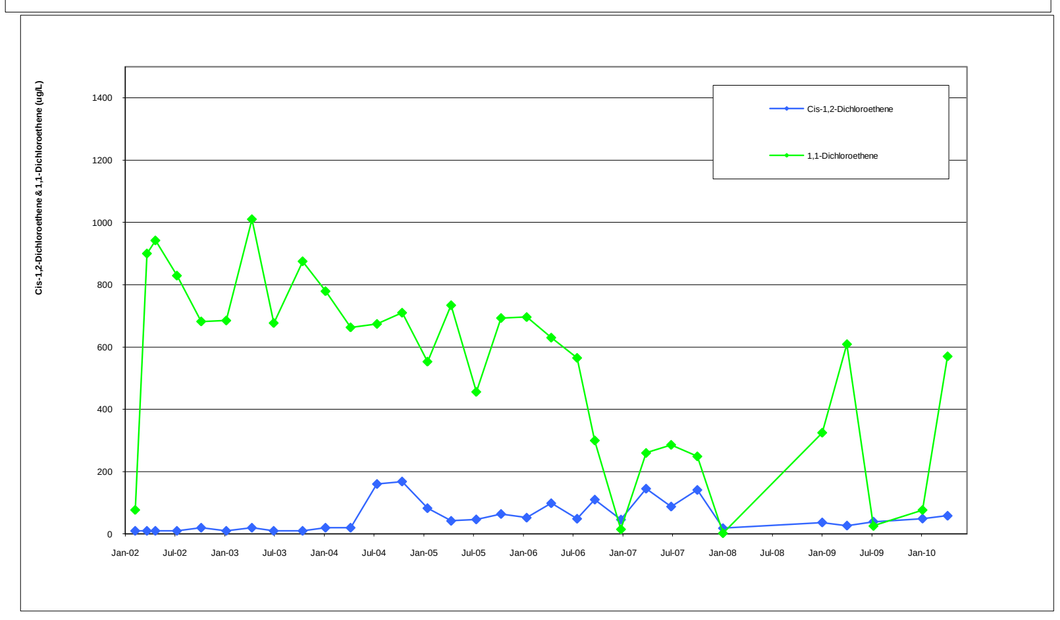
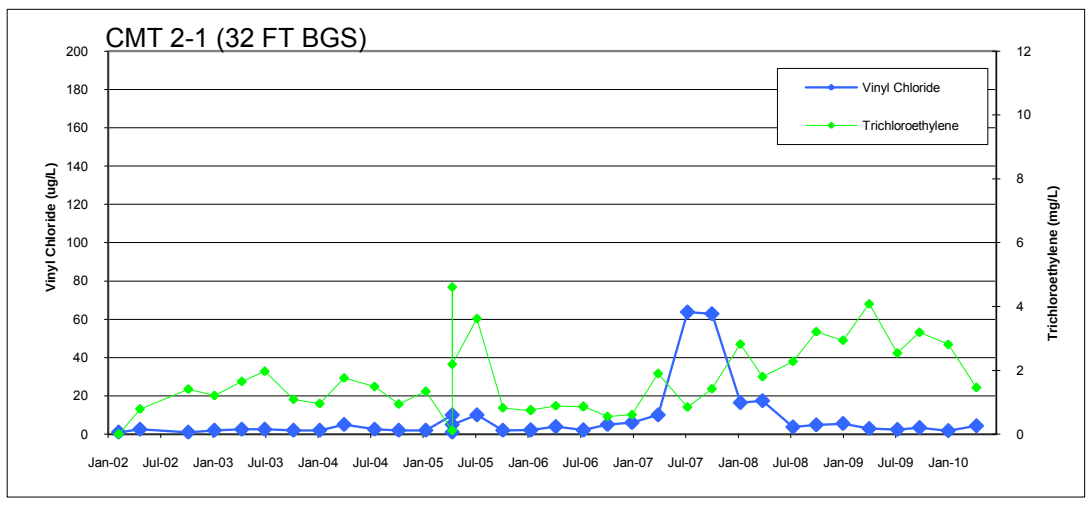
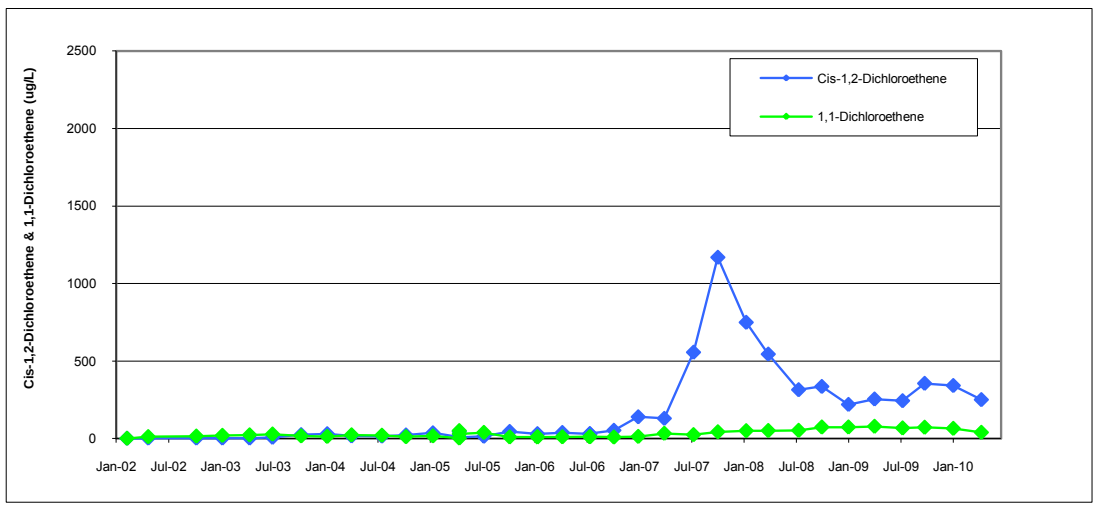
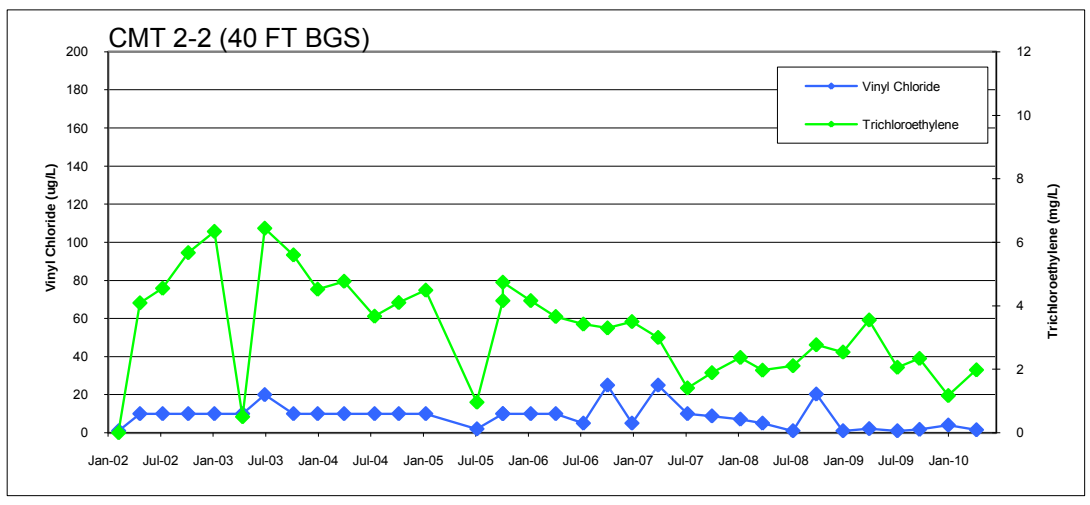


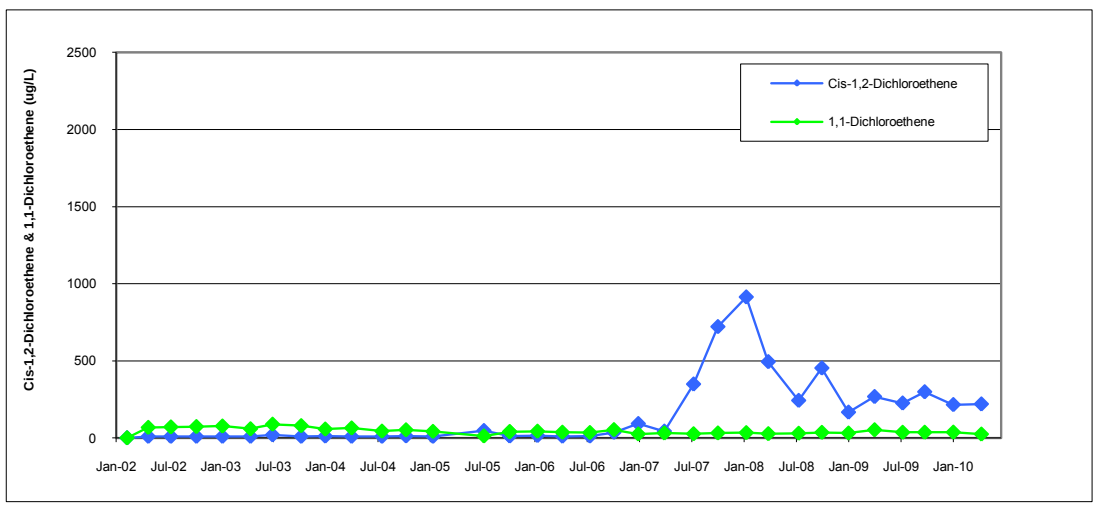


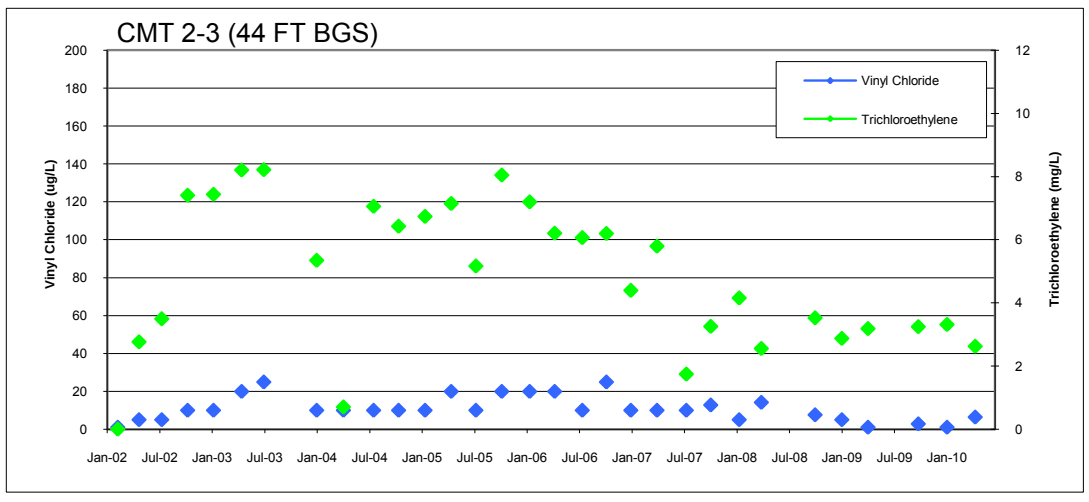
COLISEUM BOULEVARD PLUME
CMT 2 CONSTITUENT CONCENTRATION TRENDS

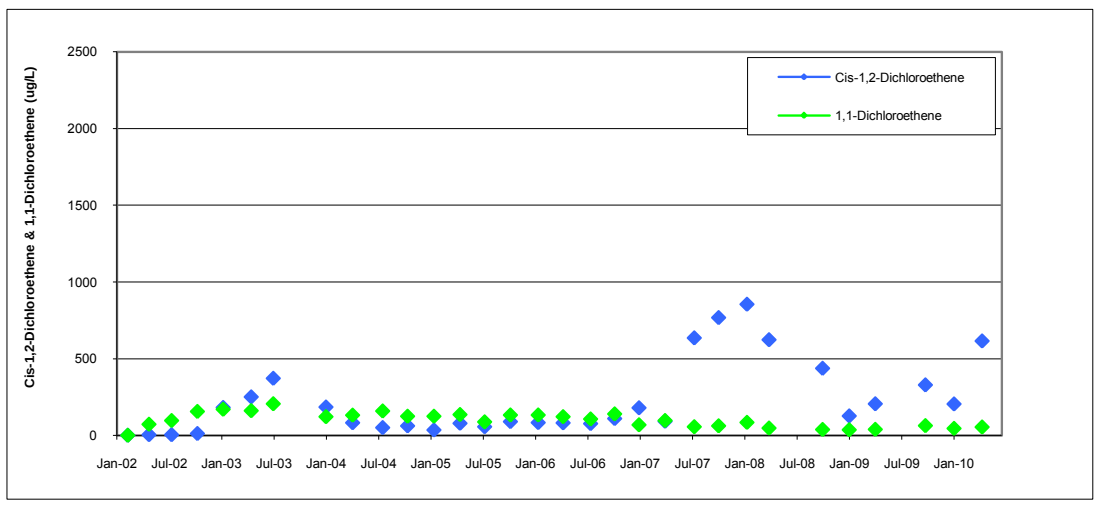


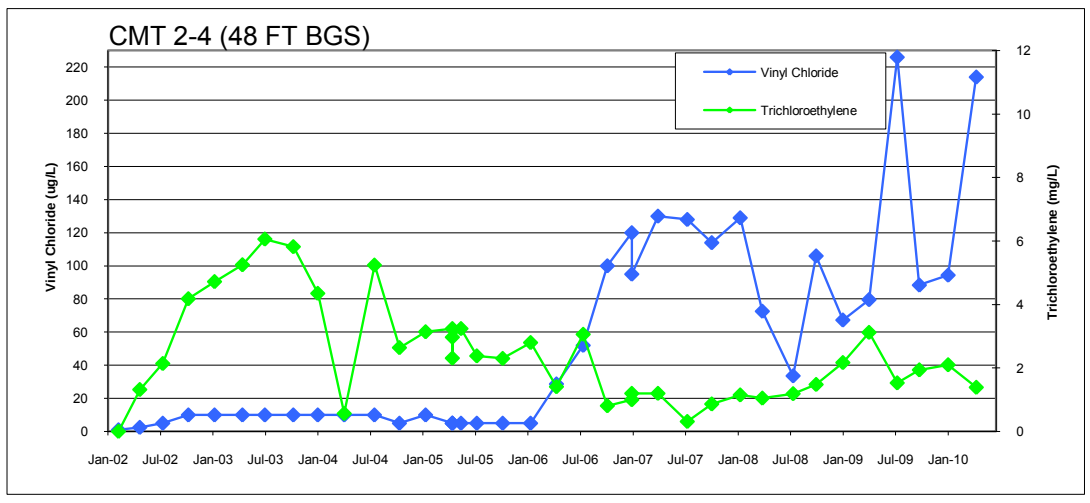


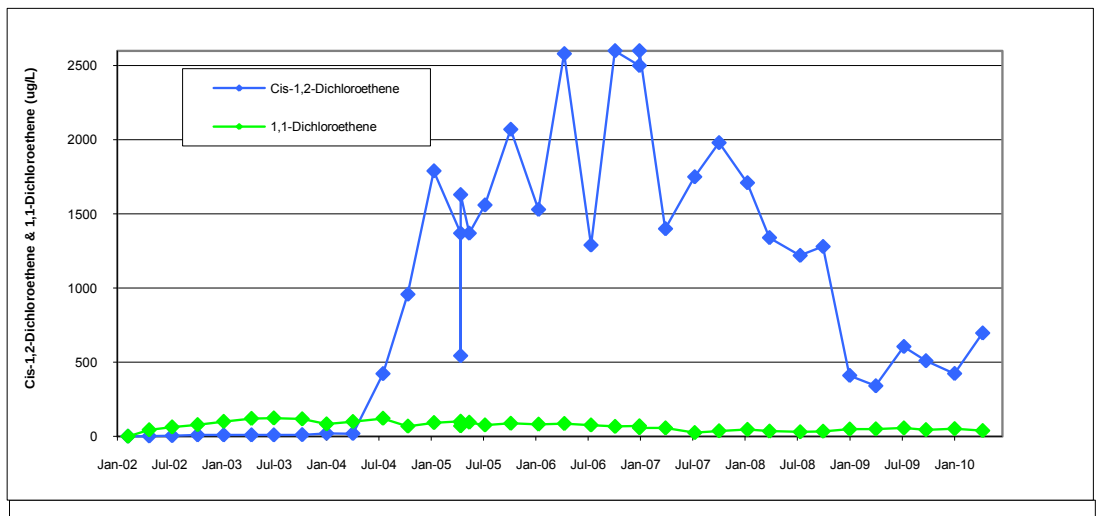


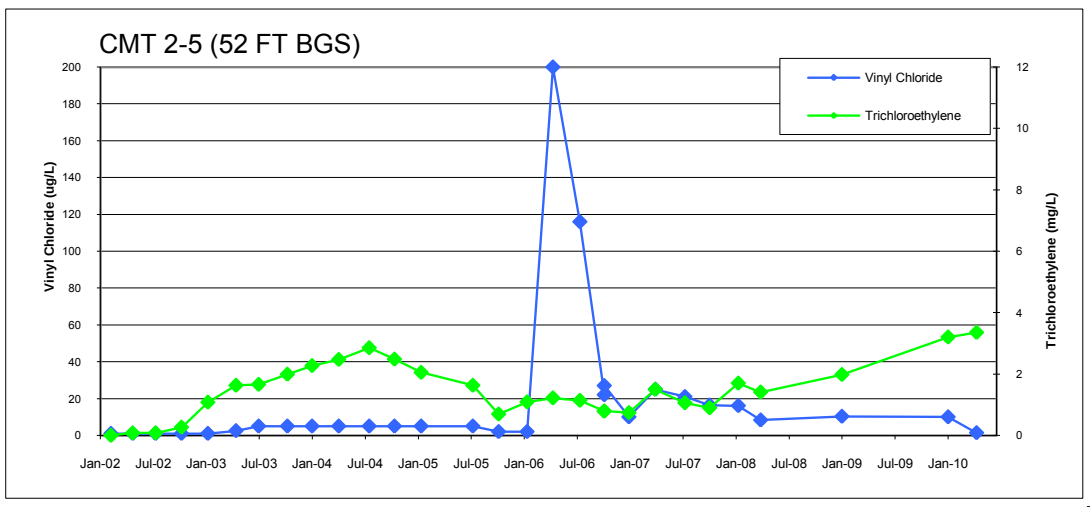


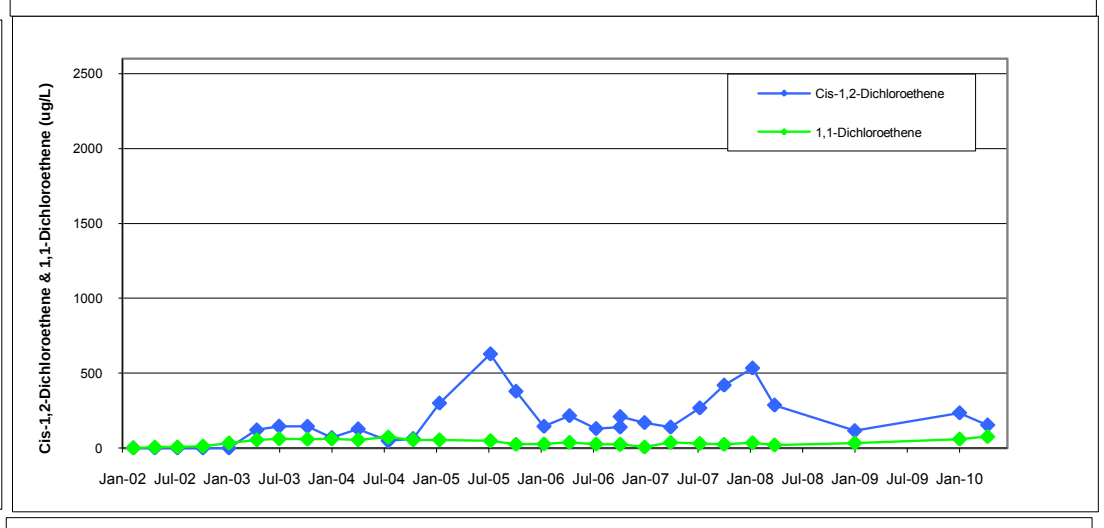


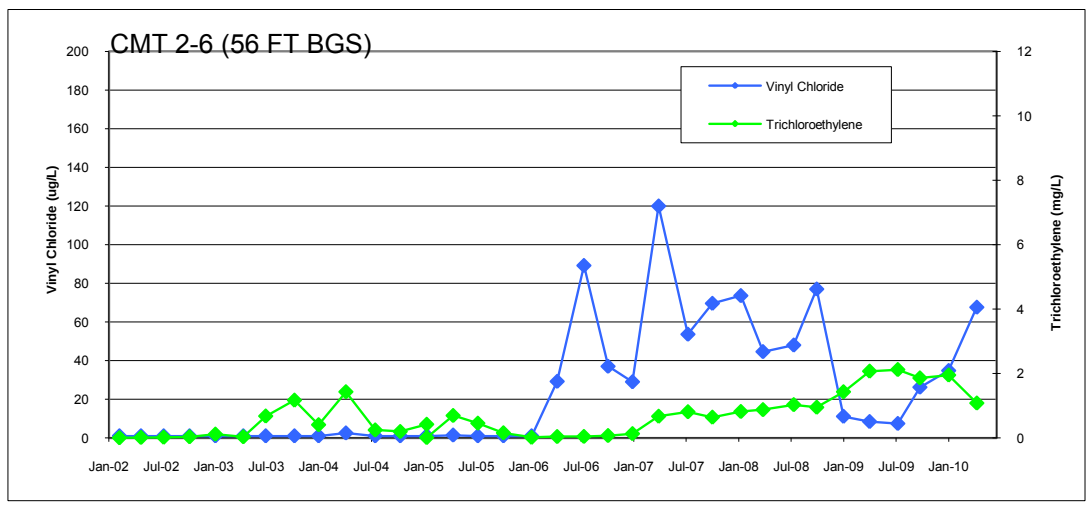


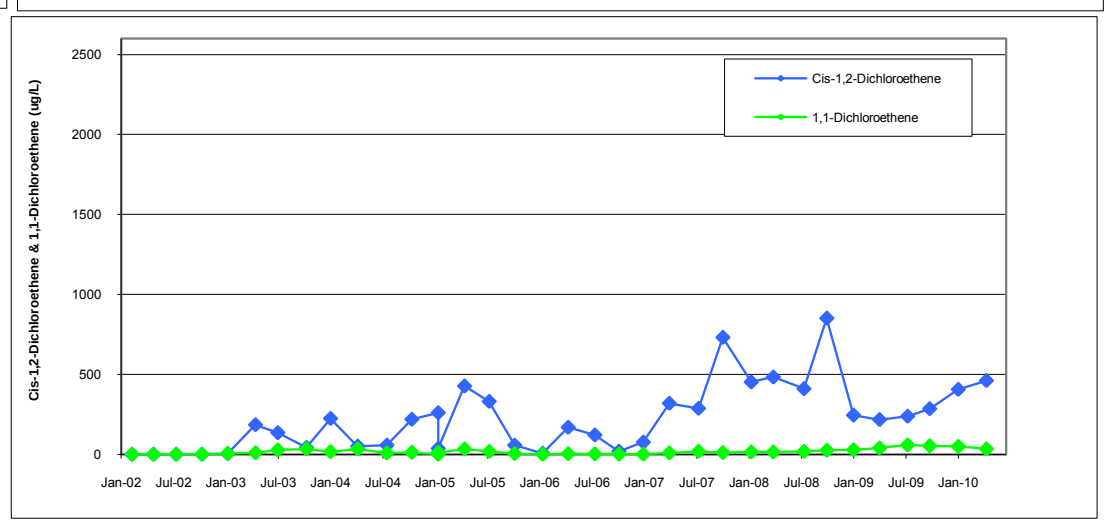


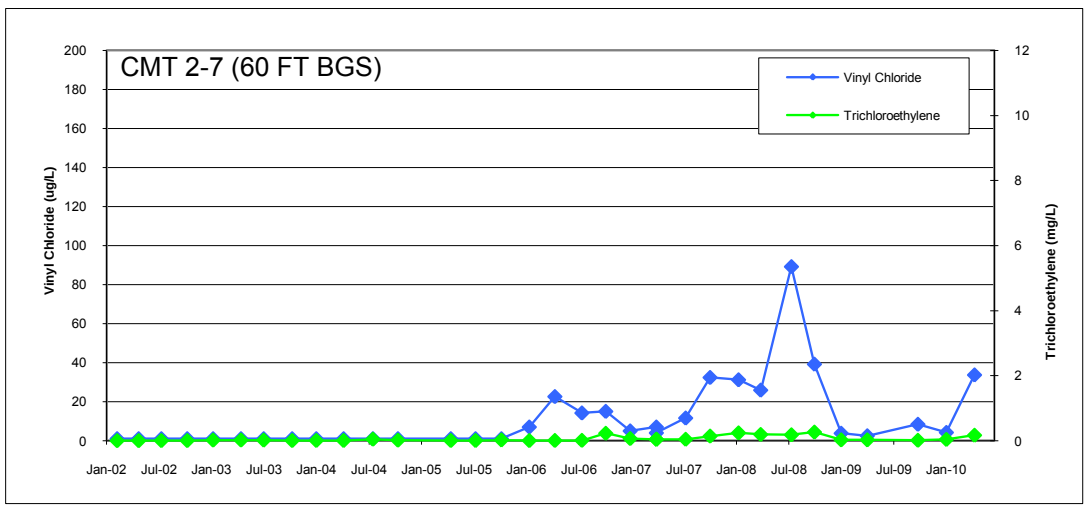


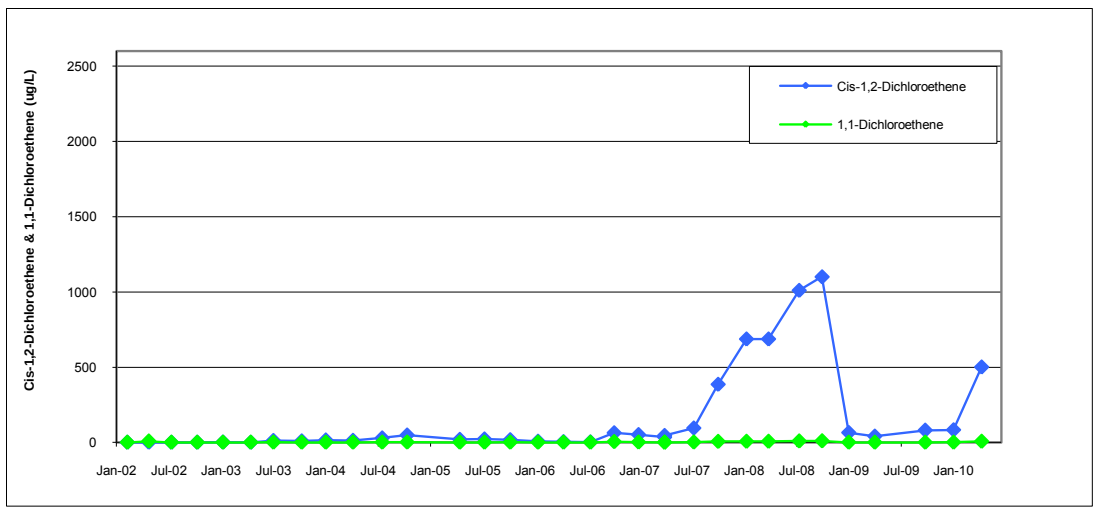




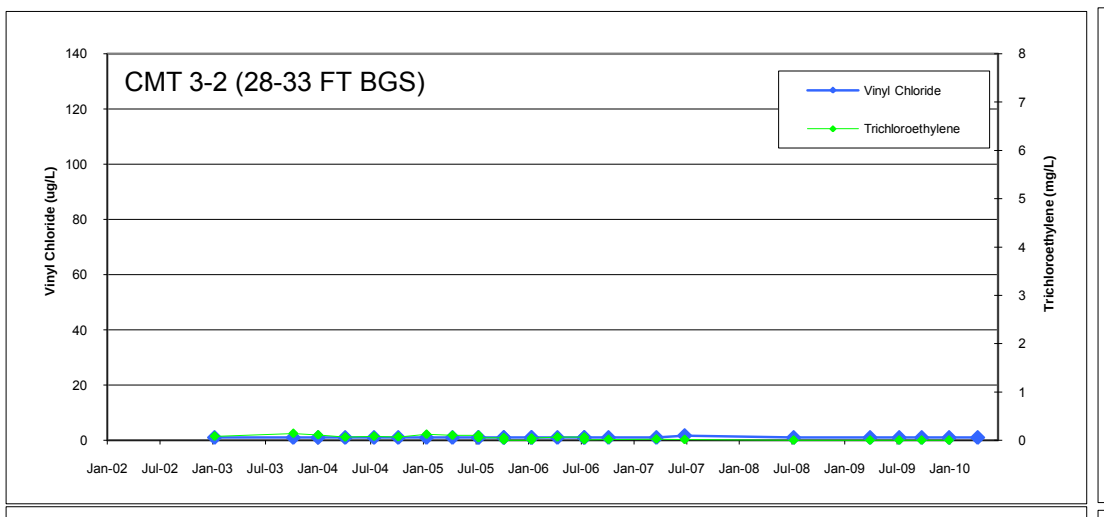


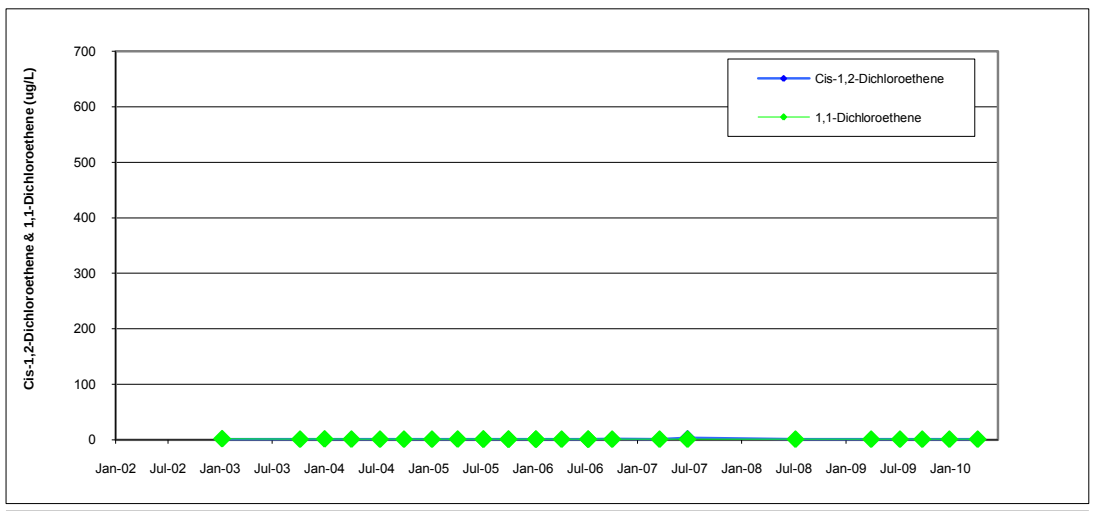


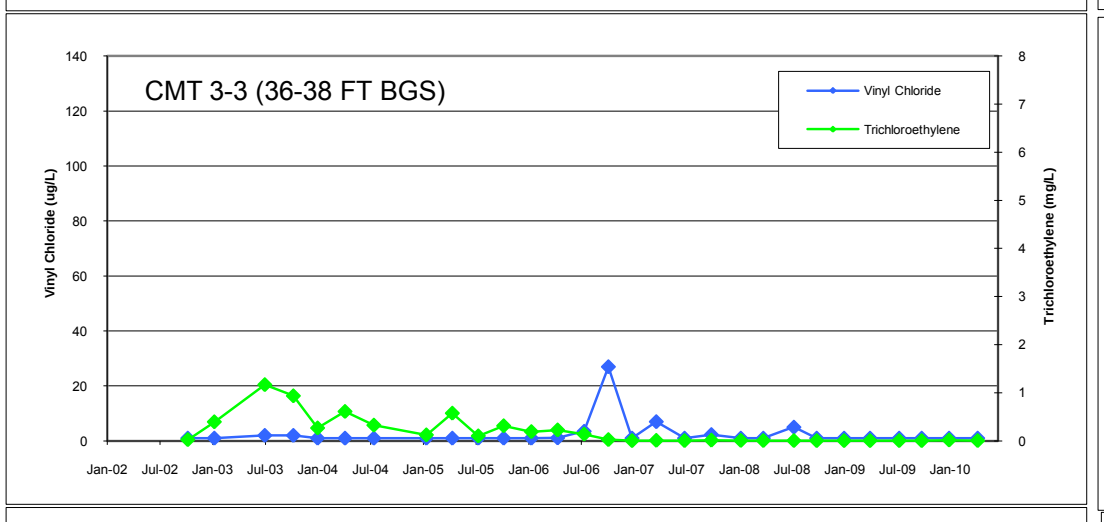


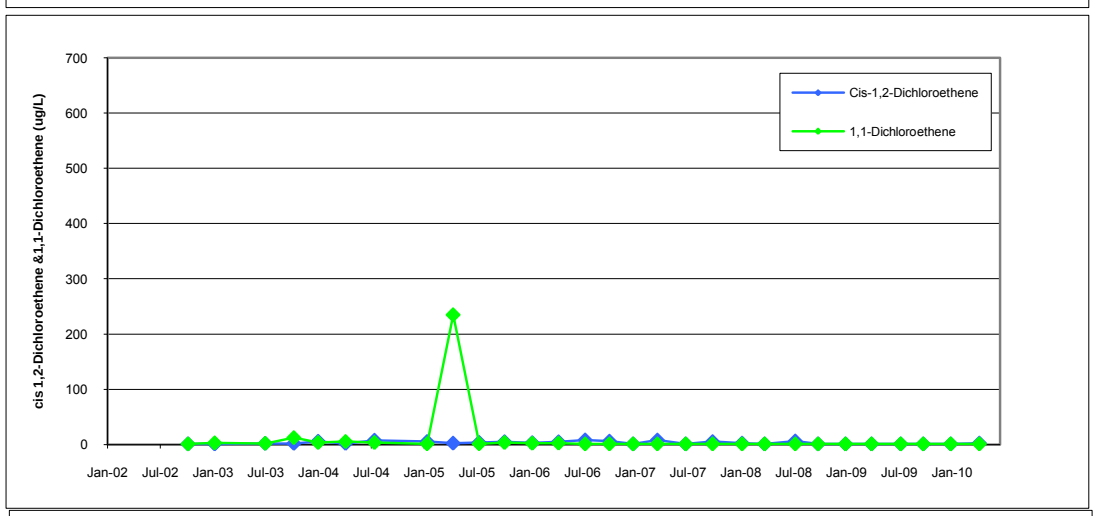


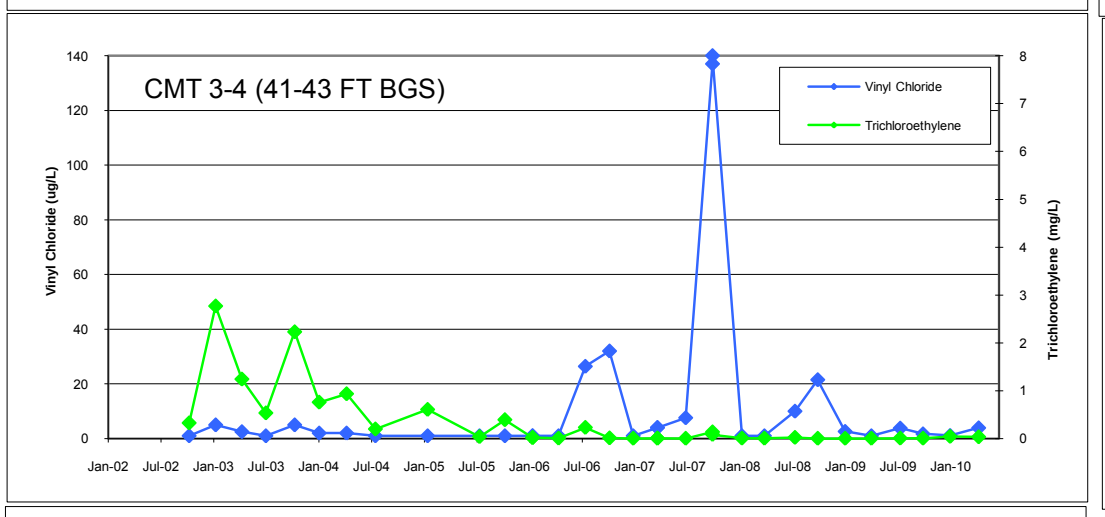
COLISEUM BOULEVARD PLUME
CMT 3 CONSTITUENT CONCENTRATION TRENDS

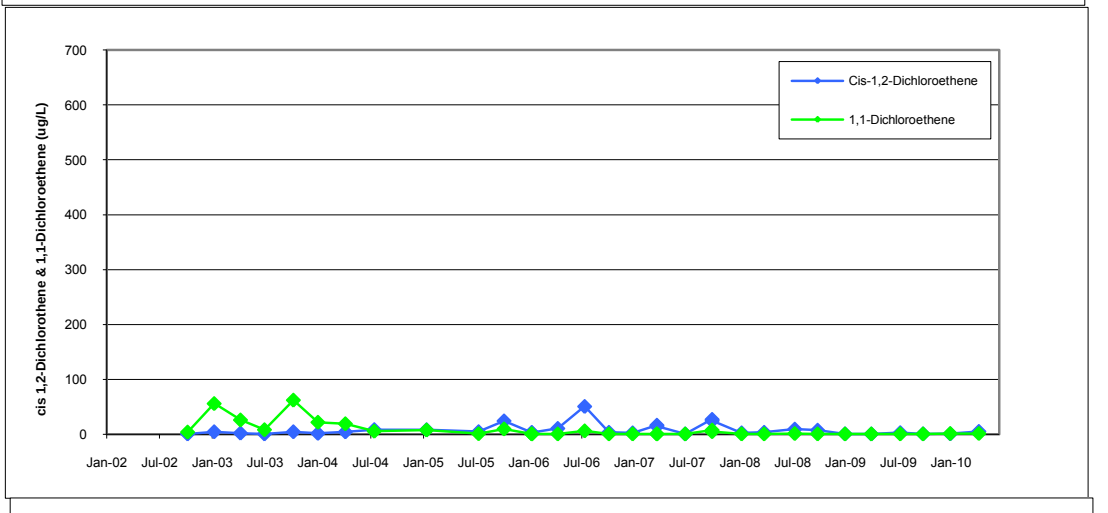


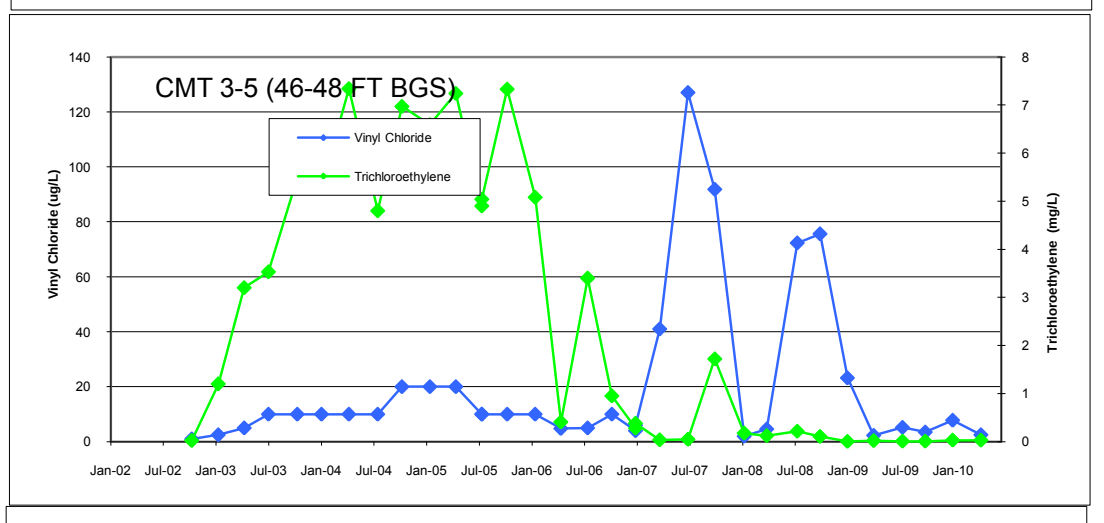


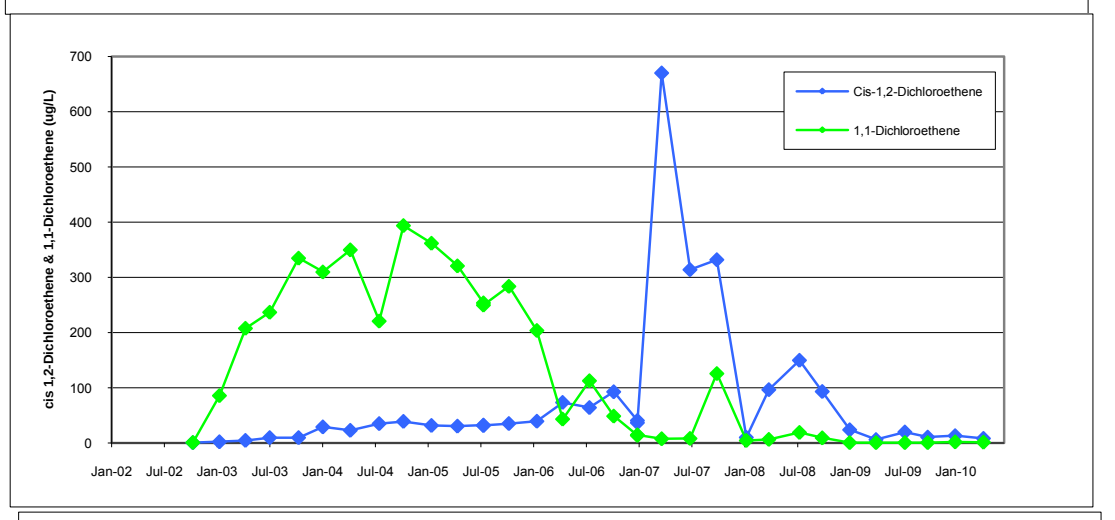


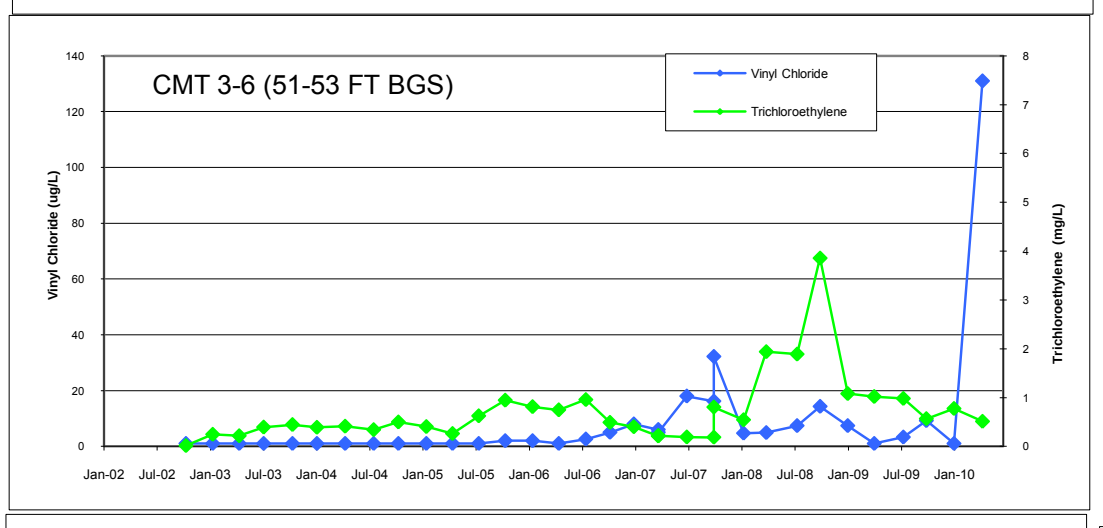


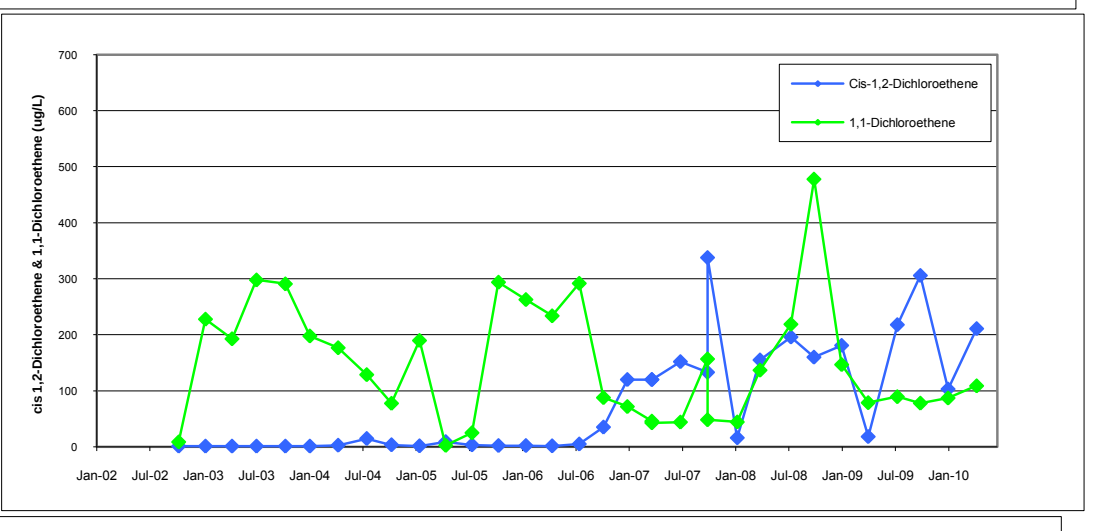


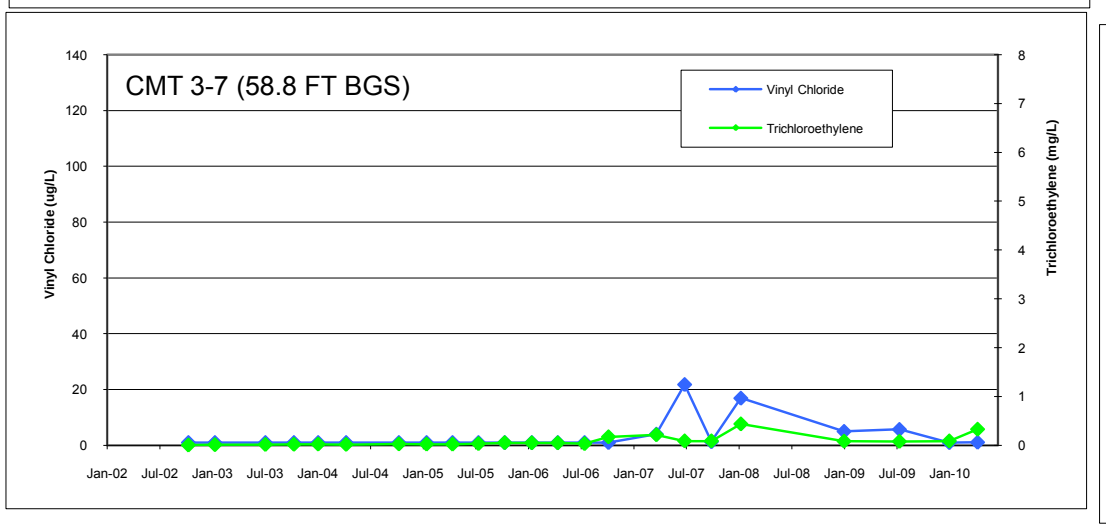


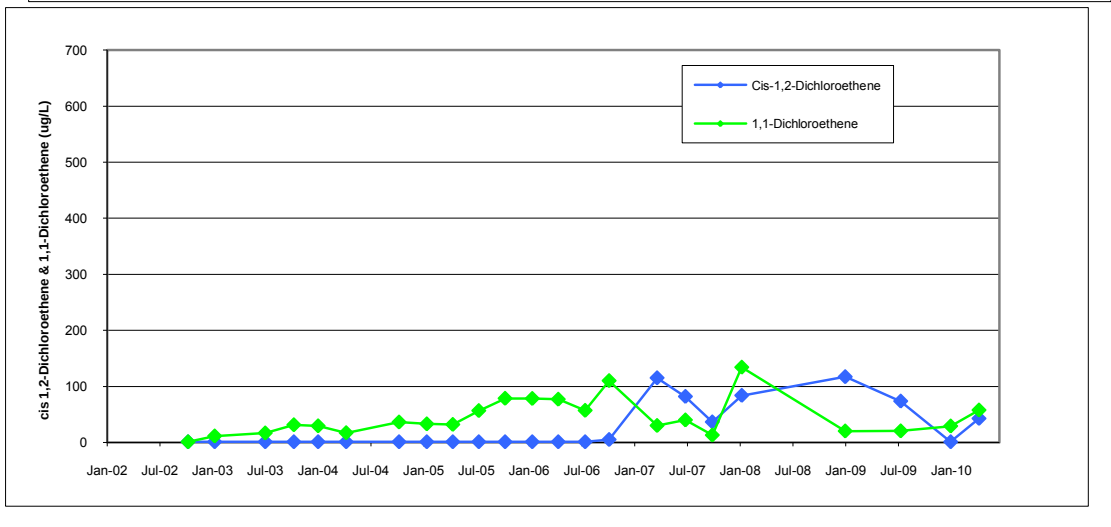




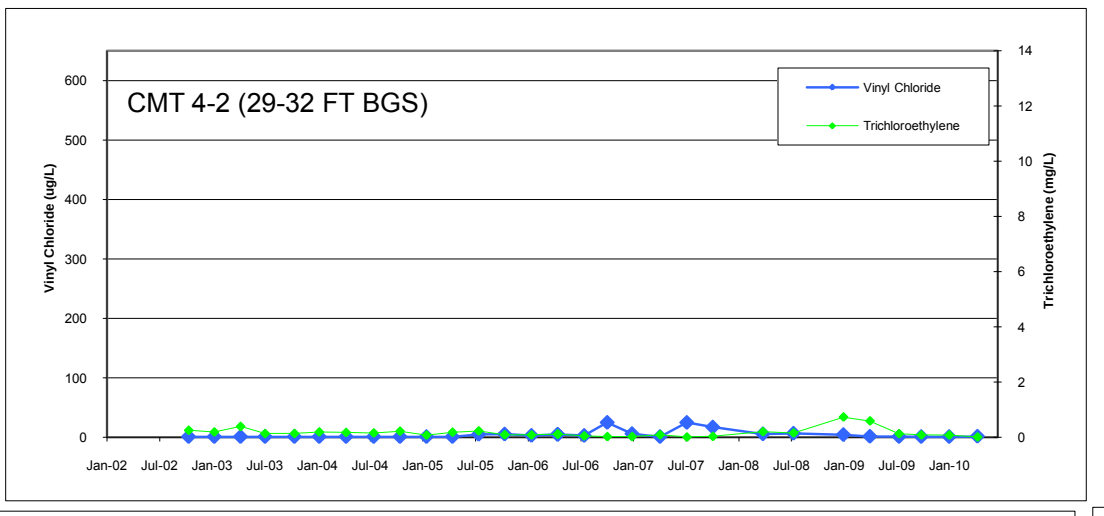


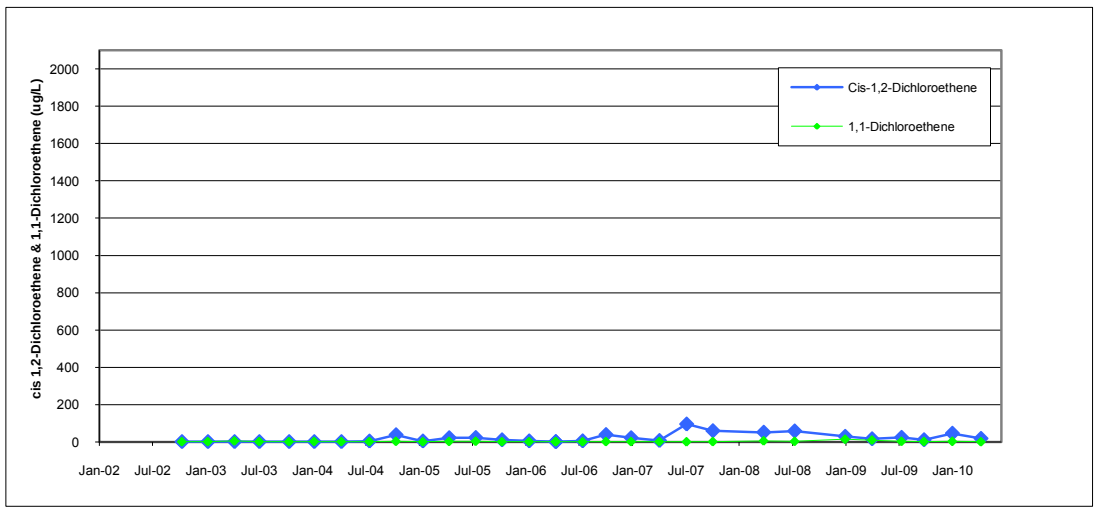


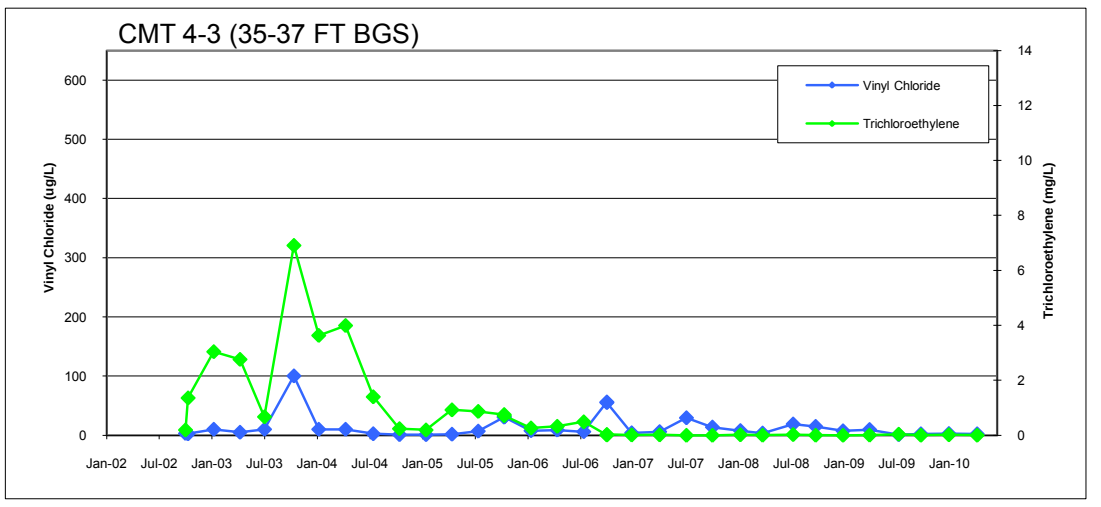


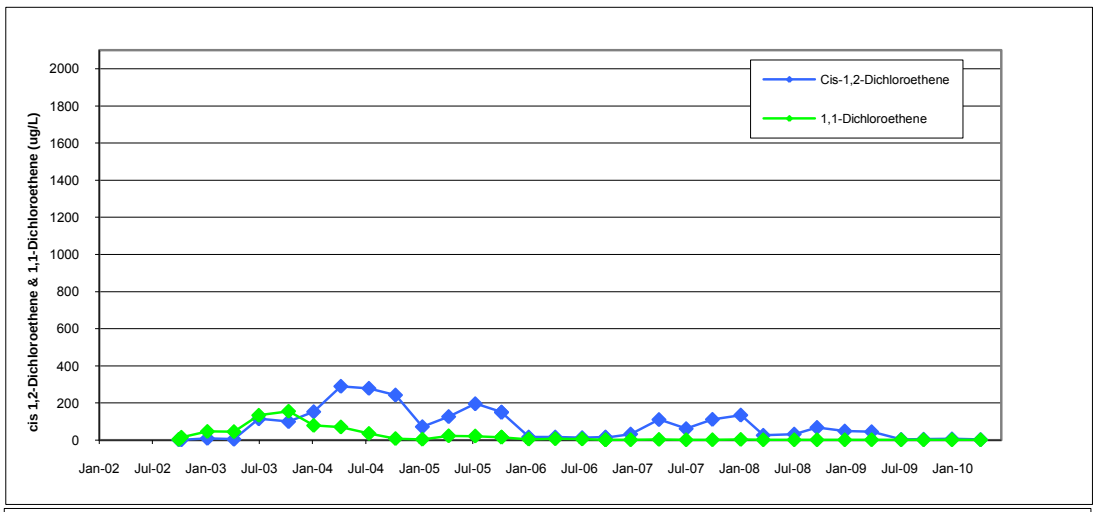


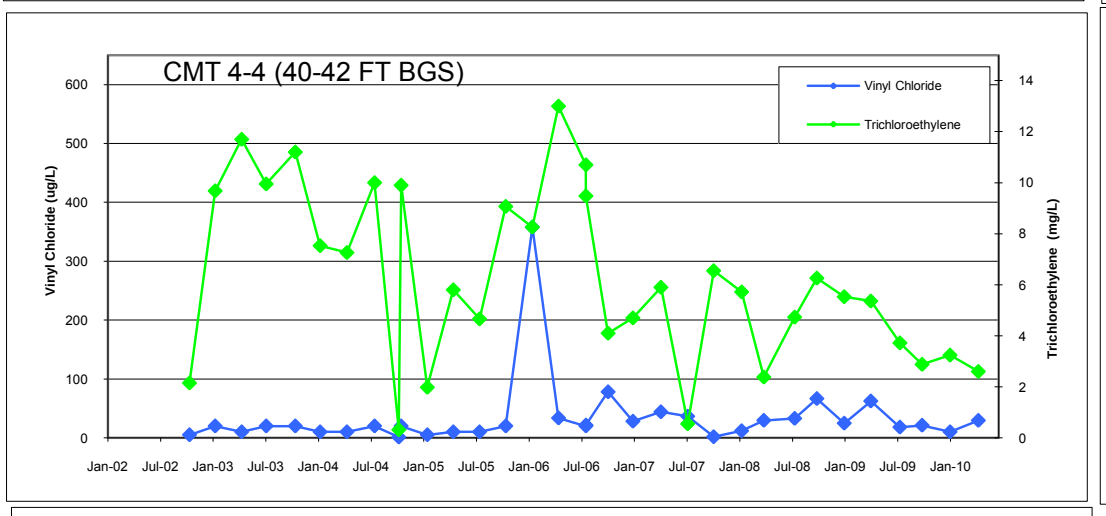
COLISEUM BOULEVARD PLUME
CMT 4 CONSTITUENT CONCENTRATION TRENDS

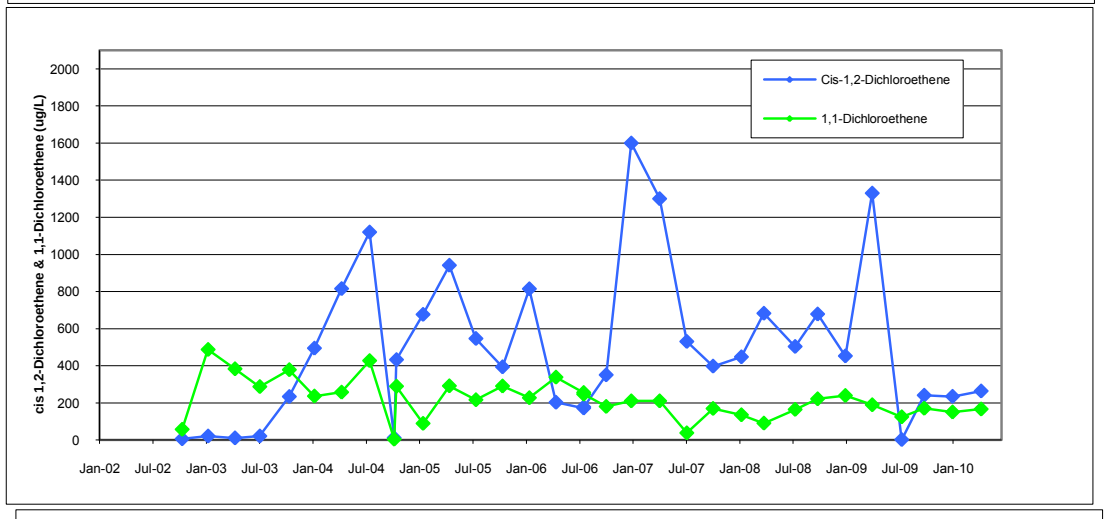


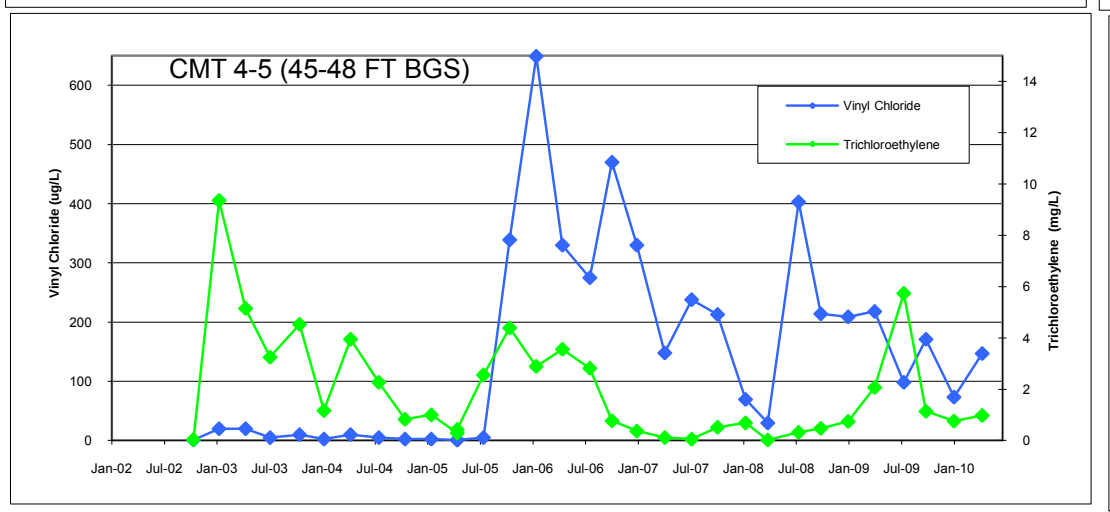


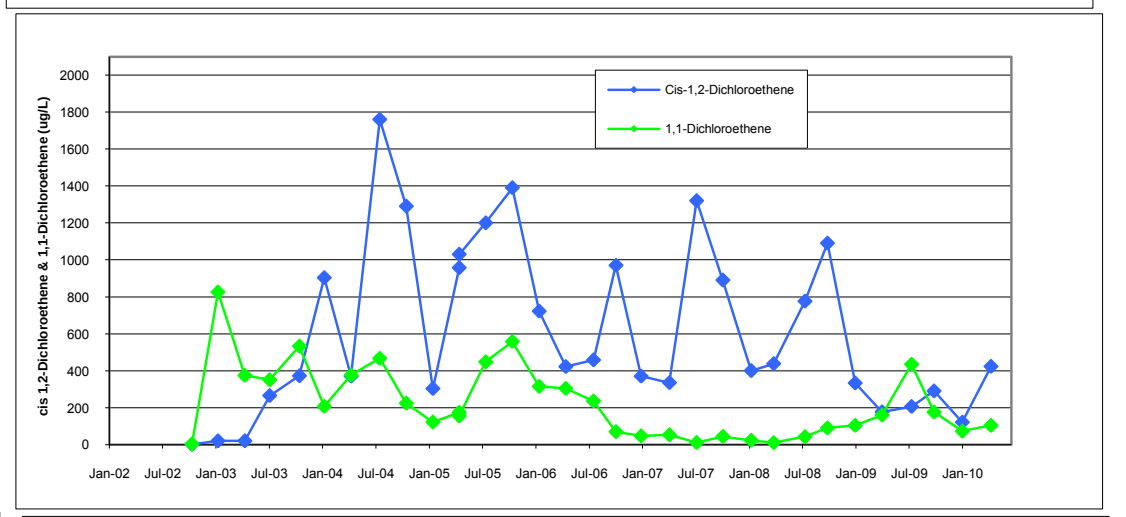


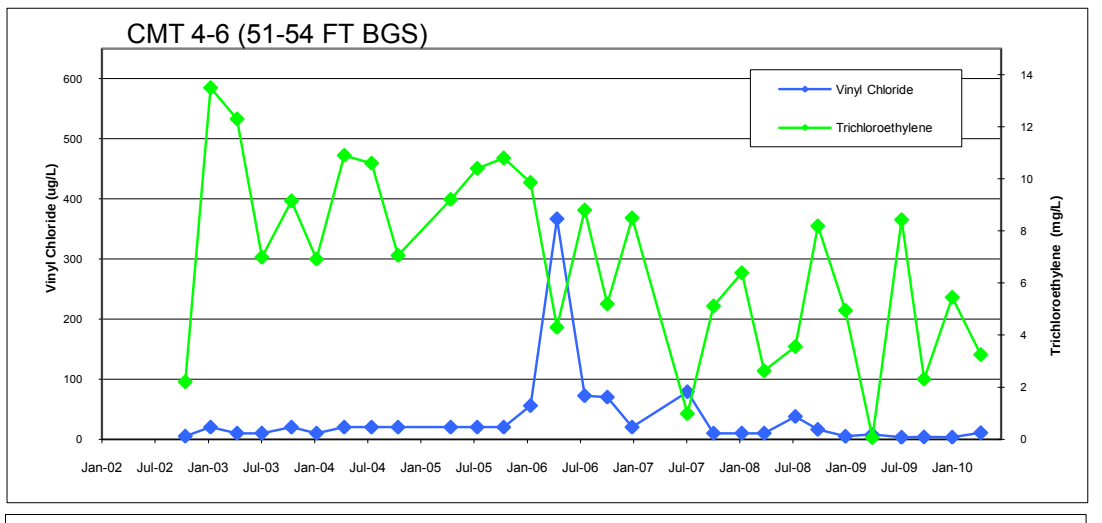


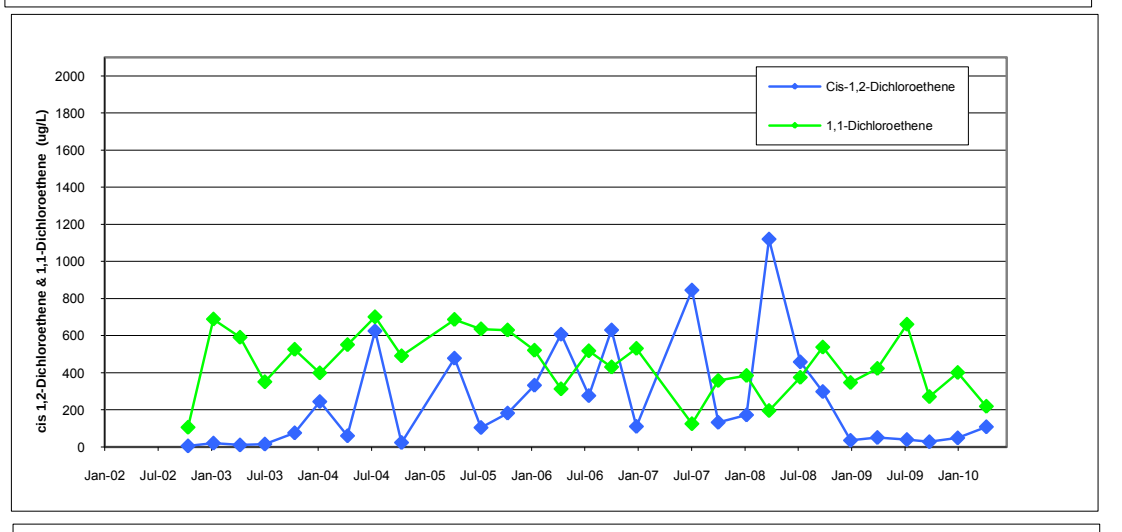


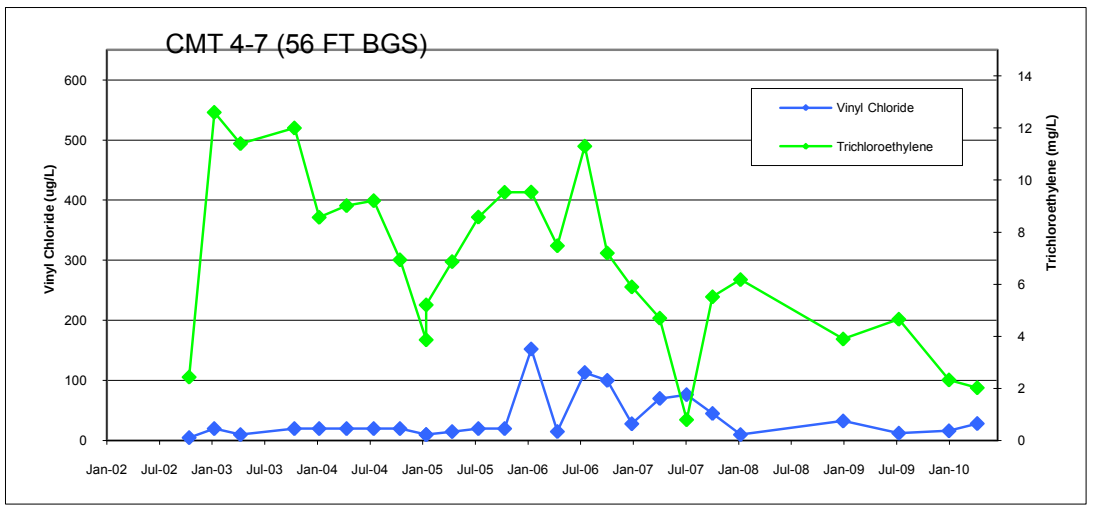


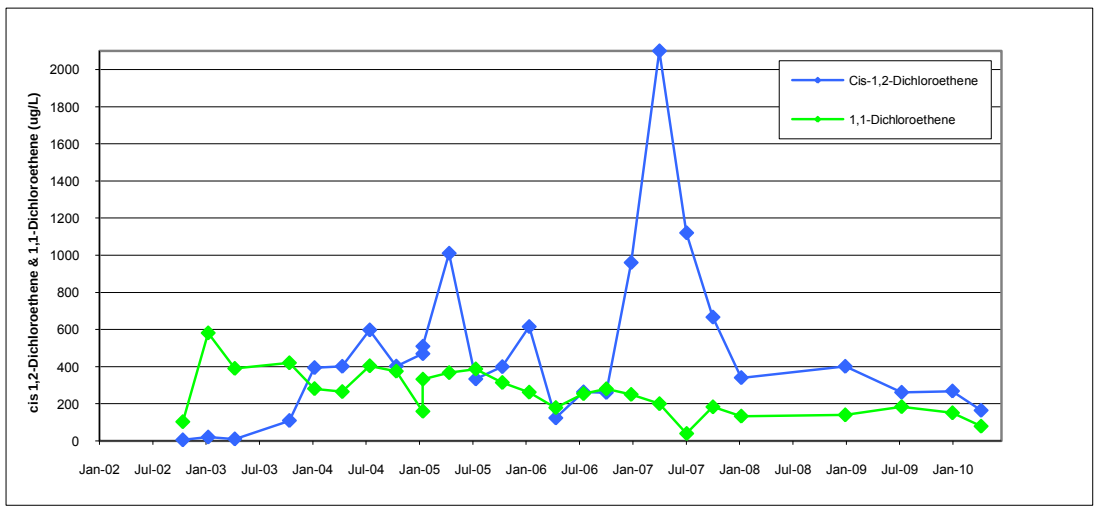
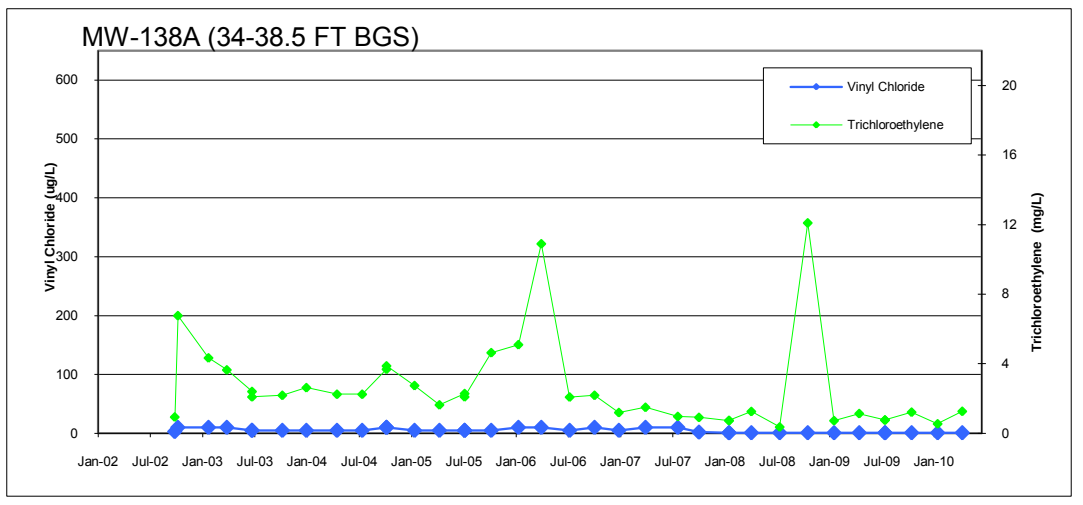
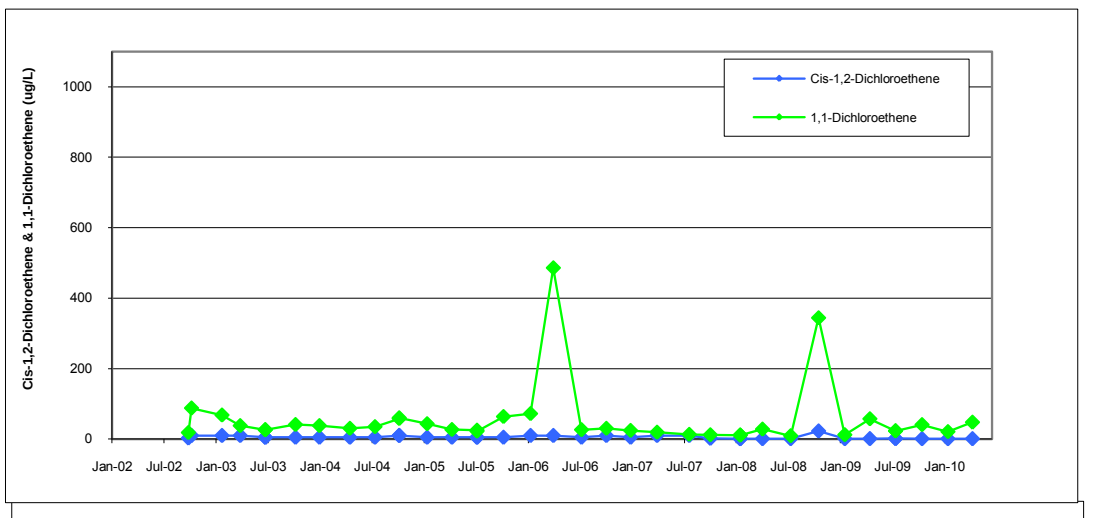
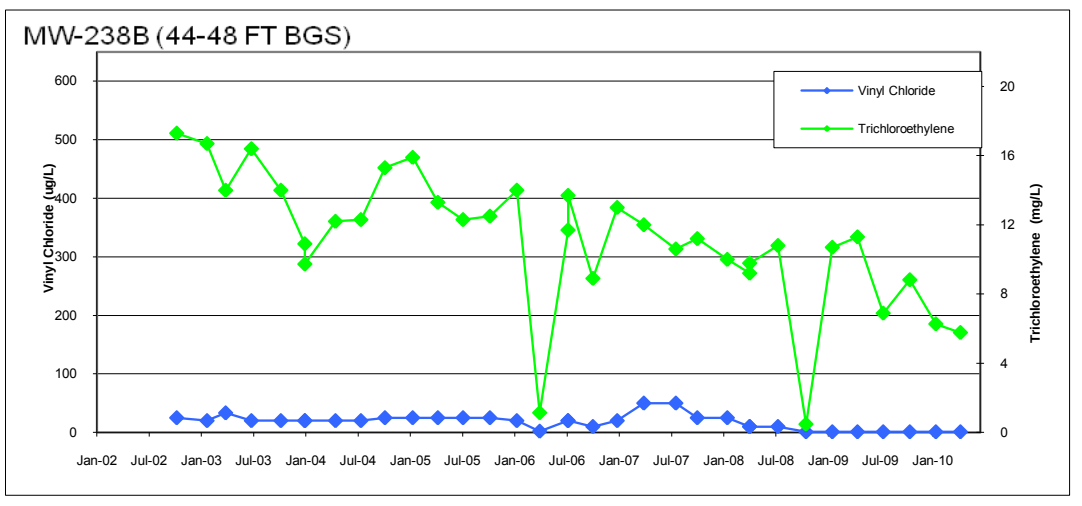
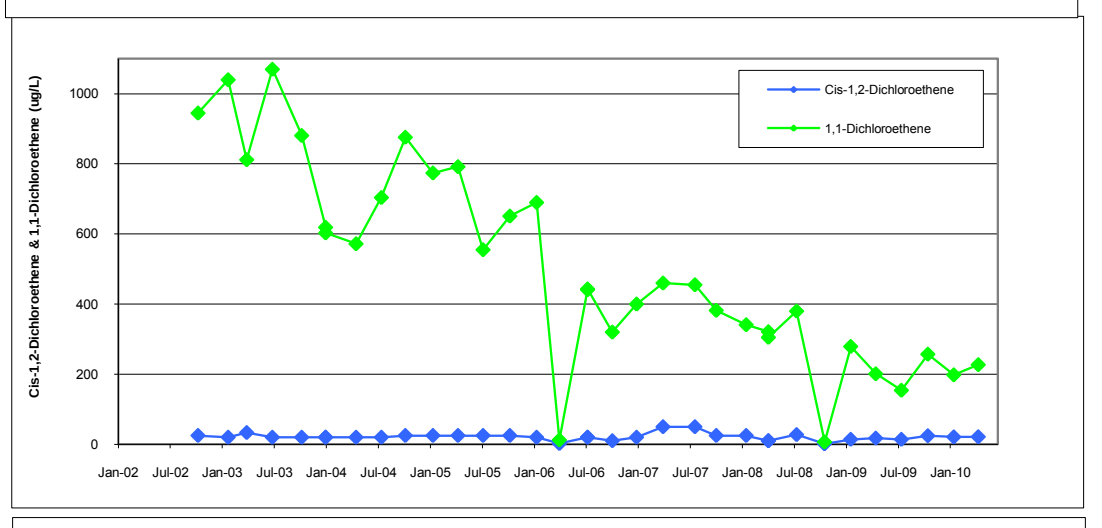
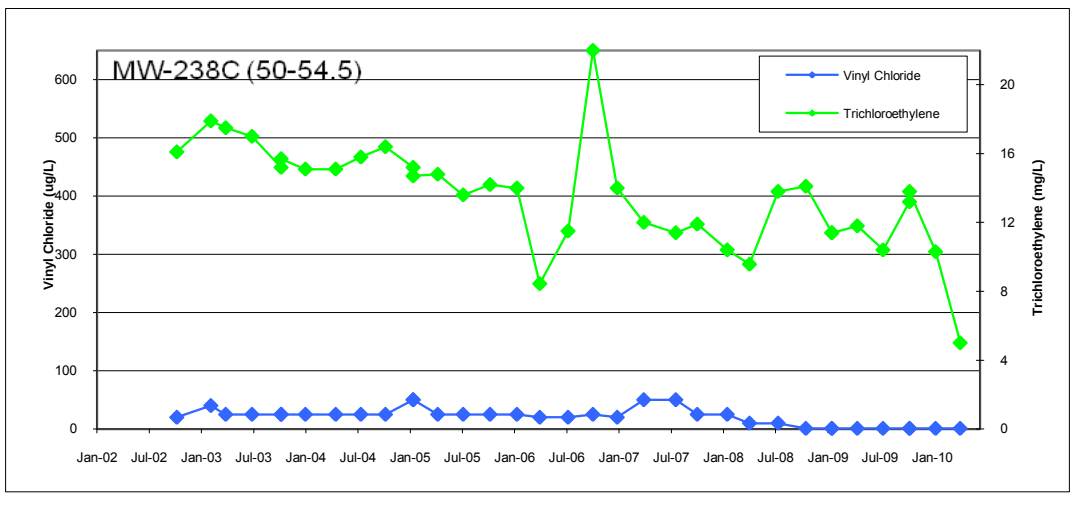
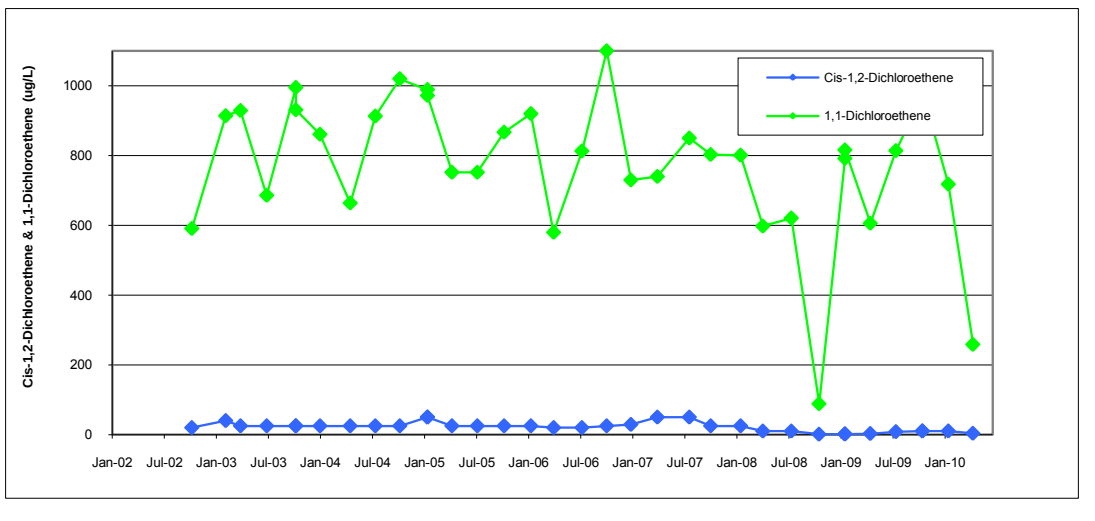












COLISEUM BOULEVARD PLUME
MW-138A/238B/238C CONSTITUENT CONCENTRATION TRENDS